Guide to Hard Milling and High Speed Machining

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Preface to Guide to Hard Milling & High Speed Machining

This volume is a continuation of *Hard Milling & High Speed Machining: Tools of Change*, my first book published by Hanser Gardner Publications in 2005. In that first book, *Tools of Change*, we showed the different cutters developed for hard milling and high speed machining.

In this book, you will find yet more variables associated with this process. Six machine manufacturers are covered in the first six chapters: Mikron, Okuma, Yasda, Roku Roku, Johnford and Moore. They will explain the different approaches to building machines for this process. Also covered in this book are two holder manufacturers Heartech Precision and Big Kaiser, one probe and laser manufacturer Blum. I also put in some of my most recent development work done on hard to machine materials and new cutters on the market today.

I hope that when you read this book you become more aware of the people and companies involved in developing there products for this process. By working with these companies, you will learn what it takes to implement hard milling and High Speed machining into your shop.

I want to thank everyone who contributed information for this book. I also want to thank Steve Bollinger of SME and John Carleo of Industrial Press for their joint effort in making this book happen. Thank you Robert Weinstein for doing such a great job on the final edits. Thank you Scott LoSasso and Jamie Bush of LoSasso Advertising for all your work and support on this project. I am looking forward to working with all of you again.

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Preface to Hard Milling & High Speed Machining: Tools of Change

Hardmilling.com is a Web site I started in 2001. I was out developing processes for companies on a contract bases, and I found there was no single individual that had all the answers for putting a complete machining process together. It was necessary, for instance, to go to one person for information on what was the best machine for machining 60 RC A2 material 24 hours a day, and to another to determine what tool would be best for 50 RC Maraging steel. Other questions, such as, "What is the best software for hardmilling high speed machining?" meant going to still another source. Everyone that produces and sells hardmilling products will tell you they have the best there is, but how do they all compare when they are added to a process as a variable? Controlling and understanding all the variables is the key to successful hardmilling and high speed machining, so I started Hardmilling.com to consolidate the information at a single, easily accessible location on the web.

How do I differentiate between high speed machining and hardmilling? My explanation is that high speed machining is done before heat treat, to rough and semi-finish parts using high feed rates and high definition cuts. Hardmilling is when you machine the finish and accuracy into a part after the heat treat process.

The first step of the process is to decide which machining center to buy. To start, you will need to determine which materials and hardness will be machined? The size of the work area and the tool diameters are also important for determining the right machine for your needs. As you look for the ideal machine, you will find a lot of different options—enough to overwhelm most people. In hardmilling, we are looking for a machine that is rigid and accurate. Lightweight high speed machines can vibrate and reduce tool life. In the machine testing I have done, I've found that one machine may have the capacity to make only 1-part per tool, while another can machine thirty of the same parts per tool. The test results, with a tool costing $258.00, showed that the first machine cost the customer $258.00 in tooling cost per part, while the second machine cost only $8.60 per part in tooling cost. Which machine would you like in your shop?

Software selection is decided by studying the variables of the machining operation. How advanced are the parts, what materials will be cut, and what cutter geometers will be needed? Hard materials require that special techniques—like trochoidal path, corner processing, and stock recognition—are built into the software. A software test that I performed brought one program to the front as the leader in this process. "Software 1" took 2 hours to program the part picked for the test. "Software 2" took just 5 minutes. "Software 2" was developed for hardmilling, while the other one was made for general machining and had to be tricked to do the cutting techniques that the hardmilling tools needed to make the part. Another software test was for evaluating slotting verses Trochodial. The test proved that using a trochoidal path provided nine times more tool life than standard slotting, which is built into most software.

High precision balanced holders are also an important variable of the process. The testing I have done with holders shows that tool life can be doubled, and sometimes tripled, with a certain brand and style of holder. We work with heat shrink and collet style holders. Heat shrink is used for long reach setups, because of their tight runout tolerance and rigidity, even at long lengths. Heat shrink holders are also great for small diameter tooling requiring light chip loads. Collet style high precision holders are the most widely used, and collet holders on the market today guarantee .0001 run out tolerance. The collet also adds damping to the process, thereby extending tool life. I do not us ER style holders. Tapers—BBT, HSK, BT and CT—also make a big difference in tool life. The problem that I run into today is that shops buy new machines and then put old worn out tool holders into that nice new spindle. This is one of the biggest reasons for lost tool life: holders that are worn out. There are taper test gages on the market for checking all the holders in your shop. Throw away any thing that doesn't make the standard! If you have been using worn holders for a long time, you may have already damaged your spindle. You can solve this problem by having the taper reground back to its standard.

The work holding variable for hardmilling needs rigid, accurate fixturing, or tool life and part accuracy will be lost. Keep your work holding as close to the machine table as possible. Rotary and indexing tables are available to be keep your tooling shorter. Mold inserts or punch tools that would otherwise be made with EDM can now be hardmilled from round stock in an indexer or rotary. Pallet tables can also be used. You will find pallets systems made just for hardmilling that allow heavy side pressures and dampen vibrations. I also tested magnets for hardmilling. This type of fixturing works for parts with larger base sizes. The magnets make for fast setups and they provide the ability to machine around the entire part with out moving clamps. This style works best for finishing and light roughing.

Lasers used for finding tool length, checking runout, checking tool breakage, and checking geometry also add to tool life. If your operator loads the cutter in the holder with over .001 in. runout, you will lose half your tool life compared to a tool with less then .0004 in. of runout. If there is a chip stuck on the taper of the holder, the laser will notify the operator with a runout alarm.

Part probes can turn CNC machining centers into part inspection centers. If your shop is ISO approved, you can inspect the part with your probe and have your controller initiate a printout of a quality report. I use part probes to find the workpiece at the initial setup level. I also use the probe to inspect the part before I pull it from the fixture. You will add unnecessary tolerance to the part by pulling it out and then putting it back in for additional machining.

Cooling the tool and workpiece while hardmilling is also critical for tool life. I use air with small amounts of oil droplets. There are cooling units you can mount on your machine to optimize this variable of the process.

Cutters are the final part of our process. I have spent a lot of time testing cutters for their ability to make hardmilling cost effective. There are a variety of coatings and geometries we can choose from. There are coatings today that make it possible to machine harder than 68 RC materials while providing super-fine finishes. Hardmilling cutters have to withstand extreme heat and vibration. The materials we cut have high chrome and nickel content, which require heavy chip loads to extend tool life.

When all these variables are controlled and optimized, hardmilling and high speed machining will reduce your part process time and improve part quality, allowing you to stay competitive in the world market. Here are some examples of the advantages of hardmilling and high speed machining.

S7 Mold: This mold was hardmilled in less than 5 hours. The material is S7 58 RC. Before hardmilling, the customer was spending 30 hours processing each part because it was necessary to machining multiple pieces of graphite, polish the graphite electrodes, premachine the part in the soft state, heat treat the part, EDM the shape, and then polish the EDM finish. Now we write a program from the model, machine the features in to the hard blank, and we are ready to shoot the mold. We have eliminated many hours from the mold making process by using these high-tech processes called hardmilling and high speed machining.

D2 Louver: In this case the customer was spending 6 hours on each of these louvers. He was premachining, heat treating, performing multiple EDM wire cutting setups, and then hand polishing. Now the customer can do a louver in 20 minutes. He makes a program from the model, then machines the hard blanks that he has in stock ready for his customers.

SM Mold Figure

D2 Louver Figure

420 Stainless Steel: This is an example of a lens mold. Previously, the customer was machining the product, then buffing and polishing them before they would shoot the plastic. After the lens was shot, the inspector would shine light through the lens. If there were flat spots from the buffing process it would show up as a light spectrum in the test. This would mean the mold was scrap, and they would have to start over. Now, the customer can hardmill the core and cavity to a superfine finish using special tooling (readily available on the market) and a rigid, accurate machining

420 Stainless Figure

center with a controller that can read 600 plus lines ahead to make these molds in less then half the time with no scrap.

The chapters in this book were written by some of the most talented professionals currently engaged in hardmilling. The information they present is the result of exhaustive research and testing, and each contribution reflects the experiences of machinists from around the world. The metalworking companies represented in this volume continuously work to provide the best technology available, and I can personally attest to their dedication to the discipline of hardmilling. You will note that there are some inconsistencies in abbreviations and other technical nomenclature throughout the book. This is because I have retained the style of each author, rather than requiring consistency for the sake of conformity.

Special thanks to everyone who cooperated and helped produce this book. I am very grateful for the time and effort that each of you gave to make it a reality. Hardmilling offers significant rewards in reducing costs, raising productivity, and improving accuracy. I hope this book will help spread these advantages to those shops and factories that are not using this amazing technology.

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Table of Contents

Chapter 1

Mikron

By Mal Sudhakar, Vice President, Mikron, Agie Charmilles Corp.

High Speed Machining Centers for Hard Milling

In recent years, with advances in high speed machining center technology, cutting tools, toolholders, CAD/CAM systems, and software, hard milling has become more widely used as a process in the die/mold industry. Direct milling of tool steels 62 HRc and over, trochoidal milling for roughing more efficiently in hardened steel, and five-axis hard milling for reducing machining times and tool wear are a few examples of the developments.

Hard milling can be viewed as a process complementary to Electrical Discharge Machining (EDM) in the manufacture of molds and dies. When considering the complete process chain for machining molds and dies (see Figure 1-1), at one end of the spectrum is a pure EDM process and at the other end is a pure hard milling process. Between them are combinations of both EDM and HSM. As you move from EDM to hard milling, the total lead time for manufacturing a mold or die reduces quite substantially. Today, with the competitive pressures in the marketplace to reduce lead times and costs, it becomes beneficial to utilize hard milling as far as possible, hence the growing interest in mold and die shops in hard milling as a process.

Mikron offers the industry's widest range of high speed and high performance machines for hard milling applications. Machines are available with longitudinal travels from 15" to 74", spindle speeds from 12,000 to 60,000 rpm, in 3- to 5-axis configurations. As of the end of 2005, Mikron delivered more than 1000 machining centers with 42,000 rpm spindles to customers, the highest among any of the high speed machining center manufacturers worldwide.

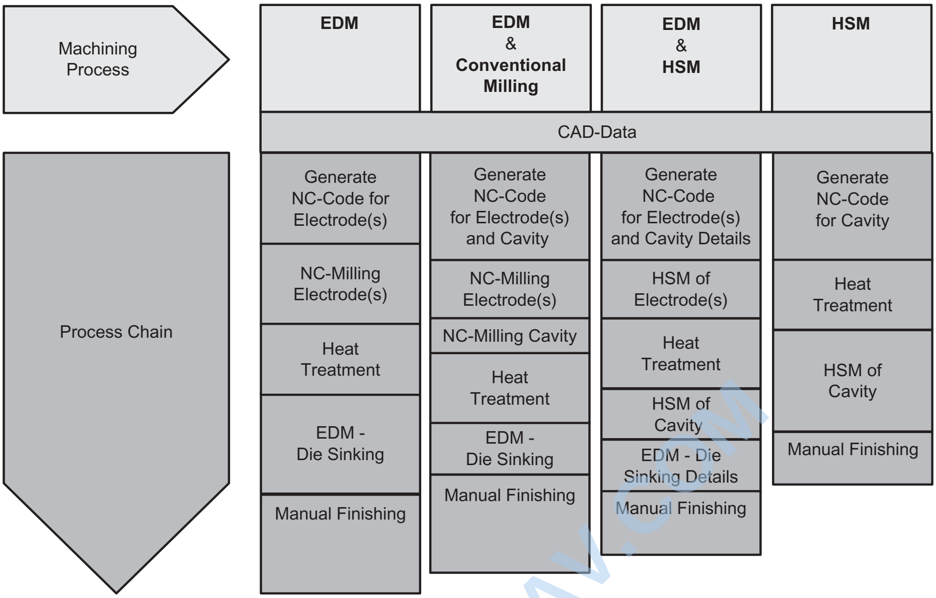


Figure 1-1 Die/Mold Process Chain

Spindle Speeds, Feed Rates, and Acceleration for Hard Milling

The selection of the right spindle with the right rpm range, power, and torque characteristics becomes a critical question in the selection of a hard milling machine. A number of high performance machines are available in the market today for hard milling applications, with spindle speeds in the 15,000-to-20,000 rpm range and acceleration characteristics of around 0.5g. Mikron offers a wide range of high performance machines called the VCP, HPM, and UCP ranges, typically sold with spindle speeds in the 20,000 rpm range. These spindles can handle cutter diameters up to 125 mm (5”) and offer a high degree of versatility for shops that require a machine to handle a variety of machining tasks, materials, and cutting tool diameters.

However, to get the optimum hard milling performance, higher spindle speeds, feed rates, and acceleration are needed on a machining center. As cutting speeds get higher and tool diameters get smaller, higher spindle speeds are required. For a given chip load, as spindle speeds increase, feed rates also increase. And to maintain a high-average effective feed rate around a contour, high acceleration is also required.

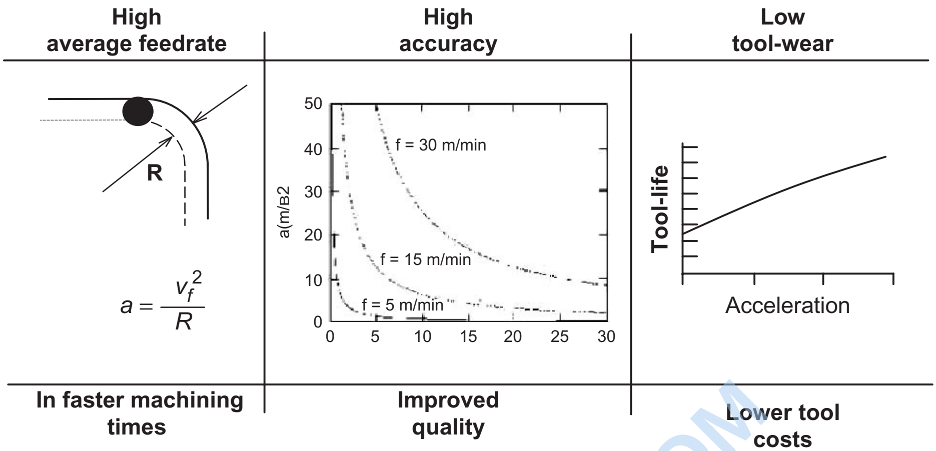


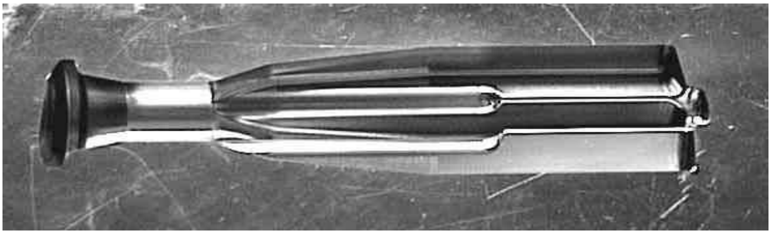
Figure 1-2 Advantages of High Acceleration

The maximum feed rate with which the axes of a machine can traverse around a given radius depends on the acceleration characteristics of the machine and is dictated by the laws of physics, as shown in Figure 1-2. The higher the acceleration, the higher will be the feed rates. Correspondingly, as the radii get tighter, higher acceleration characteristics are required to maintain a certain feed rate.

A machine with higher acceleration/deceleration characteristics can maintain a higher average effective feed rate close to the programmed feed rate, that is, maintain the desired conditions for hard milling. Machining times are faster, the contours are machined more accurately, and tool life is greatly improved. If the feed rates around a radius drop and the chip load is low when hard milling, the tool is rubbing, not cutting, generating heat that is not dissipated with the chips. The thermal load on the tool is increased, causing higher tool wear and reduced tool life.

The importance of high acceleration characteristics on a high speed machine in achieving good tool life for hard milling cannot be understated. In addition, there can be quite a dramatic difference in machining times. This is illustrated by the example in Figures 1-3 and 1-4. The same job, a cavity for a screw driver handle, was run on a machine with 1g acceleration and a machine with 0.25g acceleration. Everything else staying the same (the spindle speeds, programmed feed rates etc.), the machining

Hand milling of an injection mold cavity for screw driver handle



Ex. Influence of acceleration and the machining parameters on tool life and machining time of the cavity.

Material:	**1.2344 HRC 52-54**
Required operations:	**7**
Machines:	**HSM Machine 1G acceleration**
	conventional machine 0.2Ð0.3 G acceleration

Figure 1-3 Acceleration Differences Conventional & HSM

time on the machine with 0.25g acceleration is almost double that on the machine with 1g acceleration.

Thus, by having the right spindle speed range, feed rates, and acceleration on a high speed machining center for hard milling, it is possible to reduce machining times, improve accuracy, surface finishes, and improve tool life.

Program	Tool	Vc	N	Vf	fz	ae	ap	t/1G	t/0.25G
Cavity									
Roughing	Spherical cutter FRAISA U5282-220 ∅ 4	402	32Õ000	7Õ000	0.11	0.3	0.2	30Õ	45Õ
Pre finishing	Spherical cutter FRAISA U5282-140 ∅ 2	239	38Õ000	4Õ000	0.05	0.15	0.12	3Õ	5Õ
Pre finishing / finishing	Spherical cutter KOBELCO VC-2MB ? 3 mm	330	35Õ000	4Õ000	0.06	0.03	0.08	53Õ	115Õ
Finishing	Spherical cutter FRAISA ✶ U5282-100 ∅ 1	126	40Õ000	3Õ000	0.04	0.003 0.05	0.05	8Õ	15Õ
Comparison:								**95Õ**	**AAÕ**

Using same technology (speed, feed, tool, and NC-Program)

The machining time is cut into half when high speed machining.

Pre finishing and finishing operation, with lots of direction changes and very fine stepovers (Ra 0.6), are the main reason for the time saving.

Figure 1-4 Machining Time Comparison (1g versus 0.25g machine)

Mikron HSM Range

The premier line of machines from Mikron for hard milling applications are the HSM Range. The models and the spindles available are:

3-AXIS	24k	30k	36k	42k	60k
HSM 400		X		X	X
HSM 500		X		X	X
HSM 600	X	X	X	X	X
HSM 800	X	X	X	X	X
5-AXIS					
HSM 400U		X		X	X
HSM 600U	X	X	X	X	X

The model numbers represent the longitudinal travels in mm. For example, the HSM 800 has *x*-axis travel of 800 mm (31.5”). All machines have an acceleration of 1g in all axes or 1.7g in three axes combined.

Construction

A popular method of construction for this class of high-speed machining centers is the bridge-type construction. Compared to a C-frame, which has an overhanging spindle and overlapping guideways for the table, the bridge design provides an optimal distribution of the moving masses and the spindle is rigidly mounted close to the guideways

A drawback of the bridge construction, however, has been accessibility to the working area, both for the operator and for an automated loading device such as a pallet changer or robot. The construction of the HSM range has solved this problem while providing many other benefits. Figure 1-5 illustrates a new bridge design in polymer concrete, which provides excellent accessibility to the working area from the front for an operator. The large opening allows good access for a pallet changer or robot. The pyramid-shaped construction with three-point support provides a stiff stationary structure to absorb the high acceleration/deceleration forces of the moving slides.

The polymer concrete construction, which is becoming increasingly popular for high-speed machining centers, provides 6-to-10 times better vibration dampening than cast iron. It also offers superior thermal stability, as the thermal conductivity of polymer concrete is 1/20th that of cast iron. Overall, the benefits are better tool life, better accuracy and surface quality, and noise reduction.

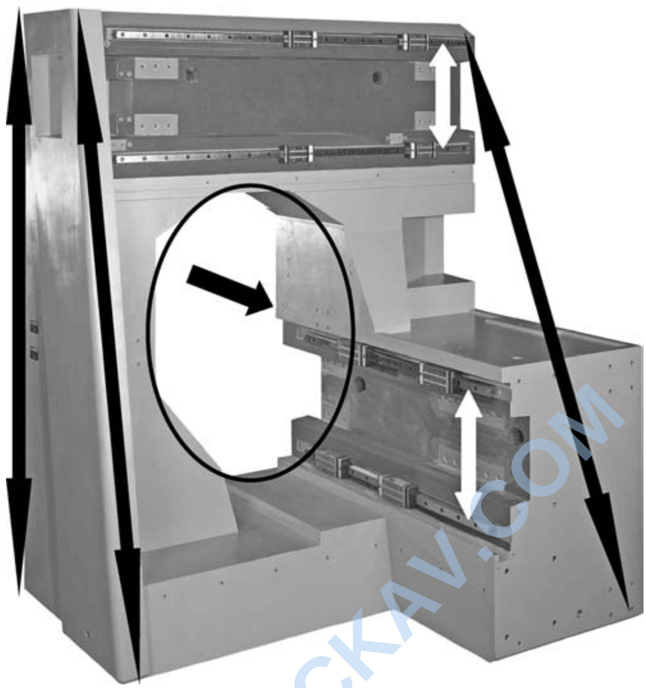


Figure 1-5 New Monoblock Bridge Type Design

The new polymer concrete construction also greatly reduces manufacturing costs and assembly times. Special bonding techniques allow complex structures to be created as a one piece or monoblock structure, eliminating any mechanical joining while providing superior rigidity. Such complex designs would be difficult to manufacture conventionally. Previously, guideway surfaces required cast in steel inserts to be machined or the surfaces themselves to be ground. Newly-developed casting techniques enable guideway surfaces to be prepared with a straightness and parallelism of 0.005 mm in 1,500 mm for the direct mounting of linear guideways. No machining or assembly is required for any of the major structural components—truly a breakthrough in machine tool construction.

The linear guideways, ballscrews, slides, motors and linear scales, etc., are mounted on the monoblock structure (see Figure 1-6). Other interesting features are that the linear guideways and ballscrews have permanent grease lubrication. No oil lines are required, there is no mixing

Figure 1-6 Assembled Machine (without Enclosure)

of the oil with coolant, there is no oil disposal, and the system is maintenance free. The spindle and feed motors are liquid cooled, thus conducting heat away from the structure. A laser tool measurement system (see Figure 1-7), a standard feature on the HSM range, serves to measure the length/radius of tools at the rotating speed, hence compensating for mechanical and thermal displacements of the spindle as well as thermal growth of the toolholder.

Glass scales with a positive pressure system are provided as a standard feature on all HSM machines to achieve very high positioning accuracies. A chiller provided with the machine cools the spindle, the feed motors, and the electrical cabinets. All HSM machines are flexible for wet and dry machining and can be set up for graphite machining. Figure 1-8 shows the Mikron HSM 400 with the enclosure.

Spindles

The HSM Range of machines are equipped with powerful integral motor spindles from STEP TEC, a sister company of Mikron.

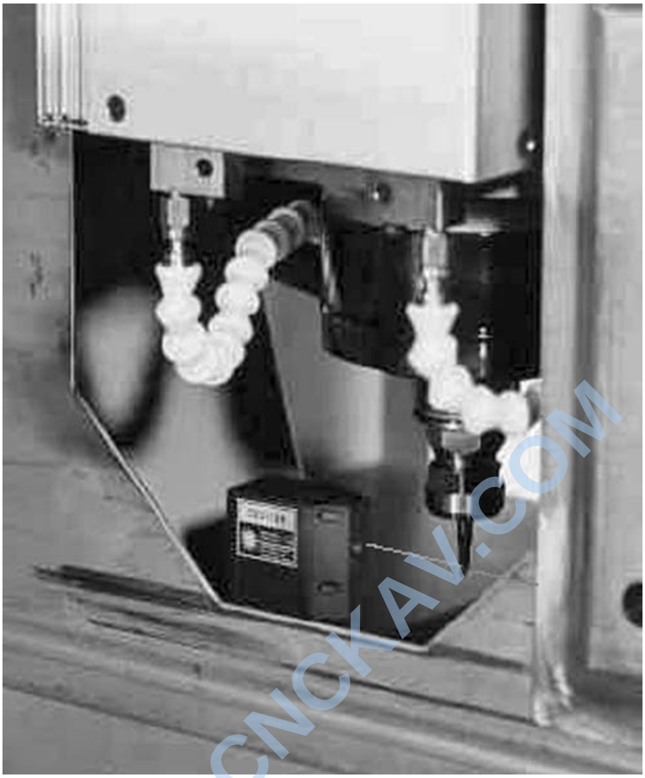


Figure 1-7 Laser Tool Measuring System

The construction of a typical spindle is shown in Figure 1-9. The spindle motor is built with a large rotor hole diameter which results in a dynamically robust construction with excellent power density. The spindles are designed with a double row of fixed bearings in the front and a floating bearing in the rear. The design allows most of the thermal expansion to take place towards the rear. With the HSK taper, the fixed bearings are located close to the spindle nose, providing high stiffness. All bearings are hybrid ceramic bearings which provide higher stiffness, have lower friction, generate less heat, run quieter, require minimal lubrication, and have a longer life. Lubrication is provided through a direct lubrication system, whereby droplets of oil are transported by air through a small hole in the bearings and spent oil is carried away by a vacuum system.

Figure 1-8 Mikron HSM 400

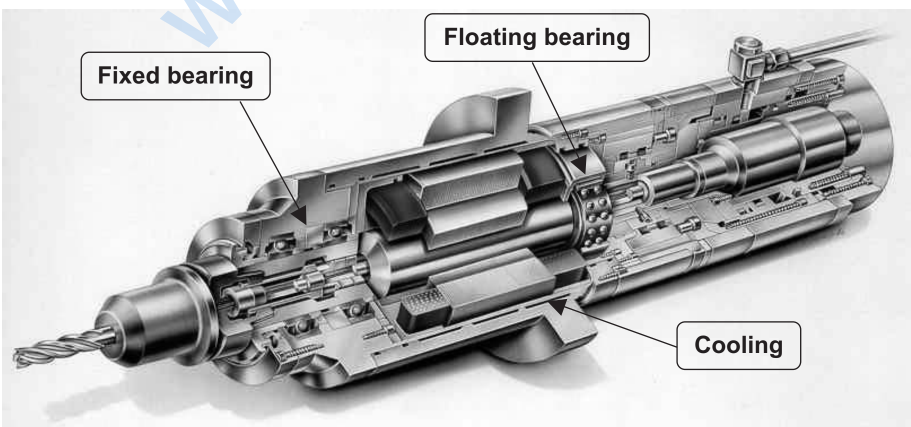


Figure 1-9 Spindle Construction

- 30,000 RPM, HSK-E40
  - S6: 12 kW / 8.9 Nm
  - S1: 10 kW / 6.4 Nm
- 36,000 RPM, HSK-E50 HT
  - S6: 32 kW / 20.6 Nm
  - S1: 24 kW / 15.5 Nm
- 42,000 RPM, HSK-E40
  - S6: 13 kW / 4.25 Nm
  - S1: 10 kW / 3.25 Nm
- 60,000 RPM, HSK-E32
  - S6: 8.5 kW / 3.5 Nm
  - S1: 6.5 kW / 2.7 Nm

Figure 1-10 Spindles Available for HSM Range

All spindles feature vector control which provides load-independent speed, a wide speed range, higher torque at low speeds for larger diameter tools, rigid tapping, and extremely fast acceleration and deceleration times.

The STEP-TEC 42,000 rpm spindle, for instance, has a speed range of 100-to-42,000 rpm, and 18 HP; it can handle tools up to 16 mm (5/8") in diameter and can accelerate from 0 to 42,000 rpm in less than 3 secs. All spindles have the HSK style taper, with tool sizes varying from HSK 40E to HSK 63A depending on the rpm range of the spindle.

The spindles available for the HSM machines are shown in Figure 1-10

Controls

All the Mikron HSM models feature the state-of-the-art Heidenhain iTNC530 Control. Heidenhain incorporates advanced software algorithms to provide smooth jerk-free motion at high feed rates in up to five-axes of motion. The block processing time is 0.5 ms, look ahead is 256 blocks, and the control comes standard with 25 GB memory and fast Ethernet at 100 mbits/sec. The control also has a host of standard features such as graphics, macro programming, 3D cutter compensation, and helical interpolation, etc.

Five-Axis Simultaneous High Speed Machining

High speed machining in three axes and five-axis simultaneous machining are in themselves well-established technologies. A pioneering development from Mikron is five-axis simultaneous high speed machining.

On a five-axis high speed machining center, the problem so far has been that the rotary/tilt axes could not match the feed rates and acceleration of the linear axes. Consequently, when machining a part that required five simultaneous axes of motion, such as a complex mold cavity in hardened steel with difficult-to-reach areas, the rotational axes could not keep up with the linear axes. The linear axes need to be slowed down and the benefits of high speed machining are lost.

Not any longer. The breakthrough is in the design of the rotary/tilt axes, which now use linear motor technology. The axes are powered by liquid-cooled, direct drive, high-torque motors, which have feed rates and accelerations that are easily ten times higher than their mechanical predecessors.

The direct drive rotary/tilt axes of the Mikron HSM 400U shown in Figure 1-11 can achieve speeds of 250 rpm and 150 rpm in the rotary

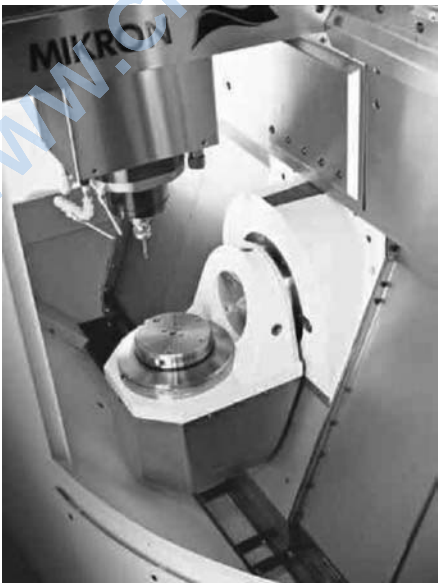


Figure 1-11 Direct Drive Table for Five-axis Simultaneous High Speed Machining

and tilt axes with corresponding accelerations of 200 and 100 radians per second squared. With these values, the rotational axes can now match the feed rates and acceleration of the linear axes, thereby enabling true high speed machining simultaneously in all five axes.

Automation

With 8,760 available hours in a year, there also is a growing requirement to automate high speed machining centers, as with other machines in the shop, to get the maximum capacity utilization out of the equipment. With improved reliability and security of the high speed machining process, machines are being designed to run around the clock. The first step toward automation is a quick-change setup system or a palletizing system on the machine. The pallets can be changed quickly in and out of the machine, enabling multiple jobs to be processed through the machine. The pallets also have a common reference system so they can be transferred from machine to machine or process to process. The next step is to automate the loading and unloading of the pallets with a mechanical arm, either a pallet changer or a robot, when the requirement is to serve multiple machines.

No longer are pallet changers or robots considered as equipment for production applications. Many mold and die shops are investing in this type of automation to keep their high-speed machining centers running around the clock and over weekends.

Mikron provides low-cost multiple station pallet changers on the HSM Range. For example, a typical 7-position pallet changer (see Figure 1-12) on an HSM 400 is priced under $ 30,000. When considering the amount of additional work that can be processed through the machine, the investment can have a payback period of just a few months.

Smart Machining

High speed machining has been around for a few years now, but as practitioners of high speed machining have come to realize, the laws of physics take on greater significance in the machining process. Factors such as centrifugal forces, unbalance, vibration, thermal expansion, etc., can affect process reliability and hinder reliable unmanned operation.

Smart machining is a new technology developed by Mikron to bring intelligence to the high speed machining/hard milling process in order to improve process reliability, optimize machining performance,

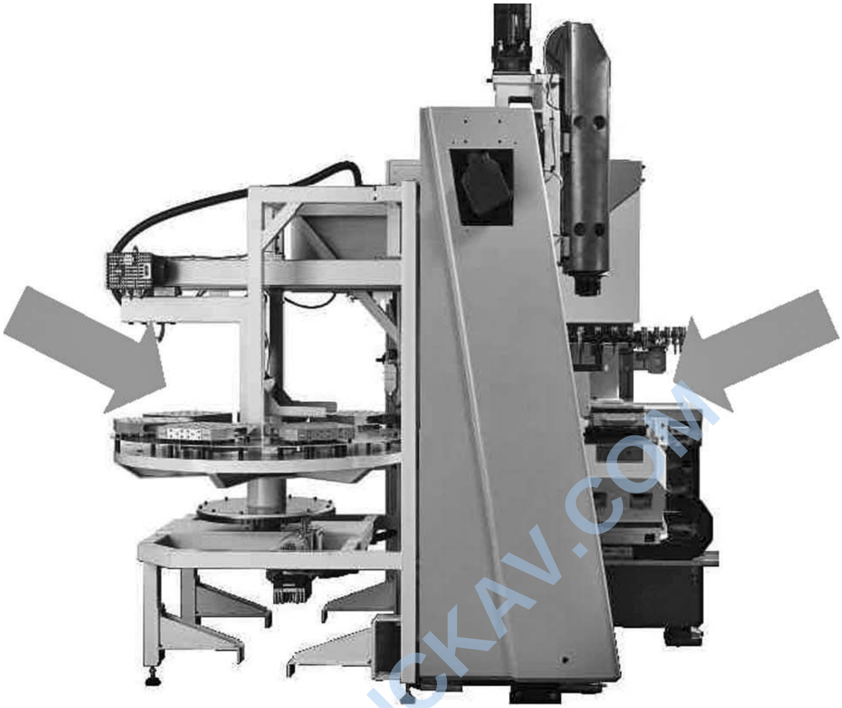


Figure 1-12 Integrated Pallet Changer

and allow reliable unmanned operation. Smart machining technology is available as various modules on the HSM Range of high-speed machining centers, as follows:

- Advanced Process System (APS)
  Monitoring of spindle vibration and support for localization of the source
- Intelligent Thermal Control (ITC)
  Active control and compensation of the thermal drift of the machine
- Operator Support System (OSS)
  Optimization of the milling process according to the requirements of the application
- Remote Notification System (RNS)
  Communication of the operating status of the machine from the CNC to a cell phone

Advanced Process System (APS)

Vibrations created through the milling process are measured with a vibration sensor which is integrated in the spindle near the front bearings. These measurements are transmitted to the control. Vibration, which can be measured as a displacement, velocity, or acceleration, is measured here as an acceleration value "g" (Figure 1-13). By activating a button on the control, the actual vibration value of the spindle can be shown on the monitor. Vibration levels can range from 0–10 g. Levels in the range 0–3 g, indicate a good process, tool, and tool holder. Values in the range 3–7 g indicate that the process must be changed as otherwise the lifetime of the spindle/tool will be reduced. Values from 7–10 g indicate that continuing in this range can cause damage to the spindle, machine, tool, and workpiece. The color of the display changes according to the range of vibration: 0–3 g green, 3–7 g yellow, 7–10 g red.

An overview of how long the spindle has been run in each vibration class is also shown, indicating how the spindle has been used over its operating life.

A further extension of the APS is that g limits can be set for warnings and NC stop. When the value of the g limit is exceeded during

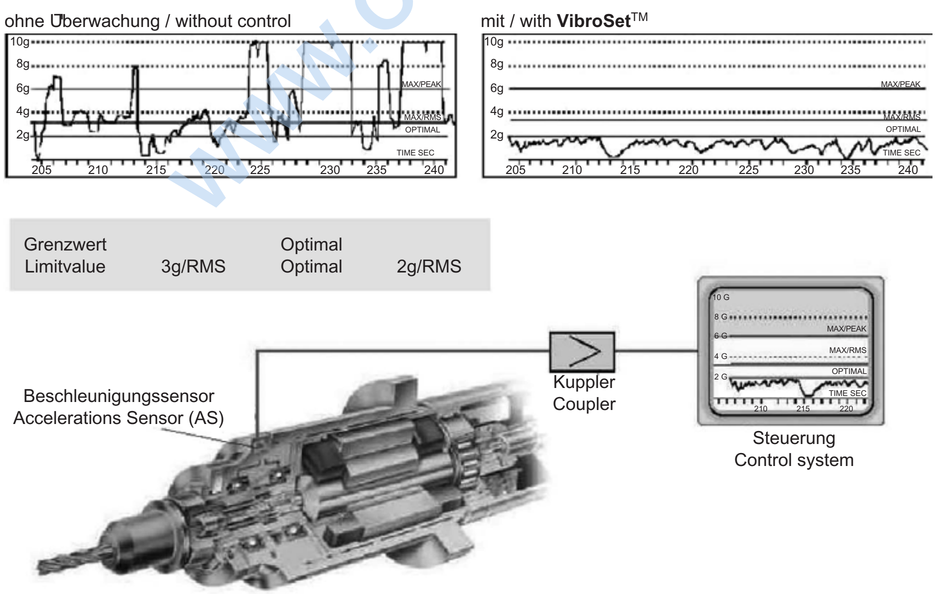


Figure 1-13 Advanced Process System

machining, a warning is issued or the machine stops automatically and the spindle is turned off according to the limit set. This helps protect the spindle during unmanned operation.

An additional feature is that measured vibrations can be recorded for analysis. For this, a g limit and a time interval have to be set in the control. Measurements are made according to the time interval. All data that exceed the limits are recorded and listed with the actual date, time, value of g, g limit, actual rpm, tool number, feed rate, NC block number, and NC program name. The log file has a size of 18,000 recordable blocks. With a time interval of 2.5 seconds, 12.5 hours of milling time over the g limit can be recorded for detailed analysis of the milling process. The analysis can then lead to an optimization of the NC program.

Intelligent Thermal Control (ITC)

With higher machining performance, the problem with heat sources inside the machine enclosure has considerably increased over the past years. Thermal drift has a significant negative impact on work piece accuracy. Compensation for thermal drift is required to ensure the desired work piece accuracy.

The goal of ITC is to compensate for thermal drift caused by heat sources inside the machine enclosure. The benefits are increased work piece accuracy, improved process reliability for unmanned machining, and reduction of machining time by eliminating or reducing the requirement for warm-up cycles.

The ITC module consists of several temperature sensors around the spindle and spindle carrier. The thermal behavior of the machine is modeled and software algorithms can predict the thermal drift of the spindle at various spindle speeds and at various points in time. ITC keeps the thermal drift in the direction of the Z-axis within a 20 micron band without any warm-up or preheat cycles. With warm-up cycles, that wait for the spindle and, in particular, the tool holder and cutting tool to be thermally stable, ITC can control the thermal drift to within a 10-micron band.

To control drifts tighter than 10 microns, especially with finishing tools when machining parting lines or blending surfaces, for instance, the laser can compensate for the actual position of the tool tip before machining. If two consecutive readings with the laser are the same, the thermal drift is stable; finish machining can take place with good results. The laser tool measurement is accurate to +/−1 micron.

Operator Support System (OSS)

While advances are taking place in controls for high speed machining centers in terms of block processing times, improved motion control algorithms, look-ahead, memory, and network capabilities, an interesting development from Mikron is a new intelligent process control system, called Cyclone, offered on the platform of the Heidenhain iTNC 530 control exclusively by Mikron.

When high speed machining complex 3-D contours, it is usually a question of optimizing three target values: speed, accuracy, and surface finish. For example, when roughing a mold, the priority could be speed. When finishing a small high precision electrode, the priority could be accuracy. When finishing a blow mold, the priority could be surface finish. Achieving these target values according to the application requires modification of hidden and usually inaccessible parameters called machine performance settings. They consist of hundreds of CNC parameters such as servo loop gains, axis jerk values, smoothing filters, etc., which have a tight relation to each other.

With the new expert control system Cyclone (see Figure 1-14), the operator is able to optimize the machine performance settings according to the application with an easy to use graphical interface. The performance of the machine tool can be optimized through a simple prioritization of the three target values: speed, accuracy, and surface finish. A selection can also be made for the complexity of the contour as simple, medium, and complex. The weight of the work piece can be defined as low, medium, or heavy. Optimum machine performance settings for each machining step from roughing to finishing can be activated.

A variety of machine performance settings for various applications are contained in the library, predefined at the factory. User experience can be easily transformed into additional machine performance settings and the number of applications specific settings can grow over time.

This expert system eliminates guesswork and provides optimal results according to the requirements of the application.

Remote Notification Systems (RNS)

With increasing automation and the use of machines during the nights and weekends, there is an increasing requirement for communication from the machine regarding its operating status.

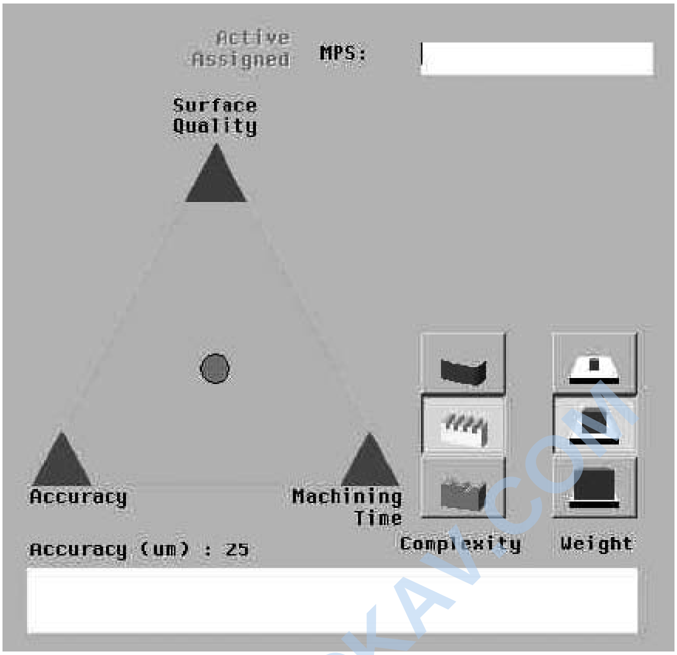


Figure 1-14 Expert Control System

The RNS is a module that allows transmission of NC messages from the control via short message system (SMS) in clear text to a specified user's cell phone. Information about the machine status as well as fixed milestones in an NC program can be transmitted.

The persons that need to be informed are listed in an address file on the machine control. The type of information to be communicated—such as machine stoppages, errors, and warnings—can also be defined.

The smart machining modules described are practical, useful, and easy-to-use modules. The Advanced Process System provides better spindle and tool life as well as better surface finishes. The Intelligent Thermal Control takes the guesswork out of controlling the thermal behavior, thereby providing more accurate molds and dies. The Operator Support System provides the desired results according to the application with minimal effort. The Remote Notification System keeps you informed about progress on the machine, eliminating surprises. In short, Smart Machining features are of great benefit to mold and diemakers when using the hard milling process.

Hard Milling Applications

The remaining figures show various applications of hard milling. Figures 1-15 and 1-16 highlight two different mold cores. Figure 1-17 illustrates a phone mold whereas Figure 1-18 features the pre-form for a PET bottle.

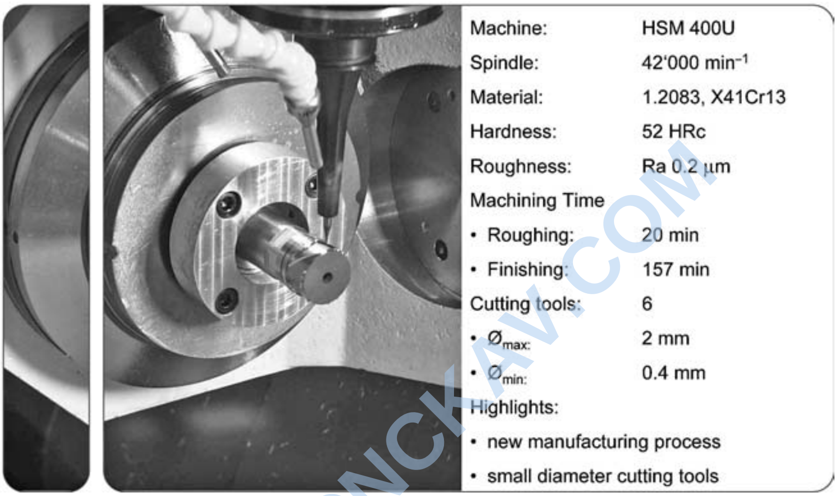


Figure 1-15 Mold Core Autofocus

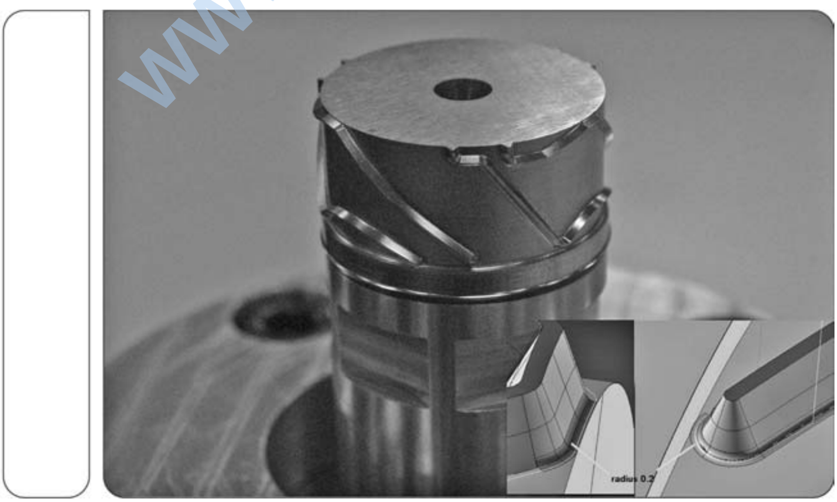


Figure 1-16 Mold Core Autofocus

Machine:	HSM 400
Spindle:	42‘000 min^{-1}
Material:	NAK 80 0.15%C,3%Ni,1.5%Mn,1%Cu,1%Al,0.3%Si
Hardness:	40 HRc
Roughness:	Ra 0.4 µm
Machining Time	
• Roughing:	17 min
• Finishing:	393 min
Cutting tools:	9
• $Ø_{max:}$	8 mm
• $Ø_{min:}$	0,4 mm
Highlights:	
• Contour accuracy, Surface quality	

Figure 1-17 Phone Mold

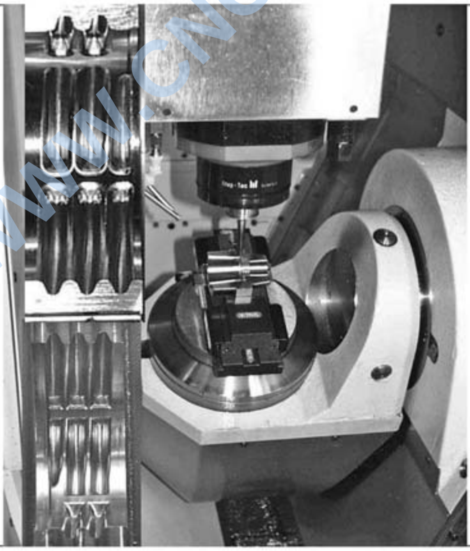


Figure 1-18 PET Bottle Pre-Form

Chapter 2

Okuma America Corporation

Data supplied by Ron Raniszewski Okuma America.

Company Background

Okuma America Corporation is the U.S.-based affiliate of Okuma Corporation, a world leader in the development of computer numeric controls (CNC) and machining technology, founded in 1898 in Nagoya, Japan.

Okuma is known for its technology leadership and world-class manufacturing, product quality, and dedication to customer service. Okuma products are used in the automotive industry, aerospace and defense, construction and farm equipment, energy, medical, mold and die, and fluid power industries.

Machines include vertical and horizontal machining centers, lathes, double-column machining centers, grinders, and wheel machines that offer users high throughput, high accuracy, and reliable solutions to production machining operations.

Okuma America began U.S. operations in 1984 in Long Island, New York, and moved to its present facility in Charlotte, North Carolina, in 1987 (see Figure 2-1). The Charlotte location is the headquarters for the manufacturing and training facilities for the North and South American operations.

Using Mechatronics, its full circle approach to equipment design, Okuma builds machines that have the exact balance of power, speed, and size to meet almost any application—machines that can hold tight tolerances, perform more sophisticated cuts, and create precision-crafted parts time and again.

The company has one of the most knowledgeable and well-established distributor networks in the industry, with 44 distributor partners

Figure 2-1

located throughout North and South America. This distributor network offers a one-stop resource for sales, service, training, engineering and more.

More than 477 industry professionals, from sales representatives to service and applications engineers, are available to work with you to design the technology solutions that address your core business needs. Okuma technology centers serve as both product showrooms and as the testing ground for advanced machining concepts.

Okuma has entered into a partnership agreement with the National Hot Rod Association and has been named Official Machine Tool Sponsor of the NHRA. This partnership is part of Okuma's High Performance Motorsports Industry program (see Figure 2-2).

Explanation of Hard Milling and High Speed Machining

Hard Milling

It has become possible to cut materials with a considerably high hardness through advances in tool materials and coating technologies.

It has become possible for objects which previously went through the rough machining (cutting) – quench hardening – grinding processes


OKUMA
"Okuma and Richard Childress Racing both strive to be number one in our respective industries. To do so requires excellent workmanship and high technology components demonstrated year after year, week after week. Our ability to jointly deliver consistent, high quality results makes both organizations clear winners and well suited as Partners in Performance."
Dean Hanaki
President & CEO
Okuma America Corporation
RCR Richard Childress Racing
"Two of our goals at Richard Childress Racing are winning races and winning championships. To accomplish this, we must be competitive and consistent every week. Race car components, especially those for engines, are held to tolerances of less than .001 of an inch. Okuma's high technology machining centers go even further and are accurately repeatable to .00008 of an inch. Their technology, coupled with unparalleled engineering support, creates a partnership that enables Richard Childress Racing to achieve its goals."
Richard Childress
President & CEO
Richard Childress Racing
RCR CAMPUS
RCR Gym
Industrial Drive
RCR Racing Museum
Pit Stop Practice
Okuma Technology Center
Warehouse
Tina Drive
Chassis Research & Development
Engineering
Cup Shop
Engine Department
Engine Research & Development
Meeting Hall
Show Car
Austin Lane
Fabrication Shop
Busch Shop
RCR Richard Childress Racing
The RCR Campus is a world-class racing complex designed to serve the production, training and publicity needs of RCR's five racing teams. In addition to the RCR/Okuma Technology Center, the complex houses the NASCAR Nextel Cup Shop and NASCAR Busch Shop where each team is headquartered and team cars are assembled. Many of the car components are created on site at the RCR/OTC to both protect trade secrets and streamline assembly and repair. RCR also plays host to racing fans and business partners at the Meeting Hall and brand new RCR Museum, which is open to the public.
PARTNERS
IN PERFORMANCE
OKUMA
Pace Yo

Figure 2-2

RCR/OKUMA TECHNOLOGY CENTER

The competition level in NASCAR is the highest it has ever been. As a result, teams have to find every edge possible to stay in front of the pack and RCR's relationship with Okuma provides the tools and equipment to do just that.

Richard Childress Racing is responsible for the manufacture and quality control of a growing list of race car components. Through the RCR/Okuma Technology Center, RCR is able to make changes on site, without some of the lag time required when working through suppliers. The benefits of this relationship have played an important role in keeping RCR one of the premier teams in NASCAR today.

ENGINEERED TO WIN

The RCR/Okuma Technology Center combines high technology with excellent workmanship to create the racing components necessary to win.

Richard Childress Racing understands the precision and durability required for parts to survive harsh racing conditions and relies on Okuma machines to produce accurate results time and again. Using Okuma's industry leading OSP control, RCR machining technicians are able to program the machines to meet and maintain the most demanding standards. When combined with the MacMan-NET system, the Okuma OSP allows for simultaneous real-time monitoring of every machine on site, and helps keep the tech center running at optimal efficiency.

The benefits of this partnership extend beyond mere efficiency to making the impossible a reality. With Okuma's highly flexible equipment on site, RCR is able to make adjustments in their race car technology specifications and produce test parts in record time.

The RCR/Okuma Technology Center offers the best machining technology in the industry, which is evaluated bi-annually to ensure optimal production capability. Here is a quick look at the machines in use today and their benefits to the RCR team.

LU300-V8 CAM
WHAT RCR USES IT FOR:

- Primarily used for research and development of pistons
- CAM turning software and hardware allows creation of both cylindrical and elliptical parts
- Special Servo system built onto X-axis allows the cutting tool to make quick diametrical movements
- Machine communicates with OSP control, tracking spindle rotational position relative to the X-axis position

LU300-BBMY
WHAT RCR USES IT FOR:

- Primarily used for longer or larger parts
- Large, robust spindle bearings allow simultaneous 4-axis machining
- M-driven spindle capabilities reduce cycle time by incorporating drilling and milling, as well as turning, on one machine
- High degree of flexibility and accuracy allows for extremely fast turn-around on a variety of parts

Captain L-370MW
WHAT RCR USES IT FOR:

- Tailored toward creation of small, detailed parts
- Live tooling and sub-spindle improves manufacturing speed
- M-driven tools allow for multiple machining functions on single machine for optimal efficiency and accuracy
- W-sub spindle minimizes operator handling by allowing processing on both ends of the component
- Offers maximum flexibility within minimal floor space

MX-55VA / MB-56VA
WHAT RCR USES IT FOR:

- Primarily used for high-speed production of larger steel and aluminum parts, including piston deck modification
- Available 4th axis allows multi-rotational position machining operations
- Fourth axis enables machining of eight pistons – four per side – from one set-up, without operator intervention
- Outfitted like the MB-46VAE, it can be used as a back up machine

MB-46VAE
WHAT RCR USES IT FOR:

- Used for piston machining and special material components
- 3D contouring capability and high spindle speed – 15,000 rpm – combine for more accurate finished parts
- Vertical spindle capitalizes on gravity to remove chips – improving both precision and productivity
- Outfitted like the MB-56VA, it can be used as a back up machine

MA-50HB / MA-500HB
WHAT RCR USES IT FOR:

- Primarily used for large components such as engine blocks and cylinder heads
- Horizontal design allows for use of 19.6 inch square pallet in mounting and automatic fixturing of components
- Superior results achieved from perpendicular relationship of spindle to engine block surfaces during machining
- Automatic pallet changer increase throughput, decreasing non-productive time of the machine

PM-600V
WHAT RCR USES IT FOR:

- Machine used for cylinder head porting
- Parallel Kinematic Design (PKM) allows 6 ballscrews to drive a suspended spindle in 5-axes
- Main advantage is that all 5 machining axes are created within the machine and not with a rotary table

GC34NH
WHAT RCR USES IT FOR:

- CNC camshaft grinding is done best when the Okuma PC-APT CAM G software is used
- Tapered and flat lobe profiles are performed on this machine
- Capable of holding 0.01° Lobe Phasing and 6-10 millionths profile accuracies

Figure 2-2 (Continued)

to be made by die sinking quench hardened materials directly, which raises expectations that lead times for die manufacturing can be shortened, etc.

It cannot be said that tool costs are no problem, but if the conditions of urgency, specialization of machining, and high material costs exist, this process is at the stages where it is sufficiently practical that it does not have to be limited to die manufacturing.

Main Points in Hard Milling and High Speed Machining

The most critical aspect for hard milling and high-speed machining is to have a very rigid and solid machine with properly-matched state-of-the-art drive motors, spindle drives and controls, and spindles.

It is necessary that tool heat generation be suppressed and that chip removal be accomplished smoothly. It is vitally important that control of cutting speeds and depth of cut, as well as a sufficient supply of air for cooling, be even more carefully maintained.

Hard Milling and High-Speed Machining Centers

MD 46/56

As die and mold designs become more sophisticated, so does the need to produce them quickly, efficiently, and precisely. The Okuma MD 46/56 Series vertical machining centers give you everything you need to produce the most complex dies and molds on a single machine. Okuma MD Series machines combine selected high performance production options into an affordable package created specifically for die and mold work. A thermally stable frame, built using exclusive Okuma TAS-C construction techniques, creates a machine that significantly reduces the influence of temperature variations on the work piece during machining. The TAS-S spindle coolant system automatically compensates for heat-induced deviations. Okuma AbsoScale encoders in all three axes provide ultra-high tool positioning accuracy. Okuma THINC intelligent numerical control with the super-high NURBS function gives you complete control over cutting path accuracy and speed for a superior surface finish—at higher feed rates than competitive machines.

Plus, with 20GB of program memory, you never have to worry about drift feeding. When you need one machine to boost your die and mold production operations to the next level, you need an Okuma MD Series vertical machining center.

MB Series

The robust MB Series is the foundation for all Okuma vertical machining centers. Its efficiency and utility make it one of the most popular machine series for mold and die work. Like all Okuma machines, the MB Series machines are built from the ground up, with construction optimized using FEM analysis for a rugged machine frame that resists the effects of vibration and thermal gradients in the X and Y axes. For all its ruggedness, its rapid spindle traverse and Hi-G acceleration make it a quick machine with the speed to significantly reduce cycle time. Okuma's thermally stable design coupled with zero table overhang let you hold tight tolerances with extreme accuracy for the most precise jobs. You can select from a wide range of Okuma options to customize MB Series machines to fit your specific die and mold production needs.

The Theory Behind Our Hard Milling and High Speed Technology

With Mechatronics, a full circle approach to machine engineering, Okuma controls every aspect of design and production—from controls to motors, drives to spindles—creating the most stable and accurate precision machine tools on the market. Okuma's extremely rigid base construction, higher spindle speeds and increased thermal stability result in more stability and greater accuracy than competitive machines. THINC intelligent numerical control with Super-NURBS and Hi-G functions gives you total command of the tool path for unprecedented accuracy in machining complex contoured shapes. Smaller machine footprints, efficient pallet loading, ergonomic design, and low noise specifications create a user-friendly technology that ultimately improves throughput and productivity. Okuma's feed rates, including high acceleration and deceleration rates, combined with shortened ATC time and a wide array of high speed spindle options, improve overall die and mold making efficiency.

New Developments for Hard Milling Products

Okuma is continually working to improve an already Hi-Tech machine and control. With the introduction of the MB-V series machines, many factors were examined and addressed concerning thermal distortion of the spindle and the construction of the machine. Okuma uses a symmetrical structure that simplifies thermal deformation of the machine. The spindles have a double-sleeve cooling jacket that balances the spindle head temperature, which removes heat evenly and prevents tilting of the spindle. There also is 4-point oil-air lubrication which balances bearing temperatures. The heat from the NC cabinet and the oil cooler is vented straight up and the chip channels are isolated from the bed.

The newest version of Super-Nurbs, our Hi-Speed interpolation function, is approximately 40% faster than about three years ago. With our Thermal Compensation packages of TAS-S (see Figure 2-3) and TAS-C (see Figure 2-4), and .0001 micron control, we can control Z-axis growth to .004 micron over long-term use for the most accurate parts possible.

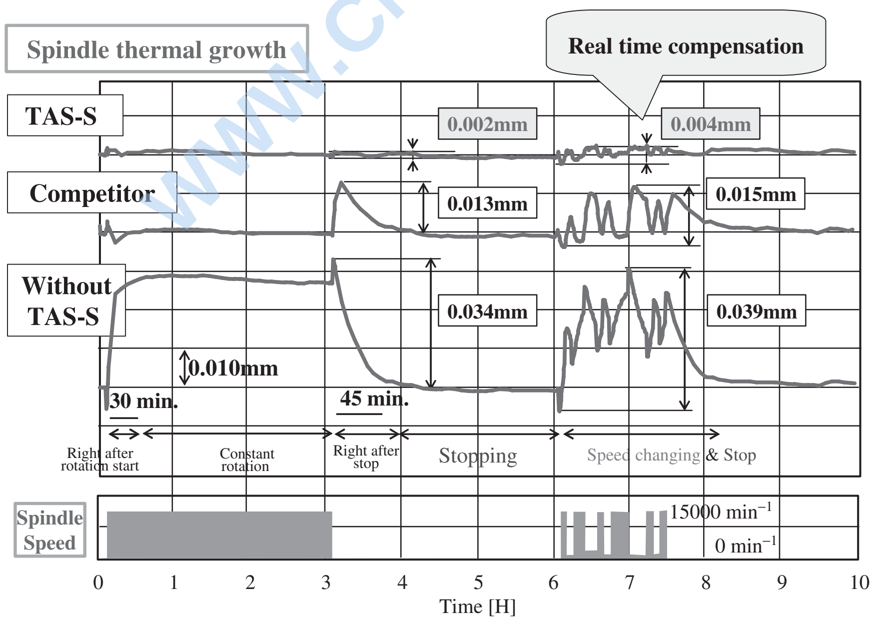


Figure 2-3 TAS-S

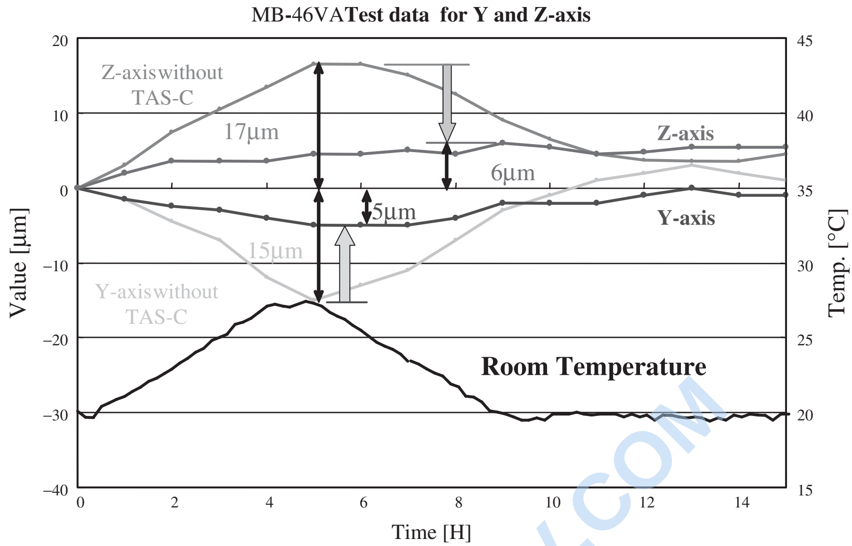


Figure 2-4 TAS-C

Description of Machines

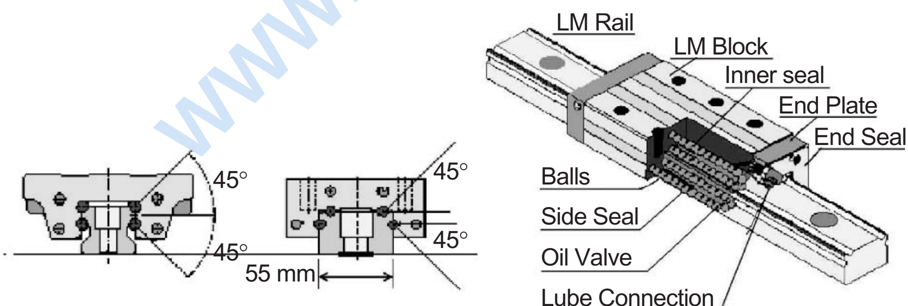
The following pages illustrate just a few of the many models Okuma now produces for hard milling and high speed machining. Table 2-1 compares several MD models. Figure 2-5 focuses on the Way System and Figure 2-6 on the numerical control THINC. Tables 2-2 and 2-3 compare spindles and holder options, whereas Tables 2-4 and 2-5 look at coolant systems and other fluid system capacities and electrical power. Finally, Figures 2-7 and 2-8 profile a variety of Okuma products.

Test Cuts

The remaining figures provide test cut information about several Okuma products. Figure 2-9 looks at the MU-400VA demo part for simultaneous 5-axis machining. Figure 2-10 details the MU-400VA's mold for rubber sealing. Figure 2-11 switches to the MD-46VA and its mold for a headlight cover. Figure 2-12 stays with the MD-46VA, this time focusing on the automobile light reflector. Figure 2-13 also looks at the MD-46VA, this time the hardened steel used for the crankshaft.

Table 2-1: Comparing MD Models

Mogdel	MD46V	MD46V-E	MD56-V	MD66-V
Tables Size (inch)	18.11 x 29.92	18.11 x 39.37	22.05 x 51.18	25.98 x 60.24
Travel X (inch)	22.05	30.00	41.34	59.06
Travel Y (inch)	18.11	18.11	22.05	25.98
Travel Z (inch)	18.11	18.11	18.11	25.98
Way System X axis Size(inch)	NRS 1.77 wide	NRS 1.77 wide	NRS 1.77 wide	NRS 1.77 wide
Way System Y axis Size(inch)	NRS 1.77 wide	NRS 1.77 wide	NRS 2.09 wide	NRS 2.09 wide
Way System Z axis Size(inch)	NRS 1.77 wide	NRS 1.77 wide	NRS 1.77 wide	NRS 1.77 wide



HSR TYPE NRS TYPE

	HSR	NR	NRS
Vertical Stiffness	100%	200%	**140%**
Horizontal Stiffness	100%	70%	**140%**

Figure 2-5 Way system

Table 2-2: Spindles

Model	MD46V	MD46V-E	MD56-VA	MD66-VB
RPM Max. (standard)	15000	15000	15000	12000
Horsepower	30	30	30	34
Cooling System	Recirculating oil for jacket and bearing	Recirculating oil for jacket and bearing	Recirculating oil for jacket and bearing	Recirculating oil for jacket and bearing
Spindle Taper (standard)	40	40	40	50
Compensation System	TAS-S	TAS-S	TAS-S	TAS-S

Hi-Content

THINC

THE INTELLIGENT NC

- . . . is a PC based machine tool control.
- . . . is a fluid platform. Hardware and Software will grow with emerging technology.
- . . . affords a simple and common approach to factory floor communication and networking.
- . . . creates an in-place PC for implementing custom strategies.
- . . . is leveraging the technology advantage of the off the shelf PC market.
- . . . means integral Ethernet for Factory, Enterprise and Corporate Communication.

THINC SPECIFICATION	
Compact PCI computer	Intel Pentium M 1.6 GHz
Windows XP OS embedded	20GB hard disk (built-in)
IEC1131-3 based PLC	512MB(DRAM)
12.1in. color TFT LCD	Touch Screen (or Mouse)
4 USB ports at OP panel	2 USB ports at PC (1 open)
(1) RS-232 Port	(1) Floppy disk at Op panel
(1) EthernetTM(*3), 10Base/100BaseTX	
IRTOS (Real Time Operating System) for deterministic control	Application Program Interfaces (Basic Set)
ABSO SCALES X,Y,Z axis	Super Nurbs Type A
User Task I & II (Macro Programming)	Hi-G servo control
Helical Cutting	Synchronized Tapping
Tool Breakage Detection	Auto Tool Length Offset Function
Auto Zero Offset Function	Auto work gauging

Figure 2-6 Control

Table 2-3: Spindle and Holder Options

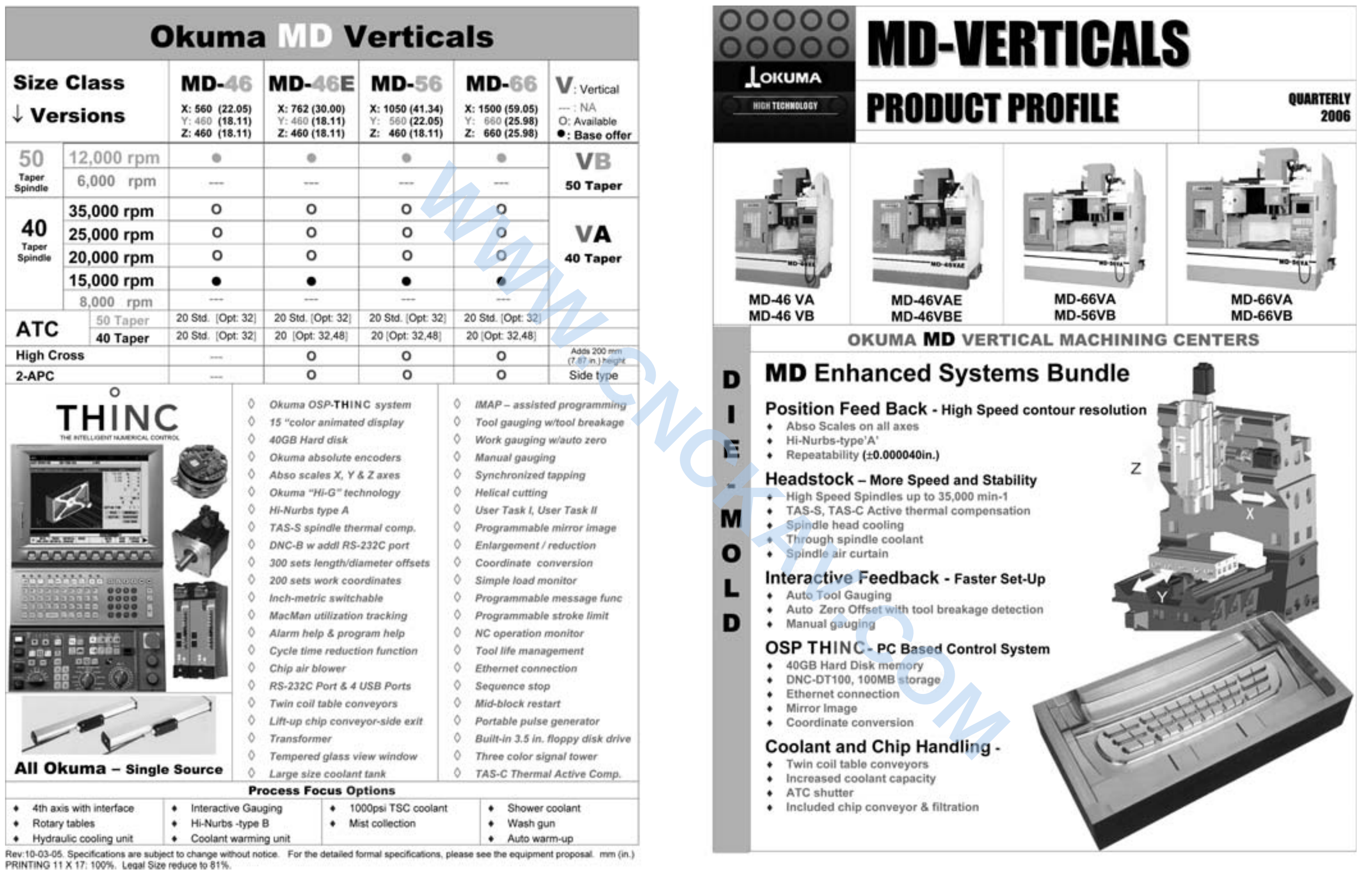
RPM Max.	20000	25000	35000
Horsepower	40	20	20
Cooling System	Recirculating oil for jacket and bearing	Recirculating oil for jacket and bearing	Recirculating oil for jacket and bearing
Holder Option	HSK-63A	HSK-63A	HSK-63F
Compensation System	TAS-S	TAS-S	TAS-S

Table 2-4: Coolant System

Coolant System – USA Standard	Inch	Metric
Reservoir Ð Roll-away tank	46 gallons to 76 gallons	175 liters to 290 liters
Flood pump power (to nozzles)	0.33 hp	0.25 kW
Pump volume	9 gal/min.	22/26 liters/min
Distribution	5 Directional Nozzles at Spindle	
Dual chip channel flush system		
Reservoir	Common as above	
Pump power	0.53hp	0.4kW
Distribution	Y piping to each gutter	

Table 2-5: Other Fluid System Capacities and Electrical Power

Spindle head cooling Unit Ð FC2	gal	10 liters
Pneumatic required minimum pressure	71 psi	0.5 Ð 0.7 MPa
Pneumatic required minimum volume	132 gal/min	500 Ni/min
Oil-air mistspindle lube unit -	0.71 gal	2.0 liters
Electrical power	3 phase 200V +/–10% 50/60 Hz	



Okuma MD Verticals
Size Class ↓ Versions
MD-46 X: 560 (22.05) Y: 460 (18.11) Z: 460 (18.11)
MD-46E X: 762 (30.00) Y: 460 (18.11) Z: 460 (18.11)
MD-56 X: 1050 (41.34) Y: 560 (22.05) Z: 460 (18.11)
MD-66 X: 1500 (59.05) Y: 660 (25.98) Z: 660 (25.98)
V: Vertical --- : NA O: Available ●: Base offer
50 Taper Spindle 12,000 rpm 6,000 rpm
VB 50 Taper
40 Taper Spindle 35,000 rpm 25,000 rpm 20,000 rpm 15,000 rpm 8,000 rpm
VA 40 Taper
ATC 50 Taper 40 Taper
20 Std. [Opt: 32]
20 [Opt: 32,48]
High Cross
2-APC
Adds 200 mm (7.87 in.) height
Side type
THINC THE INTELLIGENT NUMERICAL CONTROL
All Okuma – Single Source
Okuma OSP-THINC system
15 "color animated display
40GB Hard disk
Okuma absolute encoders
Abso scales X, Y & Z axes
Okuma "Hi-G" technology
Hi-Nurbs type A
TAS-S spindle thermal comp.
DNC-B w addl RS-232C port
300 sets length/diameter offsets
200 sets work coordinates
Inch-metric switchable
MacMan utilization tracking
Alarm help & program help
Cycle time reduction function
Chip air blower
RS-232C Port & 4 USB Ports
Twin coil table conveyors
Lift-up chip conveyor-side exit
Transformer
Tempered glass view window
Large size coolant tank
IMAP – assisted programming
Tool gauging w/tool breakage
Work gauging w/auto zero
Manual gauging
Synchronized tapping
Helical cutting
User Task I, User Task II
Programmable mirror image
Enlargement / reduction
Coordinate conversion
Simple load monitor
Programmable message func
Programmable stroke limit
NC operation monitor
Tool life management
Ethernet connection
Sequence stop
Mid-block restart
Portable pulse generator
Built-in 3.5 in. floppy disk drive
Three color signal tower
TAS-C Thermal Active Comp.
Process Focus Options
4th axis with interface
Rotary tables
Hydraulic cooling unit
Interactive Gauging
Hi-Nurbs -type B
Coolant warming unit
1000psi TSC coolant
Mist collection
Shower coolant
Wash gun
Auto warm-up
Rev:10-03-05. Specifications are subject to change without notice. For the detailed formal specifications, please see the equipment proposal. mm (in.)
PRINTING 11 X 17: 100%. Legal Size reduce to 81%.
OKUMA HIGH TECHNOLOGY
MD-VERTICALS
PRODUCT PROFILE
QUARTERLY 2006
MD-46 VA
MD-46 VB
MD-46VAE
MD-46VBE
MD-66VA
MD-56VB
MD-66VA
MD-66VB
OKUMA MD VERTICAL MACHINING CENTERS
DIE - MOLD
MD Enhanced Systems Bundle
Position Feed Back - High Speed contour resolution
Abso Scales on all axes
Hi-Nurbs-type'A'
Repeatability (±0.000040in.)
Headstock – More Speed and Stability
High Speed Spindles up to 35,000 min-1
TAS-S, TAS-C Active thermal compensation
Spindle head cooling
Through spindle coolant
Spindle air curtain
Interactive Feedback - Faster Set-Up
Auto Tool Gauging
Auto Zero Offset with tool breakage detection
Manual gauging
OSP THINC - PC Based Control System
40GB Hard Disk memory
DNC-DT100, 100MB storage
Ethernet connection
Mirror Image
Coordinate conversion
Coolant and Chip Handling -
Twin coil table conveyors
Increased coolant capacity
ATC shutter
Included chip conveyor & filtration
Z
X
Y

Figure 2-7

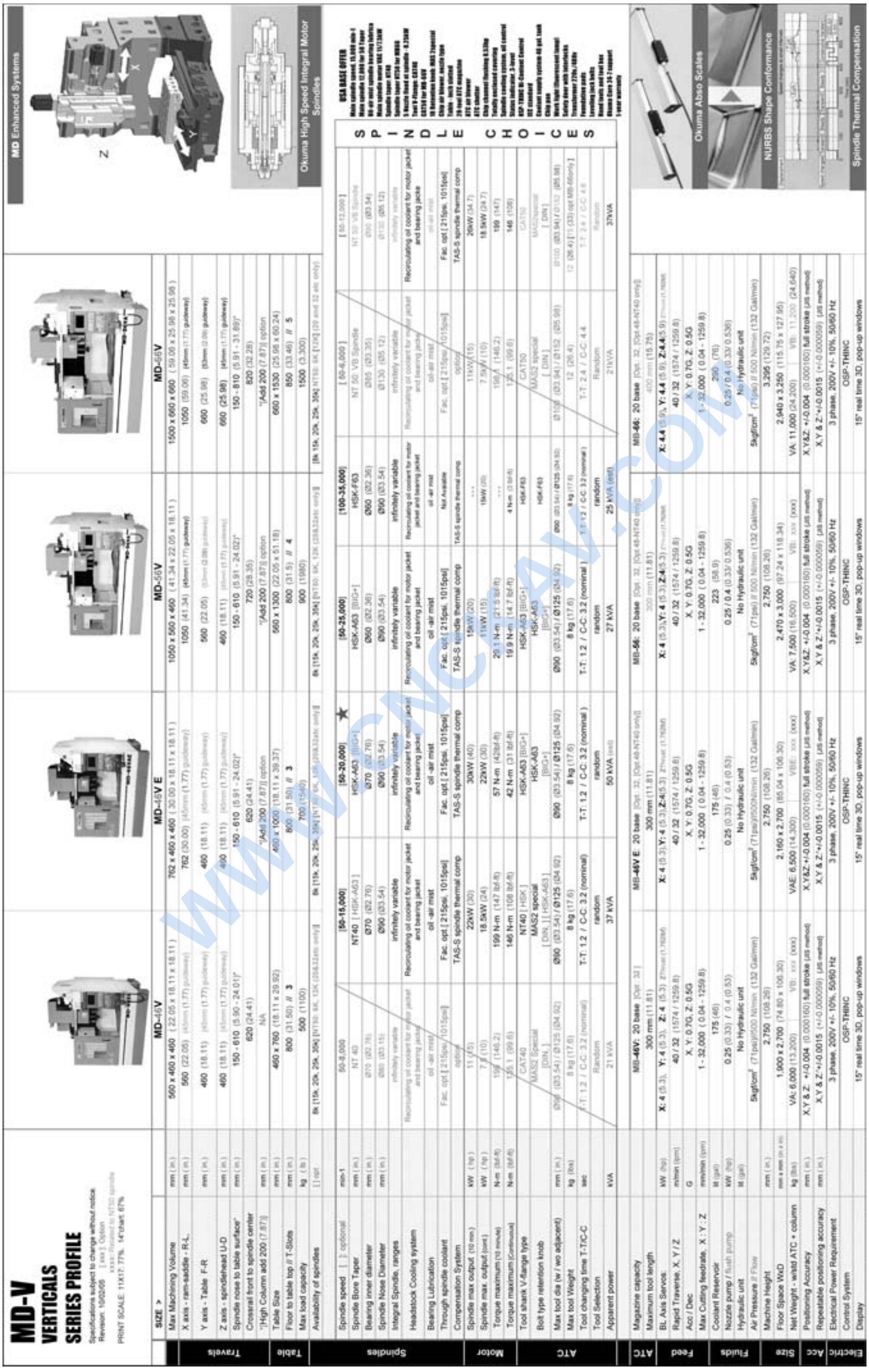


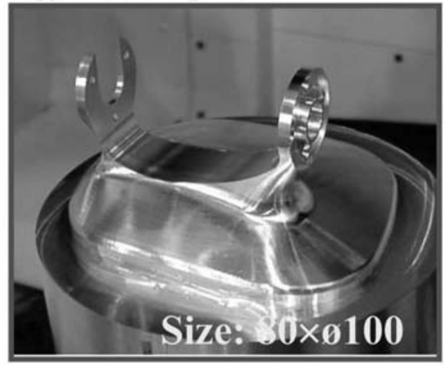
Figure 2-8

MU–400VA Simultaneous 5-axis machining Example

Part name: Demo Part

Material: 3.3523

- Avoid collision utilizing 4th/5th axis
- Shorter tooling
- Avoid machining with tool tip
- Optimized cutting conditions by controlling pitch and lead angle
- Improved surface quality



Extracts of machining conditions

Process	Tool	Spindle speed min^{-1}	Feed mm/min	Cutting condition
Mill pocket	Ø 16 EM	15000	4500	12 x 3
Semi-finish	Ø 16 EM	5000	1500	8 x 1.5
Contouring	Ø10 EM	7500	1500	8
Sim. 4-axis	Ø 6 EM	5000	500	
Sim. 4-axis	Ø 10 EM	7500	1500	
Sim. 5-axis	Ø 8 BEM	15000	3000	

NC Data :MASTERCAM

Cycle time:
2 hrs 55 min

BEM: Ball End Mill - RM: Round Insert Mill - EM: End Mill
The above data were taken from machining using water-soluble coolant.

Any technical information is subject to change without notice.

Figure 2-9

MU-400VA 15000min^{-1} Simultaneous 5-axis machining Example

Mold for rubber sealing

- **Avoid collision by 4th/5th axis**
- **Shorter tooling**
- **Avoid cutting with tool tip**
- **Optimum cutting conditions by controlling tilt and lead angle**
- **High Quality surface finishing**

Material: Die steel

Dimension: ¯ 100x75

Cycle time

5 hrs. 24 min.

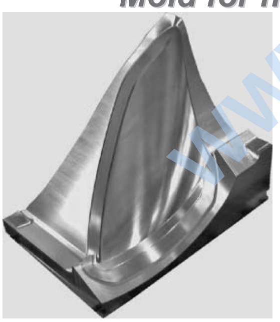
Process	Tool	Spindle speed min^{-1}	Feed mm/min	Cutting condition
Semi-Finish	¯ 16 EM	4000	400	12x0.5
Centre Cyl.	¯ 4 BEM	10000	1500	0.1x0.1
Contouring	¯ 4 BEM	12000	2400	0.1x0.1
Groove	¯ 3 BEM	8000	720	0.05x0.05
Corners	¯ 3 BEM	8000	1000	0.05x0.05
Finish	¯ 1.5 BEM	12000	1500	0.03x0.03

BEM: Ball End Mill - RM: Round Insert Mill - EM: End Mill
Any technical information is subject to change without notice.

Figure 2-10

MD-46VA 15000min^{-1} Head light Cover Machining Example

Mold for headlight cover



High Quality finishing
Required Z-Stroke: 410mm

Material:
Steel HPM7 (30HRC)
Dimension:
600x380x445

Cycle time:
18 hrs. 47 min.

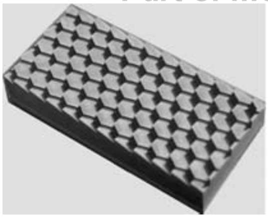
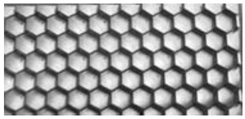
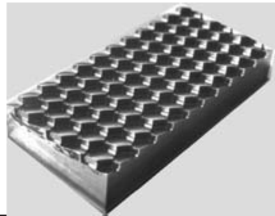
NC data: ADMAC-Die Mold

Process	Tool	Spindle speed min^{-1}	Feed mm/min	Cutting condition
Semi-Finish	¯ 6 BEM	3000	300	0.08x0.05
Semi-Finsh	¯ 6 BEM	3000	500	0.15x0.05
Finish	¯ 6 BEM	8000	800	0.08x0.05
Groove	¯ 6 BEM	15000	3000	0.15x0.05

BEM: Ball End Mill - RM: Round Insert Mill - EM: End Mill
Any technical information is subject to change without notice.

Figure 2-11

MD-46VA 25000mm^{-1} Automobile Light Reflector *Machining Example*
Part of mold for reflector

Material:
Steel (40HRC)
Dimension:
34x16x16
Cycle time:
16 hrs. 51 min.
NC data: ADMAC-Die Mold

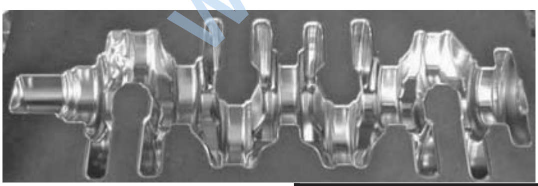
Process	Tool	Spindle speed min^{-1}	Feed mm/min	Cutting condition
Semi-Finish	¯ 3 BEM	25000	1500	a_e=0.9
Semi-Finish	¯ 3 BEM	25000	1500	a_e=0.9
Semi-Finish	¯ 1 BEM	15000	200	
Finish	¯ 1 BEM	15000	750	a_e=0.1
Finish	¯ 0.6 BEM	15000	150	
Finish	¯ 0.4 BEM	20000	150	
Finish	¯ 0.4 BEM	25000	400	a_e=0.005

BEM: Ball End Mill - RM: Round Insert Mill - EM: End Mill
Any technical information is subject to change without notice.

Figure 2-12

Figure 2-14 covers the core for the mold for the headlight reflector. Figure 2-15's focus is the PET bottle mold. Figure 2-16 returns to the MU-400VA to provide technical information about the test cut for simultaneous 5-axis maching.

MD-46VA 25000min^{-1} Hardened steel machining example
Forging Die for Crankshaft



Super L/D-ratio machining:
¯ 8 L/D=8
¯ 6 L/D=10

Material:
DACK4 (50HRC)
Dimension:
520x180x70
Cycle time:
3 hrs. 48 min.

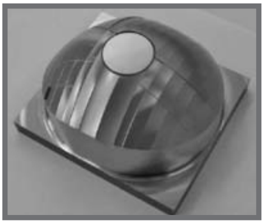
Process	Tool	Spindle speed	Feed mm/min	Cutting condition
Semi-Finish	¯ 8 BEM	14000	7000	0.6x0.6
Semi-Finish	¯ 8 BEM	10000	4000	0.5x0.02
Semi-Finish	¯ 8 BEM	8000	3000	0.4x0.02
Finish	¯ 6 BEM	17000	6000	0.2x0.08
Finish	¯ 6 BEM	10000	3150	0.2x0.09
Finish	¯ 6 BEM	7000	2100	0.2x0.10

BEM: Ball End Mill - RM: Round Insert Mill - EM: End Mill
Any technical information is subject to change without notice.

Figure 2-13

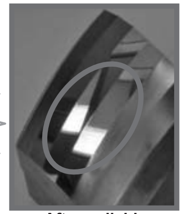
MDĐ46VA 25000min^{-1} Headlight Reflector machining example

Core for reflector mold



★ Manual finishing time 20% less

★ Increased accuracy after manual finishing



After polishing

Material: HPM38 (32HRC)

Dimension:

160x150x115

Cycle time:

19 hrs. 16 min.

NC data: ADMAC-Die Mold

Process	Tool	Spindle speed min^{-1}	Feed mm/min	Cutting condition
Pre-Rough	¯ 35 RM	1400	1960	24x0.5
Rough	¯ 4 BEM	15000	3000	t_p=0.3
Semi-Finish	¯ 2 BEM	25000	1500	t_p=0.2
Semi-Finish	¯ 1 BEM	25000	1250	t_a=0.14
Finish	¯ 0.6 BEM	23000	460	t_p=0.04
Finish	¯ 1.0 BEM	20000	1200	t_a=0.07

BEM: Ball End Mill - RM: Round Insert Mill - EM: End Mill
Any technical information is subject to change without notice.

Figure 2-14

MDĐ46VA 15000min^{-1} High quality mold machining example

PET bottle mold

Seamless machining from first to last point guaranteed by OKUMAÕs Thermo-Friendly Concept

Thermo-friendly
High quality
High accuracy

feed direction

pick feed

Material: Die steel (40HRC)

Dimension: ¯ 64x20

Cycle time:
4 hrs. 36 min.

NC data: ADMAC-Die Mold

Process	Tool	Spindle speed min^{-1}	Feed mm/min	Cutting condition
Rough	¯ 10 EM	6000	4000	0.8x21
Rough	¯ 6 BEM	4000	800	a_p=0.15
Semi-Finish	¯ 4 BEM	6000	1200	a_p=0.1
Finish	¯ 2 BEM	15000	3000	a_p=0

BEM: Ball End Mill - RM: Round Insert Mill - EM: End Mill Any technical information is subject to change without notice.

Figure 2-15

MU-400VA
Test Cut on 5-axis Die/Mold Machining

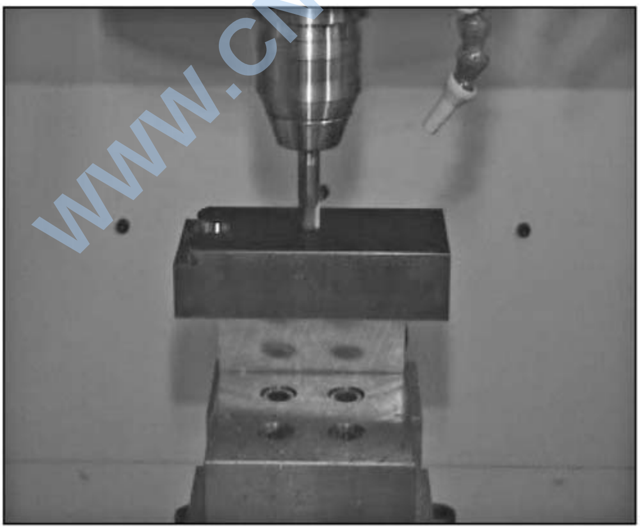
1. Appeal point of the test cut

   Simultaneous 5-axis machining in hardened steel.

2. Conditions

Date	10. Mar. 2005
Machine	MU-400VA
Purpose of Demo/ Test Cut	Demo part for 5-axis cutting in hardened steel
Machine specification	15,000 min^{-1} spindle DNC-DT, Hi-Nurbs, Abso scale, 5-axis Machining function
Toolings	Mitsubishi
NC Data	CAD – CAM by Delcam
Workpiece Name	Test piece
Workpiece Material	1.2767
Material hardness	55 HRC
OEG Engineer	J. Klaeser

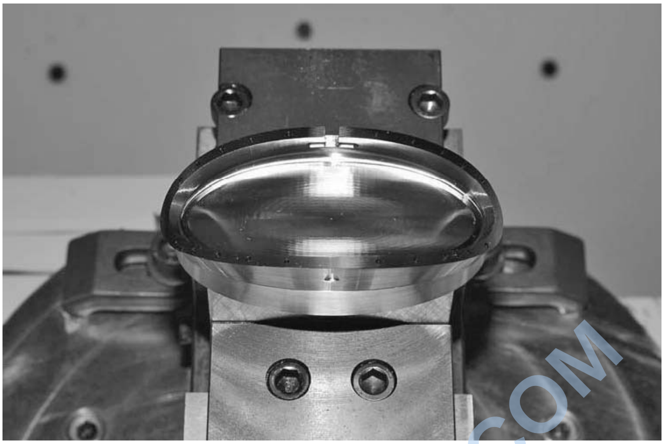
3. Video



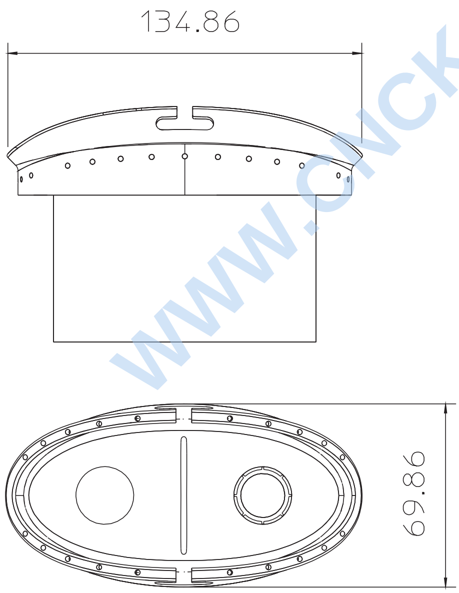
Any technical information is subject to change without notice.

Figure 2-16

4. Workpiece photo



5. Workpiece Drawing



Any technical information is subject to change without notice.

Figure 2-16 (Continued)

Chapter 3

YASDA

By Hutch Hachiuma President & CEO of Yasda Precision America Corporation

Thanks to recent developments in CNC technology and HSM (high speed machining capability), as well as advances in cutting tool technology (especially coating technology), hard milling technology is getting increasingly popular in machining, particularly in mold and die applications. Hard milling involves machining hardened material with milling cutters, drills, and boring tools.

HARD MILLING TECHNOLOGY

The ability to accurately machine hardened tool steel—and in most cases, eliminate jig grinding and significantly reduce or eliminate the use of EDM and polishing—has caught the attention of the mold and die industry. By reducing or eliminating these conventional time-consuming and labor-intensive processes, the mold and die-making industry benefits substantially by shortening lead-time and increasing profitability. The main objective of hard milling should be to shorten lead-times, and to do so in a more cost-efficient way.

MORE THAN JUST A HIGH SPEED SPINDLE

Some manufacturers equip their standard vertical machining centers with spindles that are capable of higher-than-normal rpm (10,000rpm – 50,000rpm) and market them as hard milling machines. These machines were never really designed for machining hard materials. They don't provide the accuracy, tool life, and surface finish that is usually required. Their use may lead to the conclusion that the hard milling process is very expensive and not worth the effort.

A true hard milling machine has the specific design features and assembling techniques, from the machine base to the spindle nose, needed to achieve a successful and profitable approach to hard milling. Essential characteristics of "true" hard milling include the combination of:

1. Vibration-free stiff spindle
2. Rigid and thermally stable machine structure
3. Smooth and stiff slide-ways

Vibration-Free Stiff Spindle

Direct Drive, Not Built-In Motor Spindle

Most high speed spindles available in the market today employ a built-in motor spindle. This results in vibration and heat from the spindle unit. A large mass (motor rotor) rotates at high speed between bearings, which means balancing is very difficult to maintain at optimal levels. The longer bearing distance causes the natural spindle frequency to be lower than cartridge-type spindles. These conditions are not optimal for hard milling.

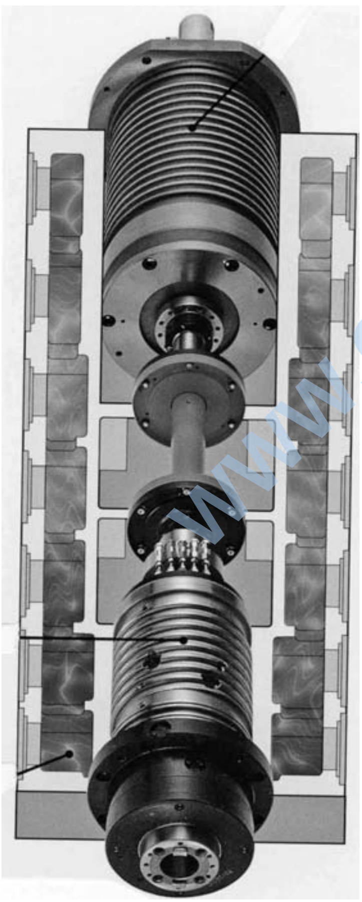


Figure 3-1 YASDA's Direct Drive System

YASDA's direct drive system utilizes a diaphragm coupling that co-axially connects the spindle and the drive motor without any backlash (see Figure 3-1). This design isolates the electric vibration and heat caused by the drive motor and results in improvement of the spindle's rotational accuracy because the spindle's drive force does not work in the radial direction. The diaphragm coupling allows the load inertia from the spindle drive motor to provide the spindle cartridge with a smooth, vibration-free, and rotationally accurate ride. The YASDA direct drive design enables superior spindle performance for fine grade machining.

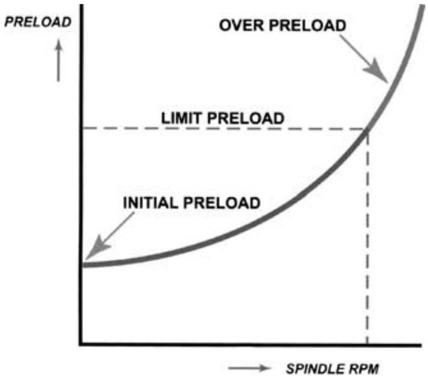


Figure 3-2 Typical Spindle Bearing Preload Curve

Bearing Preload Self Adjusting System

A spindle is designed to cut at low or high rpm, with little or no run-out regardless of cutting forces. When the spindle rotates at high speed, bearings generate heat, resulting in thermal expansion of the spindle, and causing the preload value to increase (see Figure 3-2). Because of this phenomenon, the initial preload value must be adjusted downward to avoid an over preload condition as the spindle grows. This makes the spindle bearing too loose at low rpm and too tight at high rpm. These conditions also result in shorter life of the spindle bearing.

The preload self-adjusting spindle developed by YASDA is a system that self-adjusts the optimum preload value given to the spindle bearings throughout the full range of the spindle (see Figure 3-3). Maintaining a

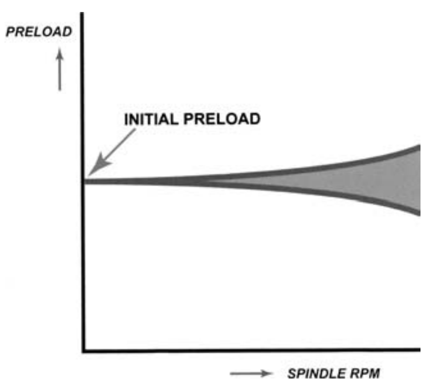


Figure 3-3 Spindle Bearing Preload Self-adjusting System

consistent stiff spindle condition allows optimal heavy cutting conditions at low rpm, as well as fine finishing conditions at high rpm; it also guarantees fine surface finish and longer tool life. Subsequently, this spindle design significantly contributes to longer bearing life.

Rigid and Thermally Stable Machine Structure

Symmetric bridge-style machine construction and box ways are mandatory for hard milling. A rigid structure with high damping capability is a key requirement for better surface finishes and longer tool life. Most hard milling operations require long cycle times. During this long cycle time, the machine structure must be maintained at a constant posture. In addition to the symmetric design feature, a progressive thermal distortion stabilizing system is necessary.

Today's CNC technology can compensate for thermal distortion error with the combination of sensing devices. However, the compensation can be made only in the axial direction; angular errors cannot be compensated. In most cases, a thermal distortion error comes out as an angular error. In vertical spindle designs, the spindle center line usually tends to grow toward the operator direction at the lower end. Under this condition, the *Z*-axis targets the same depth, but the actual *Y*-axis locations may vary by the difference of tool length, due to angular error.

YASDA's thermal distortion stabilizing system circulates a temperature-controlled fluid through the majority of the machine's structure in order to maintain consistent posture during long cycle times.

Smooth and Stiff Slide Ways

Box-Type Slide Way

The stiffness and damping capability of the slide way is another important factor for better surface finishes and longer tool life. Recently, most machining centers employ the linear (roller or ball) guide slide ways. This slide way has an advantage in production cost and, most of all, faster positioning speed. Milling machines with this type of slide way may be fine for aluminum machining, but insufficient for hard milling applications. YASDA's slide ways are hybrid, combining a unique friction slide way with roller packs, for better damping capability and faster movement. All slide ways are made from tool steel, hardened (HRC60), individually ground, and then hand-lapped. Slide ways are then bolted down to the precisely hand-scraped surface.

Servo/Axis Rigidity

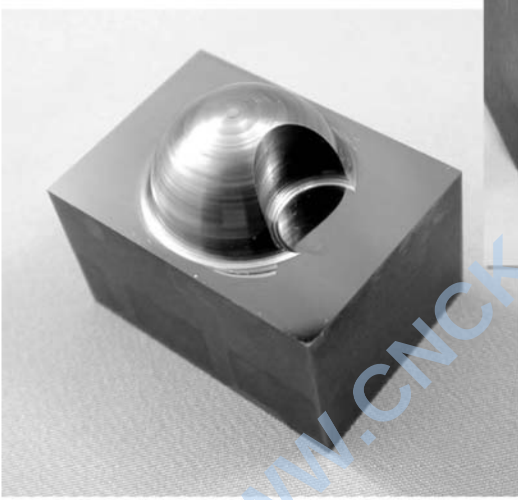
Most high-speed milling machines employ course pitch ball screws for faster positioning speed. However, course pitch ball screws cannot generate enough servo/axis rigidity for hard milling. This results in poor accuracy, surface finish, and shorter tool life. YASDA's YBM-640V Ver. III employs 8mm pitch ball screws for all axes (see Figure 3-4). Perpendicularity of the ball screw supporting bearing and slide ways is also very important for servo/axis rigidity. All balls rotating around the ball screw must support the load equally for high rigidity and longevity of the ball screw. At YASDA, the ball screw supporting bearing bracket and ball nut mounting surfaces are precisely hand-scraped to ensure the highest rigidity and life of ball screw/axis drive.

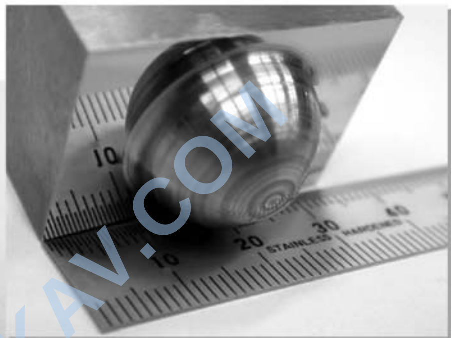
Figure 3-4 YASDA YBM-640V Ver. III

Test Cuts

The remaining figures (Figure 3-5 through Figure 3-24) provide test cut information for several different work pieces. Much of this information is summarized in Table 3-1.

HIGH SPEED DIE MOLD MACHINING WITH YASDA YBM 950V





Machine	: YASDA YBM 950V *Mold & Die Miller*
Work piece	: Test piece
Material	: Cemented carbide G5 (Hardness:HRA88)
Work piece dimension	: 35×25×50 (mm)
Cutting tool	: Diamond EP Cutter
Cutting oil	: Water-miscible Cutting Fluid (Emulsion)

High speed machining with YASDA HAS-3 system					
Machining process	Cutting tool	Spindle speed (min^{-1})	Feed rate (mm/min)	Cutting time (min)	Total cutting time (min)
Rough	Ø6×R1 Diamond EP Cutter	15000	500	239	10 Hr. 8 Min.
Finish	Ø6×R1 Diamond EP Cutter	15000	500	369	

Figure 3-5

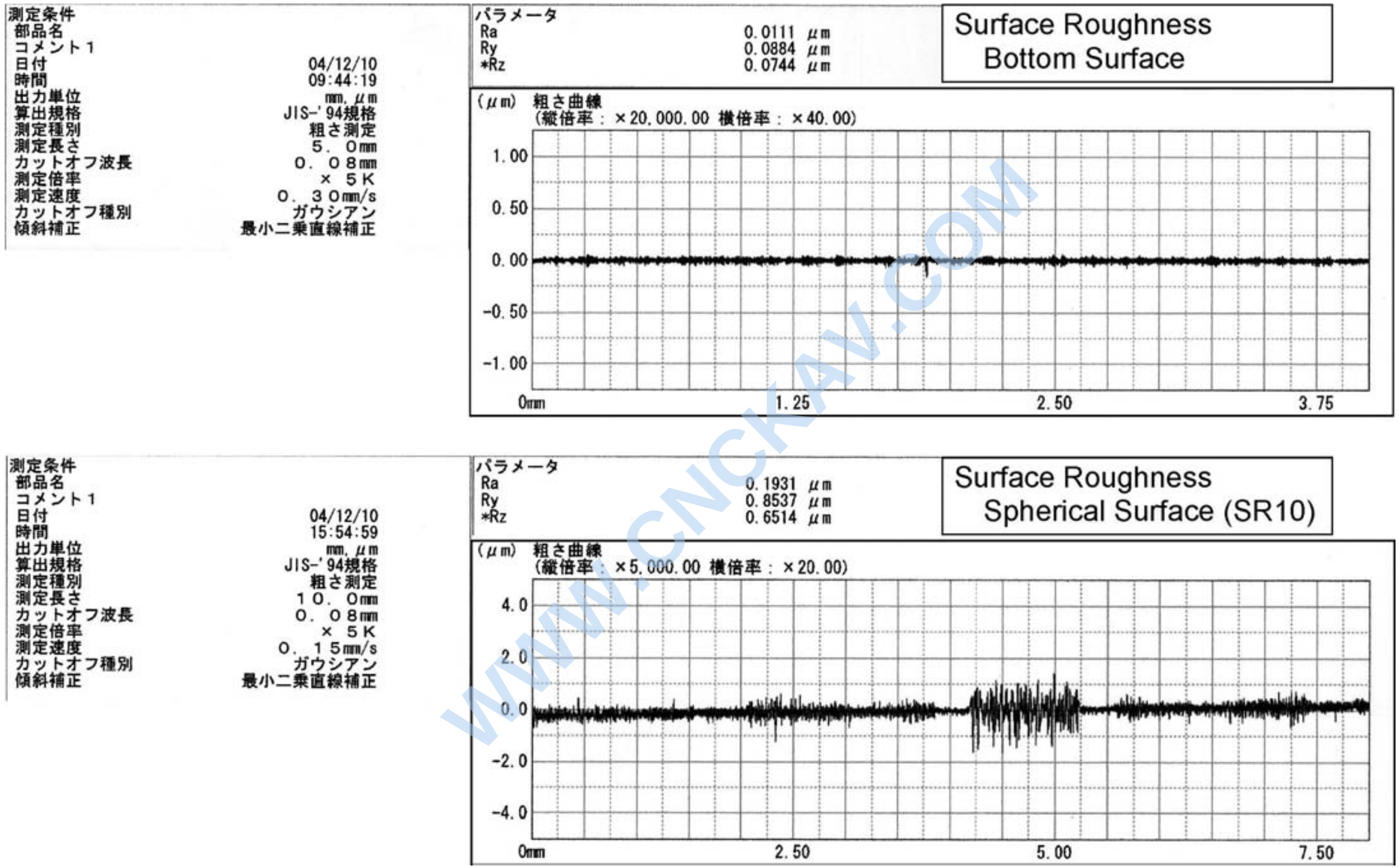


Figure 3-5 (Continued)

Profile Acuracy
Spherical Surface (SR10)

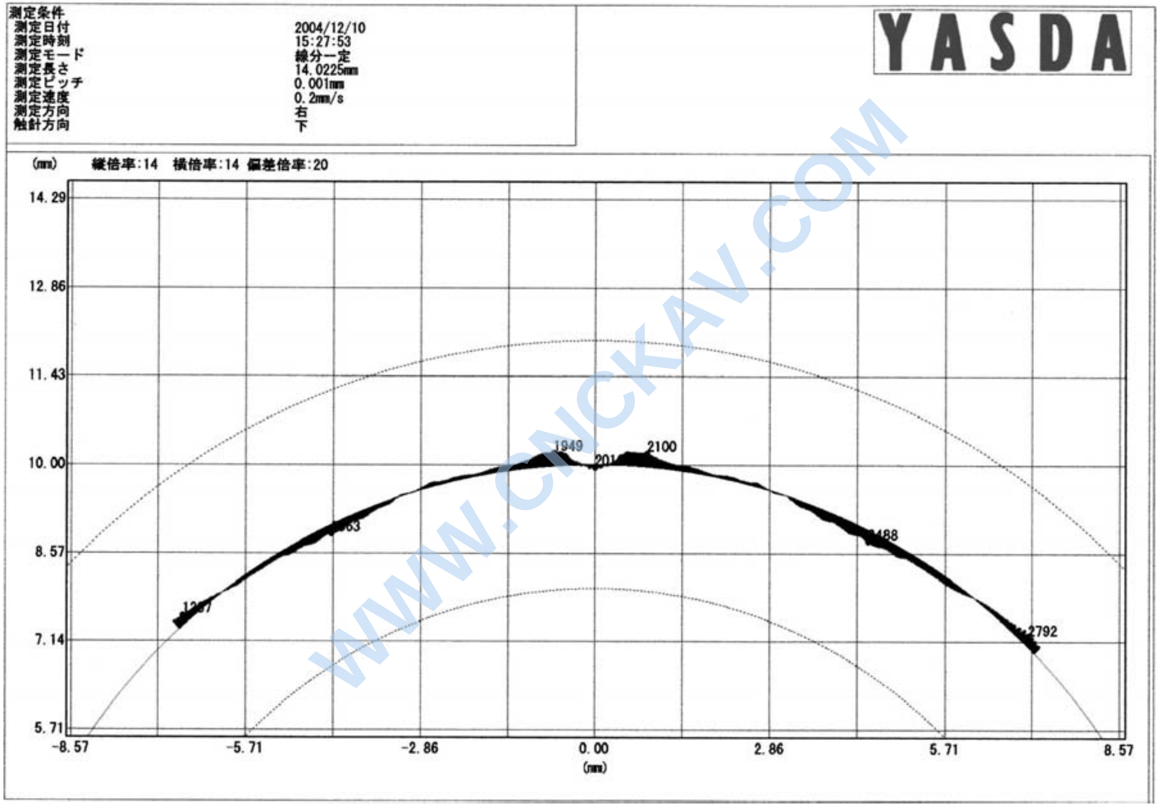


Figure 3-5 (Continued)

HIGH SPEED DIE & MOLD MACHINING WITH YASDA YBM 640V

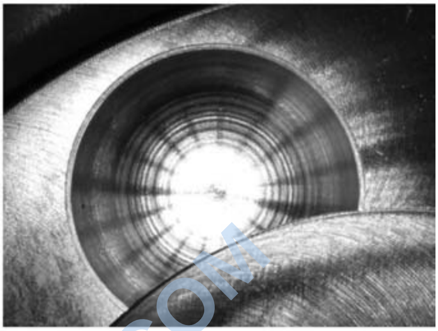
Machine	: YBM 640V *Mold & Die Miller*
Work Piece	: CVJ Tripod Die
Material	: DRM2 (Hardness: HRC62)
Machining details	: Finish Machining with R1×8 CBN End Mill
Work Piece Dimensions	: ø102×50h (mm)
Cutting Oil	: Oil Mist

High speed machining with YASDA HAS-3 system

Machining Process	Cutting Tool	Spindle Speed (min^{-1})	Feed Rate (mm/min)	Cutting Time (min)	Total Cutting Time
Rough	R5 Ball End Mill	600 3150	240 800	29.5	2Hrs. 27Min.
	Ø10 Square End Mill	4000	200 2500	6.1	
Finish	Ø10 Square End Mill	4000	200	1.4	
Semi-Finish	R2 Ball End Mill	15000	1400	15.3	
	R1×8 Ball End Mill	18000	1800	21.9	
Finish	R1×8 Ball End Mill	20000	1000	0.9	
	R1×8 Ball End Mill (CBN)	20000	1800	71.4	

Figure 3-6

HIGH SPEED DIE MOLD MACHINING WITH YASDA YBM 950V



Machine	:	YBM 950V *Mold & Die Miller*
Work Piece	:	Bearing Retainer
Material	:	DC53 (Hardness: HRC60)
Work Piece Dimensions	:	50×50×40 (mm)
Cutting Oil	:	Oil Mist

High speed machining with YASDA HAS-3 system

Machining Process	Cutting Tool	Spindle Speed (min^{-1})	Feed Rate (mm/min)	Cutting Time (min)	Total Cutting Time
Rough	R5 Ball End Mill	1000 2000	240 250	11	2hr 10min
Rough	Ø10 Square End Mill	2000 3000	200 800 2000	14	
Semi-Finish	Ø10 Square End Mill	2000	500	3	
Finish	Ø10 Square End Mill	1500	150	6	
Rough	R3 Ball End Mill	5000	1000	11	
Semi-Finish	R1 Ball End Mill	20000	1500	21	
Finish	R0.5 Ball End Mill (CBN)	20000	800 500	64	

Figure 3-7

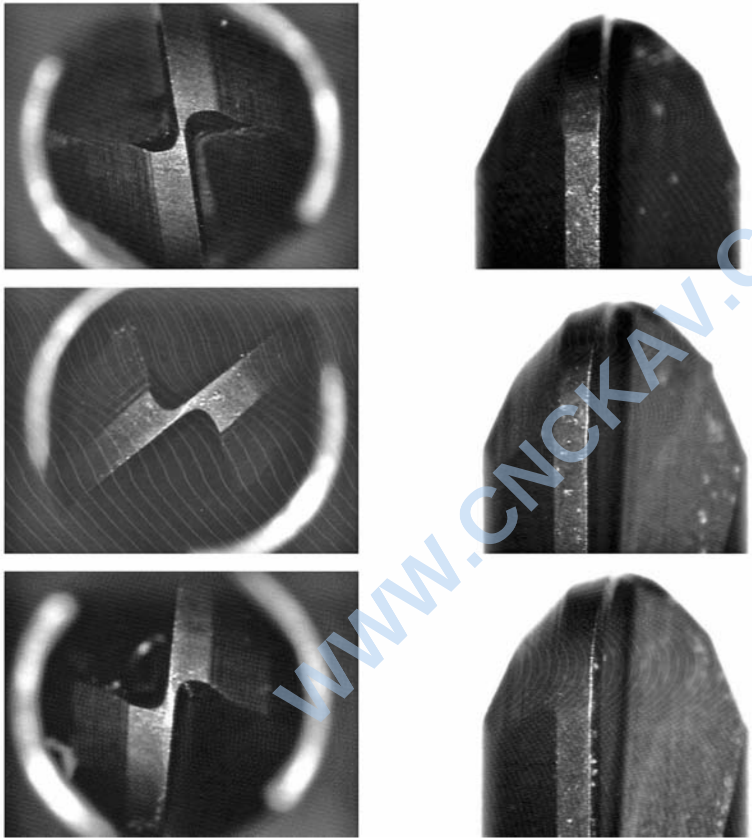
HIGH SPEED DIE MOLD MACHINING WITH YASDA YBM-640V

Machine	: YASDA YBM-640V *Mold & Die Miller*
Work piece	: Bevel gear cavity
Material	: DC53 (Hardness:HRC60) equivalent to AISI D2
Work piece dimension	: 60×60×40 (mm)
Cutting tool	: Carbide coated end mill, CBN end mill
Cutting oil	: Oil mist

High speed machining with YASDA HAS-2 system					
Machining process	**Cutting tool**	**Spindle speed (min^{-1})**	**Feed rate (mm/min)**	**Cutting time (min)**	**Total cutting time**
Starting hole	R5 ball end mill	600	240	7.4	2 hours 28 min.
Rough	Ø10 flat end mill	4000	2500	6.2	
Rough	R3 ball end mill	5000	1200	19.0	
Semi-finish	R1.5×8 ball end mill	8500	2000	36.1	
Semi-finish	R1×8 ball end mill	15000	2400	28.5	
Finish	R1×8 ball end mill (CBN)	20000	2000	50.3	

Figure 3-8

Wear On CBN End Mill



New End Mill

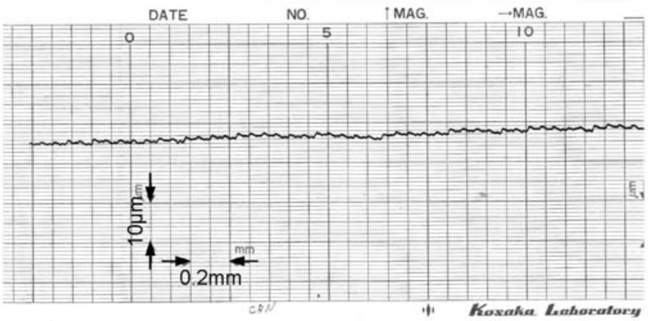
After Machining 2 pieces

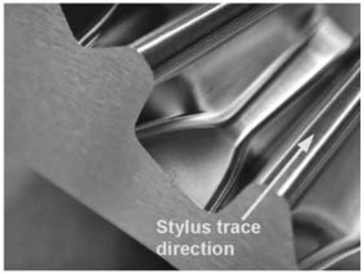
After Machining 5 pieces

Figure 3-8 (Continued)

Surface Roughness

Finishing With CBN End Mill Ry 1.5





Finishing With Carbide End Mill Ry 2.8

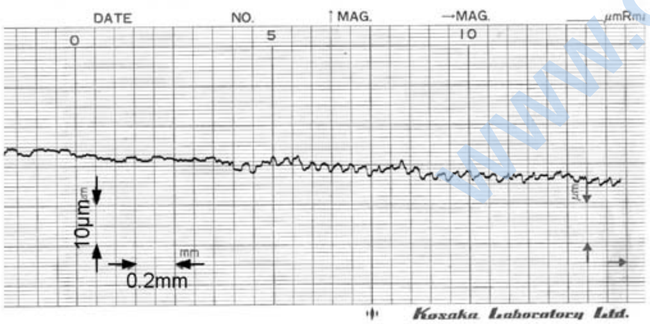
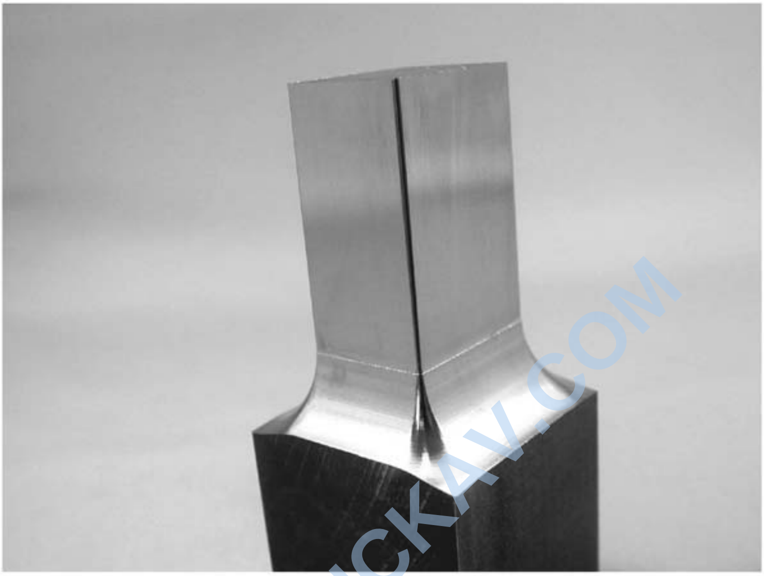


Figure 3-8 (Continued)

HIGH SPEED DIE MOLD MACHINING WITH YASDA YBM 640V

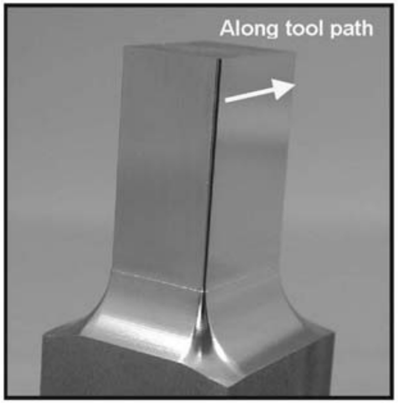


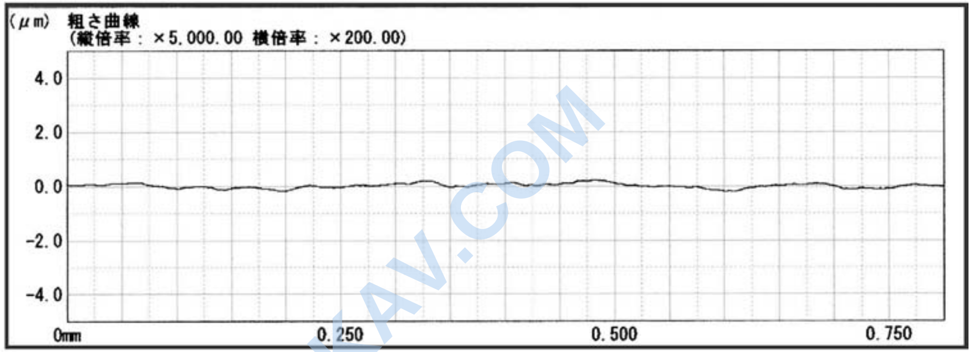
Machine	: YBM 640V *Mold & Die Miller*
Work Piece	: Punch
Material	: SKD11 (Hardness: HRC60)
Machining Details	: Helical Profiling
Work Piece Dimensions	: 30×30×80 (mm)
Cutting Tool	: Coated Carbide End Mill (4Nos.), CBN End Mill (1Nos.)
Cutting Oil	: Oil Mist

High speed machining with YASDA HAS-3 system					
Machining Process	**Cutting Tool**	**Spindle Speed (min^{-1})**	**Feed Rate (mm/min)**	**Cutting Time (min)**	**Total Cutting Time**
Rough	Ø12 Square End Mill	3000	2500	4.2	1Hr. 14Min.
Rough	R5 Ball End Mill	2500	400	16.7	
Semi-Finish	Ø12 Square End Mill	2000	200	1.5	
Semi-Finish	R5 Ball End Mill	2500	400	14.3	
Finish	Ø10 Square End Mill (CBN)	4800	240	37.0	

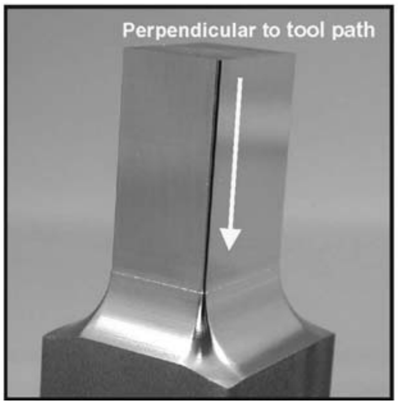
Figure 3-9

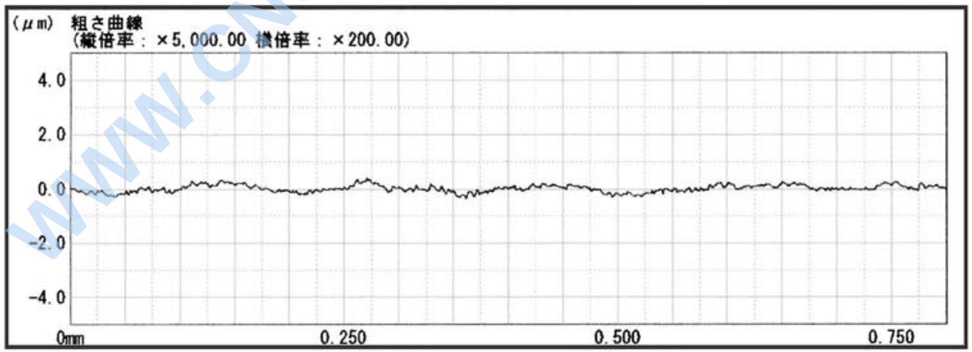
Surface Roughness





Ra 0.0711 Ry0.4388

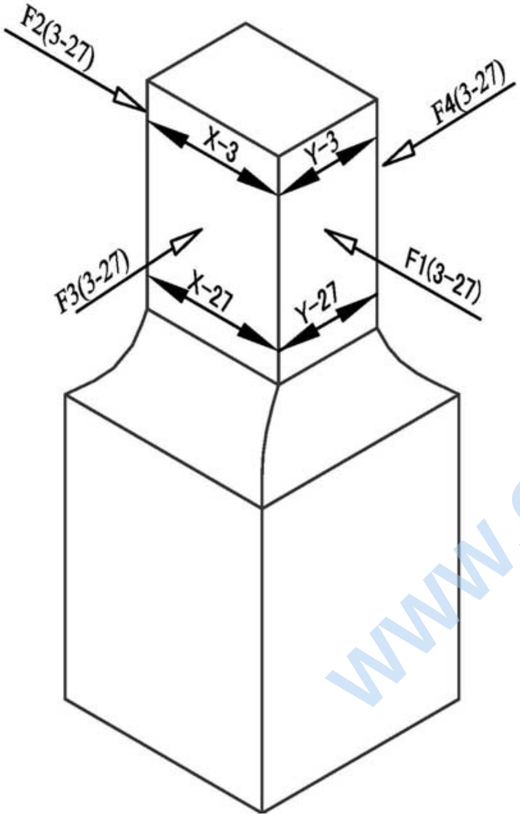




Ra 0.1072 Ry0.7526

Figure 3-9 (Continued)

Measuring Results

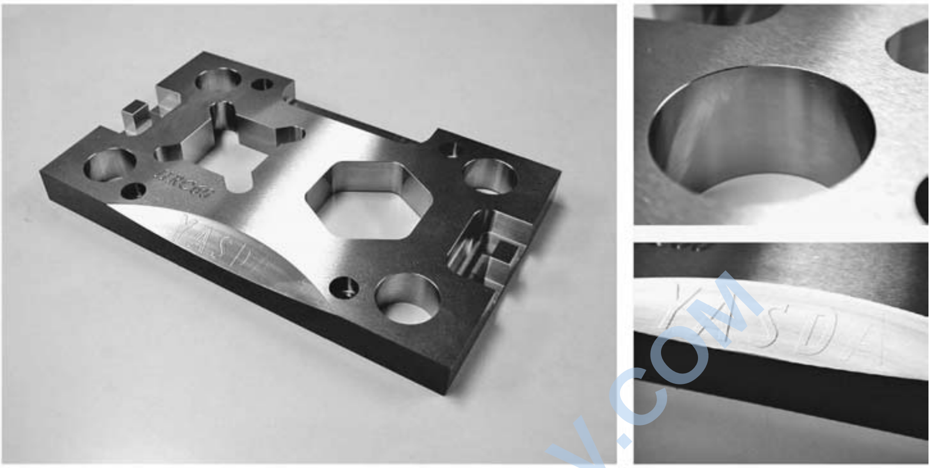


Measuring Equipment	Leitz: PMM 12 10 6
Date	2005 / 04 / 08

	Dimension	Actual	Measurement	Error
Width	X-3	20.0000	20.0000	0.0000
	X-27	20.0000	19.9997	-0.0003
	Y-3	15.0000	14.9987	-0.0013
	Y-27	15.0000	14.9986	-0.0014
Parallelism	F1(3-27)	0.0000	-0.0001	-0.0001
	F2(3-27)	0.0000	0.0000	0.0000
	F3(3-27)	0.0000	-0.0005	-0.0005
	F4(3-27)	0.0000	0.0002	0.0002

Figure 3-9 (Continued)

HIGH SPEED DIE MOLD MACHINING WITH YASDA YBM-950V



Machine	: YASDA YBM-950V *Mold & Die Miller*
Work piece	: Sample plate
Material	: ARK1 (HRC60) equivalent to AISI D2
Work piece dimension	: 250×150×22 (mm)
Cutting tool	: Carbide coated end mill, CBN boring chip
Cutting oil	: Oil mist

High speed machining with YASDA HAS-2 system

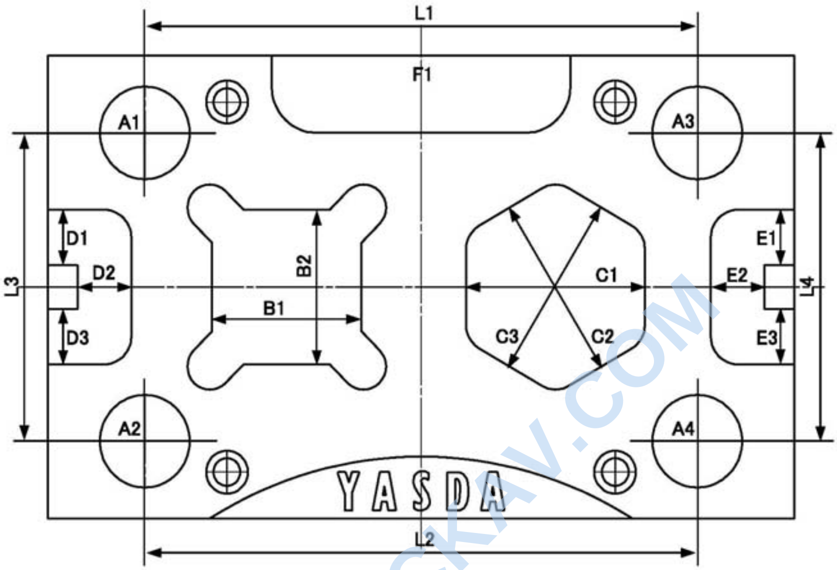
Machining process	Cutting tool	Spindle speed (min^{-1})	Feed rate (mm/min)	Cutting time (min)	Total cutting time (min)
Rough	Ø10 flat end mill	4000	2500	45.9	**97.8**
Semi-finish	Ø10 flat end mill	2000	150	20.2	
Finish	Ø10 flat end mill	2000	150	27.7	
Boring	Ø30 boring bar	1000	300	4.0 (2 – Ø30)	
YASDA letters Rough	Ø10 flat end mill	4000	3600	7.5	**66.5**
YASDA letters Semi-finish	R4 ball end mill	5000	1000	14.0	
YASDA letters Finish	R4 ball end mill	9000	600	45.0	

Figure 3-10

Next Page

RESULTS OF MEASUREMENT

EQUIPMENT: CMM LEITZ PMM 1210 6



Unit (mm)

	Measuring point	Target value	Actual value	Target value	Actual value
Boring	A1	X-92.5	X-92.5024	Y50.0	Y49.9993
		Circularity	0.0016	ϕ30	ϕ30.0018
	A2	X-92.5	X-92.5027	Y-50.0	Y-50.0014
		Circularity	0.0012	ϕ30	ϕ30.0019
Contouring	A3	X92.5	X92.5007	Y50.0	Y-49.9993
		Circularity	0.0021	ϕ30	ϕ29.9950
	A4	X92.5	X92.5004	Y-50.0	Y-49.9969
		Circularity	0.0024	ϕ30	ϕ29.9954
	B1	50	50.0011		
	B2	50	49.9987		
	C1	60	60.0031	*Parallelity*	0.0005
	C2	60	60.0024	*Parallelity*	0.0031
	C3	60	60.0008	*Parallelity*	0.0019
	D1	18	17.9993		
	D2	18	18.0002	15 (Depth)	15.0048
	D3	18	18.0015		
	E1	18	17.9992		
	E2	18	18.0018	15 (Depth)	15.0049
	E3	18	18.0021		
	F1			15 (Depth)	15.0043
	L1	185	185.0025		
	L2	185	185.0011		
	L3	100	100.0007		
	L4	100	99.9983		

Figure 3-10 (Continued)

Previous Page

HIGH SPEED DIE MOLD MACHINING WITH YASDA YBM 640V

Machine	: YASDA YBM 640V *Mold & Die Miller*
Work piece	: Special form sample piece
Material	: DC53 (Hardness:HRC60) equivalent to AISI D2
Work piece dimension	: 60×60×40 (mm)
Cutting tool	: Carbide coated end mill
Cutting oil	: Oil mist

High speed machining with YASDA HAS-3 system					
Machining process	**Cutting tool**	**Spindle speed (min^{-1})**	**Feed rate (mm/min)**	**Cutting time (min)**	**Total cutting time**
Rough	Ø10 flat end mill	4000	3600	4.3	2hrs 58min
Rough	R5 ball end mill	3150	800	26.7	
Semi-finish	R3 ball end mill	15000	2400	11.1	
Semi-finish	R1×8 ball end mill	15000	1500	26.8	
Semi-finish	Ø10 flat end mill	4000	500	5.9	
Semi-finish	R0.5×2 ball end mill	20000	750	36.6	
Finish	R3 ball end mill	20000	1800	13.0	
Finish	R0.5×2 ball end mill	20000	1600	37.2	
Finish	R0.3×1 ball end mill	20000	400	6.2	
Finish	Ø10 flat end mill	2000	200	9.4	

Figure 3-11

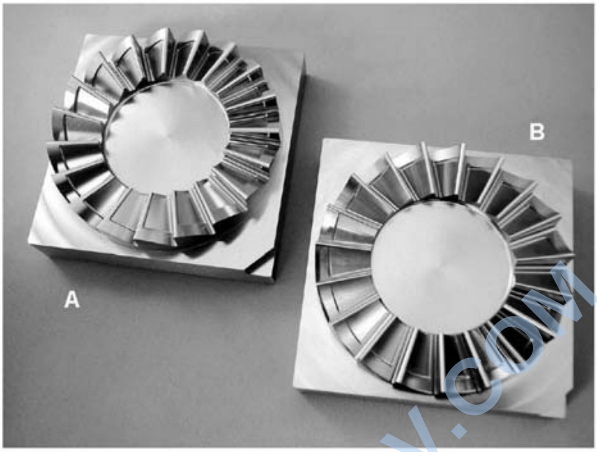
HIGH SPEED DIE MOLD MACHINING WITH YASDA YBM 640V

Machine	:	YASDA YBM 640V *Mold & Die Miller*
Work Piece	:	Electric Toothbrush Die
Material	:	8420 (Hardness: HRC55)
Work Piece Dimensions	:	160×50×50 (mm)
Cutting Tool	:	Coated Carbide End Mill (8Nos.)
Cutting Oil	:	Oil Mist

High speed machining with YASDA HAS-3 system					
Machining process	**Cutting tool**	**Spindle speed (min^{-1})**	**Feed rate (mm/min)**	**Cutting time (min)**	**Total cutting time**
Rough	R5 Ball End Mill	5800	1350	15.4	**7hr 24min**
Semi-finish	R3 Ball End Mill	11000	2500	14.8	
	R1×8 Ball End Mill	18000	2700	78.9	
	R0.5×2 Ball End Mill	20000	1000	37.8	
Finish	R1×8 Ball End Mill	20000	1700	151.0	
	R0.5×2 Ball End Mill	20000	1700	83.9	
	R0.3×2 Ball End Mill	20000	750	18.1	
	R0.2×0.6 Ball End Mill	20000	350	43.4	

Figure 3-12

HIGH SPEED DIE MOLD MACHINING WITH YASDA YBM 640V



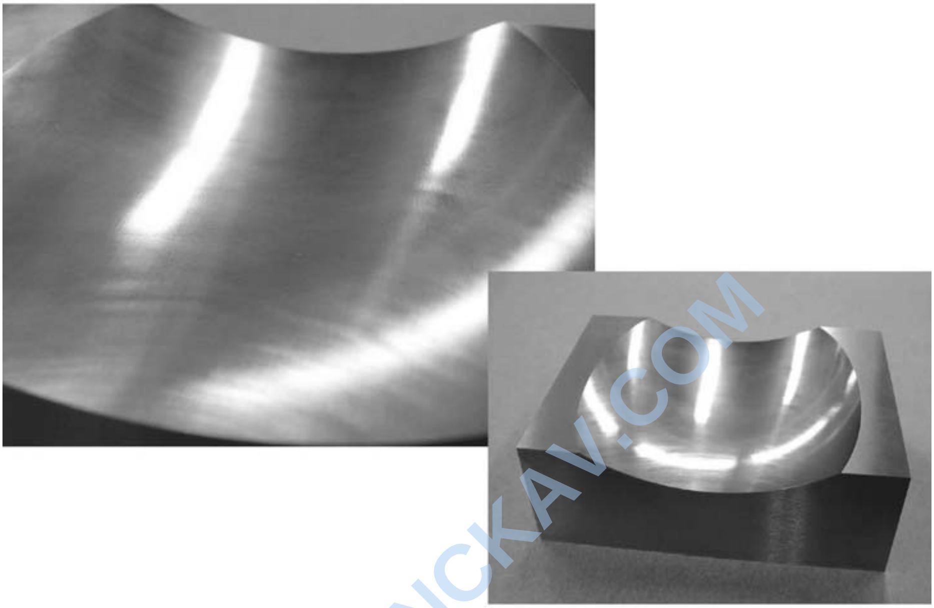
Machine	:	YASDA YBM 640V *Mold & Die Miller*
Work Piece	:	Mating Test Piece
Material	:	8407 (Hardness:HRC52)
Work-Piece Dimension	:	90×90×30 (mm)
Cutting Oil	:	Oil Mist

High speed machining with YASDA HAS-3 system

	Machining Process	Cutting tool	Spindle speed (min^{-1})	Feed rate (mm/min)	Cutting time (min)	Total cutting time
A	Rough	ϕ 10 Square End Mill	6000	3600	5.6	12Hrs 56Min
		R3 Ball End Mill	12000	2800	39.3	
		R1.5 Ball End Mill	15000	2400	84.3	
	Semi-Finish	R1 Ball End Mill	15000	1000 2400	152.6	
		ϕ 10 Square End Mill	6000	600	2.3	
	Finish	R1 Ball End Mill	15000	1800	389.4	
		R0.75 Ball End Mill	15000	750	91.0	
		ϕ 10 Square End Mill	1000	150	10.8	
B	Rough	ϕ 10 Square End Mill	6000	3600	5.5	12Hrs 3Min
		R3 Ball End Mill	12000	2800	28.3	
		R1.5 Ball End Mill	15000	2400	69.3	
	Semi-Finish	R1 Ball End Mill	15000	1000 2400	160.3	
		ϕ 10 Square End Mill	6000	600	2.2	
	Finish	ϕ 10 Square End Mill	1000	150	10.7	
		R1 Ball End Mill	15000	1800	397.2	
		R0.75 Ball End Mill	15000	750	49.2	

Figure 3-13

HIGH SPEED DIE MOLD MACHINING WITH YASDA YBM 950V

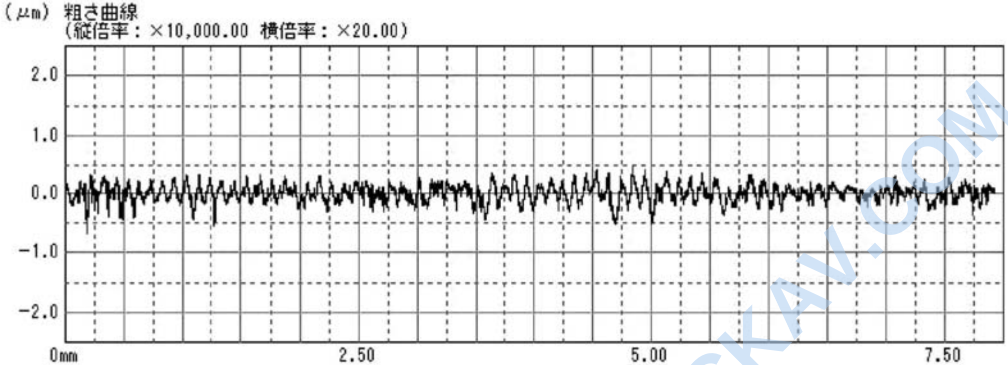


Machine : YASDA YBM 950V *Mold & Die Miller*
Work piece : Lens mold
Material : STAVAX (Hardness:HRC52) equivalent to 420 mod.
Work piece dimension : 100×74×35.7 (mm)
Cutting tool : Carbide coated end mill
Cutting oil : Oil mist (Roughing only)
Water Miscible Cutting Fluid (Emulsion)

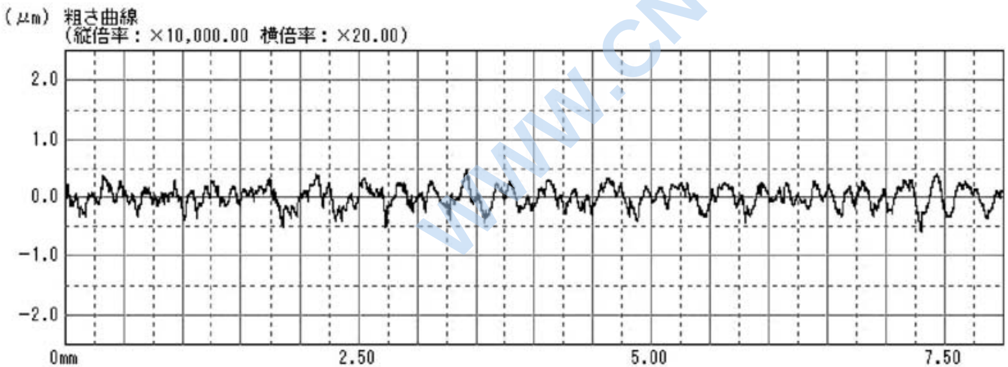
High speed machining with YASDA HAS-3 system					
Machining process	**Cutting tool**	**Spindle speed (min^{-1})**	**Feed rate (mm/min)**	**Cutting time (min)**	**Total cutting time**
Rough	R5 ball end mill	5000	1500	80.5	6 hrs 22 min
Semi-finish	R5 ball end mill	8000	2500 2000	42.3	
Finish	R5 ball end mill	8000	800	258.3	

Figure 3-14

Surface Roughness



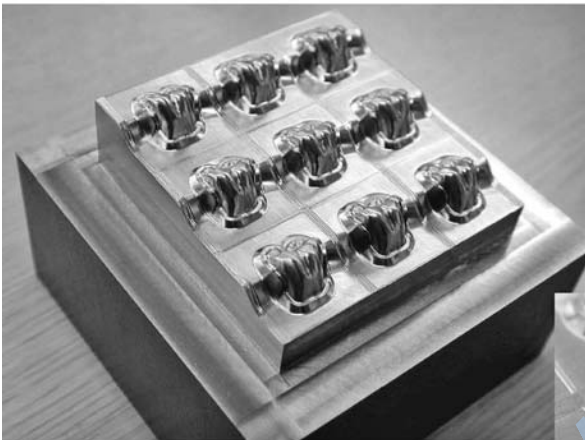
Along tool path	
Ra	0.1166 μm
Ry	0.7416 μm



Perpendicular to tool path	
Ra	0.1378 μm
Ry	0.7846 μm

Figure 3-14 (Continued)

HIGH SPEED DIE MOLD MACHINING WITH YASDA YMC 325

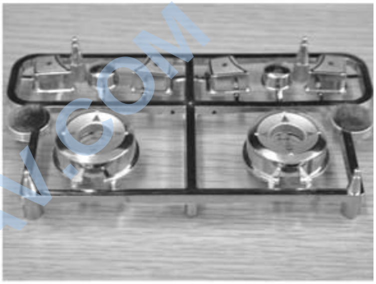



Machine	: YASDA YMC 325 *Micro center*
Work piece	: Sample piece - Tooth
Material	: HPM38 (Hardness:HRC52) equivalent to STAVAX
Work piece dimension	: 50×50×35 (mm)
Cutting tool	: Carbide coated end mill
Cutting oil	: Oil mist

High speed machining with YASDA HAS-2 system					
Machining process	**Cutting tool**	**Spindle speed (min^{-1})**	**Feed rate (mm/min)**	**Cutting time (min)**	**Total cutting time (min)**
Rough	R1.5×8 ball end mill	26000	3600	16.0	**16/All area**
Rough	R1.5×8 ball end mill	26000	3600	4.0	**49/1tooth**
Semi-finish	R0.5×2 ball end mill	30000	2400	7.0	
Finish	R0.5×2 ball end mill	30000	1200	19.0	
Finish	R0.3×2 ball end mill	30000	600	19.0	

Figure 3-15

HIGH SPEED DIE MOLD MACHINING WITH YASDA YBM 640V



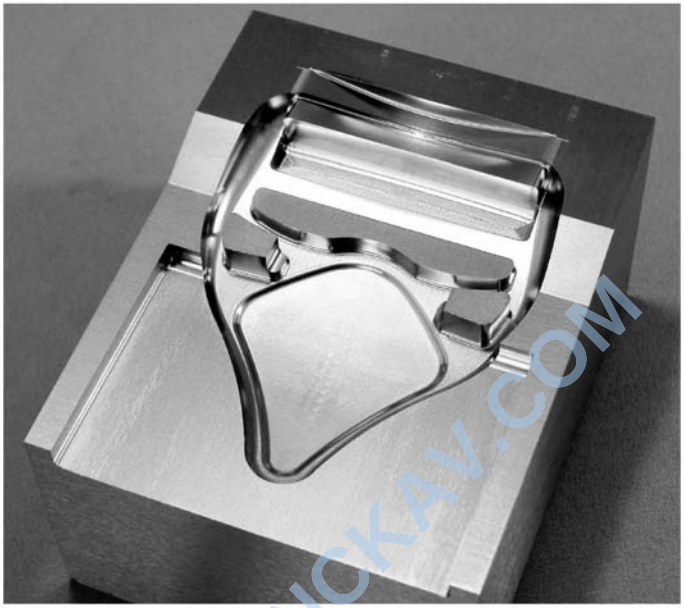
Machine	: YASDA YBM 640V *Mold & Die Miller*
Work piece	: Button of mobile phone
Material	: 420 (Hardness:HRC52) equivalent to STAVAX
Work piece dimension	: 160×54×50 (mm)
Cutting tool	: Carbide coated end mill
Cutting oil	: Oil mist

High speed machining with YASDA HAS-2 system

Machining process	Cutting tool	Spindle speed (min^{-1})	Feed rate (mm/min)	Cutting time (min)	Total cutting time
Rough	R5 ball end mill	12000	2800	4.5	8hrs 12min
Rough	R1×6 ball end mill	15000	2400	43.9	
Semi-finish	R0.6×6 ball end mill	15000	750	56.9	
Semi-finish	R0.4×5 ball end mill	15000	500	54.8	
Finish	R5 ball end mill	15000	1800	18.2	
Finish	R0.4×5 ball end mill	15000	300	205.0	
Finish	R0.3×5 ball end mill	15000	200	35.2	
Finish	R0.25×2 ball end mill	15000	200	73.0	

Figure 3-16

HIGH SPEED DIE MOLD MACHINING WITH YASDA YBM 950V



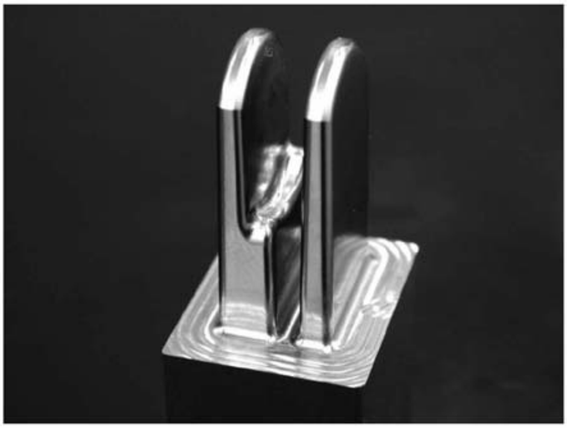
Machine	: YASDA YBM 950V *Mold & Die Miller*
Work piece	: Buckle mold
Material	: STAVAX (Hardness:HRC52)
Work piece dimension	: 80×64×42 (mm)
Cutting tool	: Carbide coated end mill
Cutting oil	: Oil mist

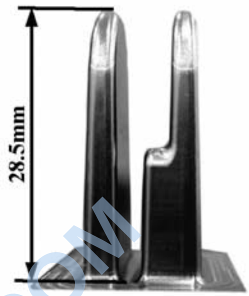
High speed machining with YASDA HAS-3 system

Machining process	Cutting tool	Spindle speed (min^{-1})	Feed rate (mm/min)	Cutting time (min)	Total cutting time
Rough	R5 ball end mill	6000	1500	16.2	5hrs 10min
Rough	R2 ball end mill	15000	3000	14.3	
Semi-finish	R1×8 ball end mill	20000	2400	44.8	
Semi-finish	R0.5×6 ball end mill	20000	750	66.0	
Finish	R1×8 ball end mill	20000	1800	49.5	
Finish	R0.5×6 ball end mill	20000	750	118.6	

Figure 3-17

HIGH SPEED DIE MOLD MACHINING WITH YASDA YBM 640V





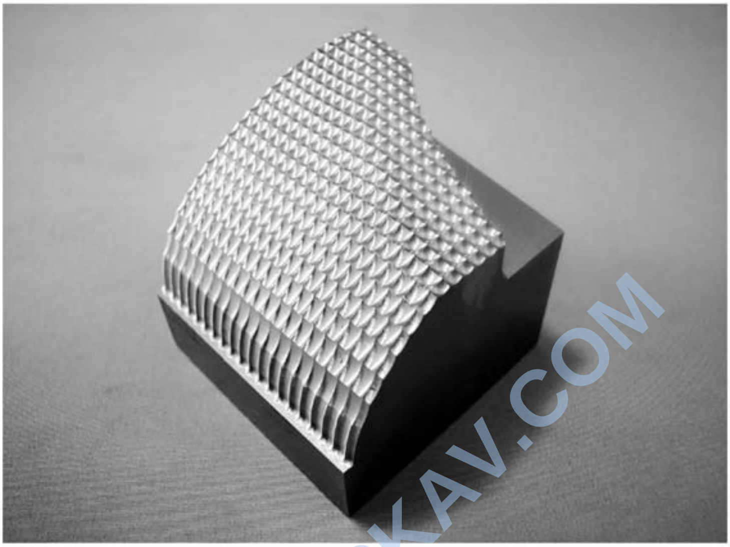
Machine	: YASDA YBM 640V *Mold & Die Miller*
Work piece	: Insert - Die-casting
Material	: SKD61 (Hardness:HRC49) equivalent to AISI H13
Work piece dimension	: 20×25×50 (mm)
Cutting tool	: Carbide coated end mill
Cutting oil	: Oil mist

High speed machining with YASDA HAS-2 system

Machining process	Cutting tool	Spindle speed (min^{-1})	Feed rate (mm/min)	Cutting time (min)	Total cutting time
Rough	Ø10 flat end mill	6000	3600	1.5	6 hours 37 min.
Rough	Ø4×R1 corner radius end mill	4000	2000	25	
Semi-finish	R1×25 ball end mill	7000	1100	193	
Semi-finish	R1×30 ball end mill	7000	1100	63	
Finish	Ø4×R1 corner radius end mill	7000	900	1.5	
Finish	R1×30 ball end mill	7000	900	113	

Figure 3-18

HIGH SPEED DIE MOLD MACHINING WITH YASDA YBM 640V



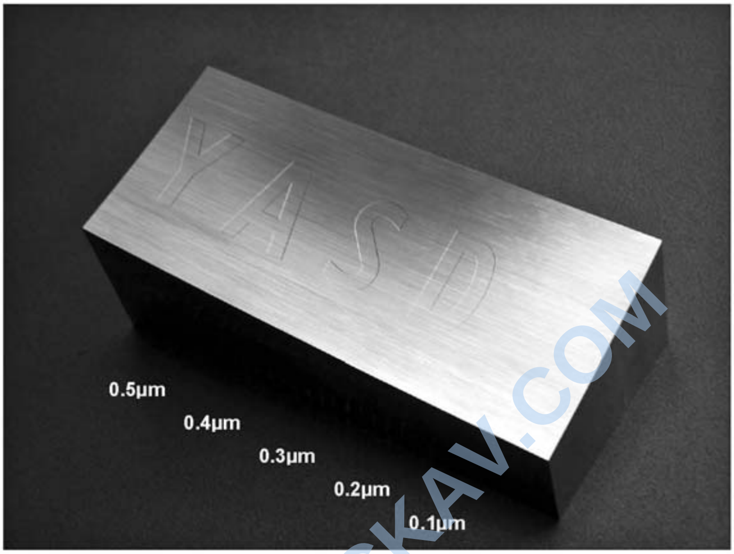
Machine	: YASDA YBM 640V *Mold & Die Miller*
Work piece	: Test piece II
Material	: NAK80 (Hardness:HRC40)
Work piece dimension	: 50×50×50 (mm)
Cutting tool	: Carbide coated end mill
Cutting oil	: Oil mist

High speed machining with YASDA HAS-3 system

Machining process	Cutting tool	Spindle speed (min^{-1})	Feed rate (mm/min)	Cutting time (min)	Total cutting time (min)
Rough	R4 ball end mill	8000	2000	39	4 Hours 37 min
	R1.5 ball end mill	20000	2500	37	
Semi-finish	R1 ball end mill	30000	2000	30	
Finish	R1.5 ball end mill	30000	2000	12	
	R1 ball end mill	30000	1800	159	

Figure 3-19

HIGH SPEED DIE MOLD MACHINING WITH YASDA YBM-640V



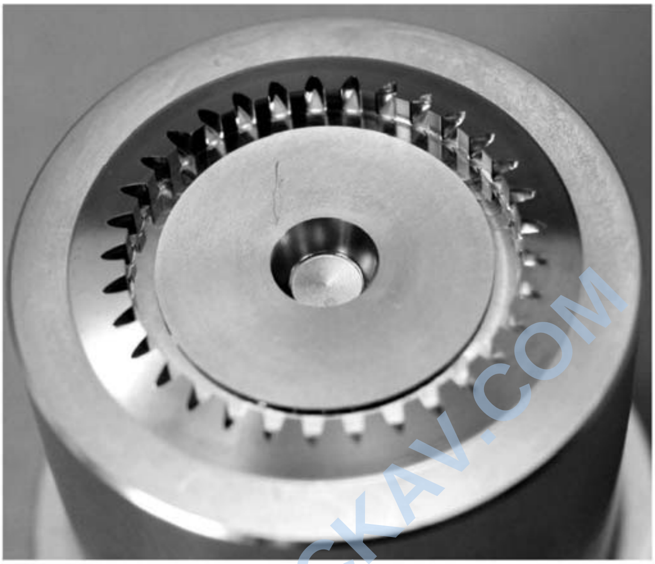
"Y"=0.5µm, "A"=0.4µm, "S"=0.3µm, "D"=0.2µm, "A"=0.1µm

Machine	: YASDA YBM-640V2 *Mold & Die Miller*
Work piece	: YASDA letters (Minimum depth 0.1µm)
Material	: NAK80 (Hardness:HRC40) equivalent to AISI P21
Work piece dimension	: 140×50×50 (mm)
Cutting tool	: Carbide coated end mill
Cutting oil	: Oil mist

High speed machining with YASDA HAS-2 system					
Machining process	**Cutting tool**	**Spindle speed (min^{-1})**	**Feed rate (mm/min)**	**Cutting time (min)**	**Total cutting time (min)**
Rough	Ø10 square end mill	8000	4800	7.5	557.0
Semi-finish	R2 ball end mill	15000	3000	25.0	
Finish	R2 ball end mill	15000	600	524.5	

Figure 3-20

HIGH SPEED DIE MOLD MACHINING WITH YASDA YBM 640V (30,000rpm)

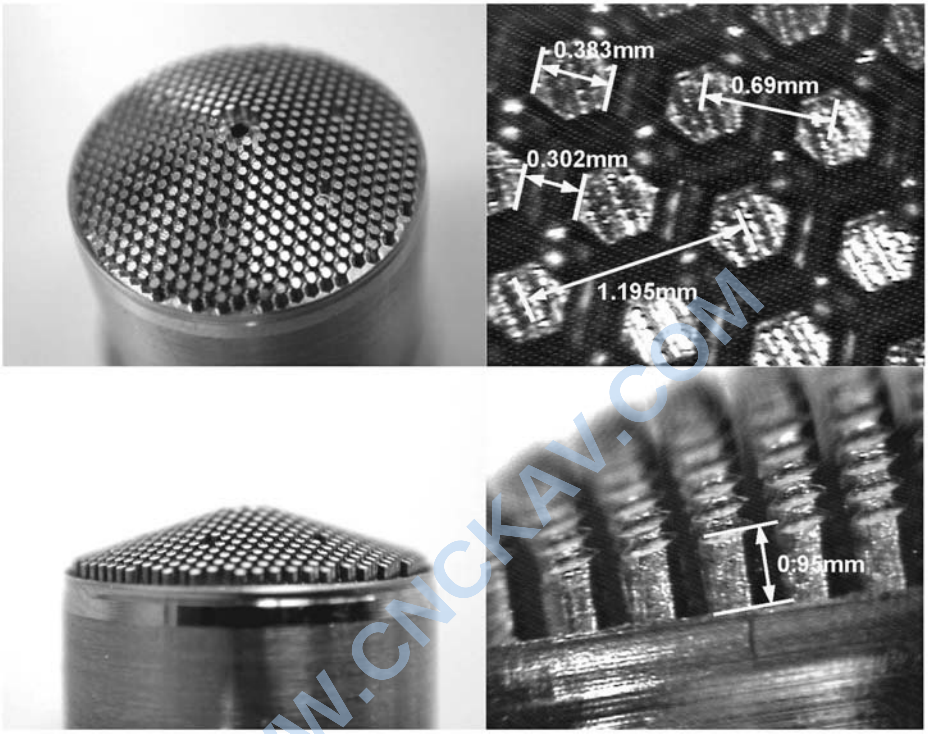


Machine	: YASDA YBM 640V (30,000rpm) *Mold & Die Miller*
Work Piece	: Test Piece
Material	: NAK80 (Hardness: HRC40)
Work-Piece Dimensions	: Ø25×30 (mm)
Machining Details	: Gear profile finishing with R0.1 Ball End Mill
Cutting Tool	: Coated Carbide End Mill (8 Nos.)
Cutting Oil	: Oil Mist

High speed machining with YASDA HAS-3 system					
Machining Process	**Cutting tool**	**Spindle speed (min^{-1})**	**Feed rate (mm/min)**	**Cutting time (min)**	**Total cutting time**
Rough	R0.5 Ball End Mill	15000	2000	7.5	**4hr. 17min.**
	Ø1 Square End Mill	18000	400	3.7	
	R0.3 Ball End Mill	24000	500	6.2	
Semi-finish	R0.2 Ball End Mill	30000	500 400	48.1	
	R0.5 Ball End Mill	30000	1500	9.0	
Finish	Ø1 Square End Mill	18000	150 100	2.9	
	R0.5 Ball End Mill	30000	1200	27.0	
	R0.2 Ball End Mill	30000	400	27.3	
	R0.15 Ball End Mill	30000	150	50.2	
	R0.2 Ball End Mill	30000	100	75.1	

Figure 3-21

HIGH SPEED DIE MOLD MACHINING WITH YASDA YMC 325



Work piece : Filter mold
Material : W-Nr. 1.2344
Work piece dimension : Ø17×18.6 (mm)
Cutting tool : Carbide coated end mill
Cutting oil : Oil mist

High speed machining with YASDA HAS-3 system					
Machining process	Cutting tool	Spindle speed (min^{-1})	Feed rate (mm/min)	Z Step (mm)	Total cutting time
Finish	R0.15×1.5 ball end mill	30000	200	0.005	**24 hours**

Figure 3-22

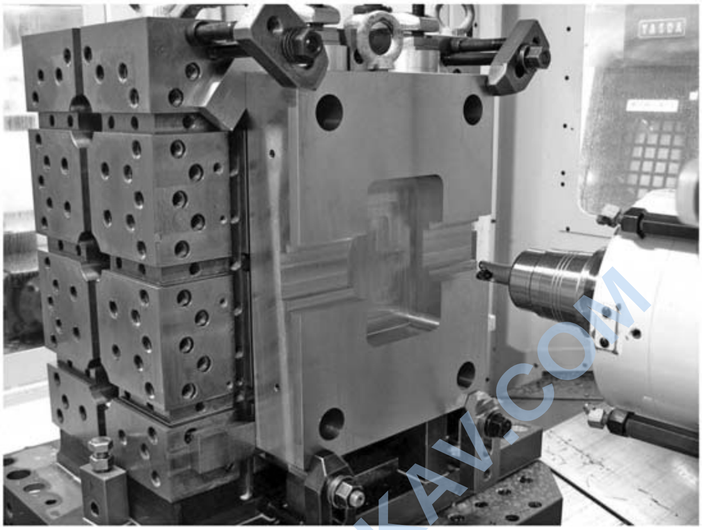
HIGH SPEED DIE MOLD MACHINING WITH YASDA YBM-950V

Machine	: YASDA YBM-950V *Mold & Die Miller*
Work piece	: Damper core
Material	: STAVAX (Hardness:HRC33)
Work piece dimension	: Ø67×99 (mm)
Cutting tool	: Carbide coated end mill
Cutting oil	: Oil mist

High speed machining with YASDA HAS-2 system					
Machining process	**Cutting tool**	**Spindle speed (min^{-1})**	**Feed rate (mm/min)**	**Cutting time (min)**	**Total cutting time (min)**
Rough	R6 ball end mill	7500	1800	16	8 hours 45 min.
Rough	Ø10 flat end mill	1300	420	12	
Rough	Ø10×R2 corner radius end mill	2400	5000	22	
Semi-finish	R5 ball end mill	3000	400	65	
Semi-finish	Ø10 flat end mill	1300	200	7	
Finish	R5 ball end mill	4000	600	199	
Finish	Ø9×R1.5 corner radius end mill	2000	200	72	
Finish	Ø10 flat end mill	1300	200	10	
Finish	R2×59 ball end mill	4000	400	73	
Finish	R2×65 ball end mill	2000	200	49	

Figure 3-23

HIGH SPEED HIGH PRECISION MACHINING WITH YASDA YBM 660N

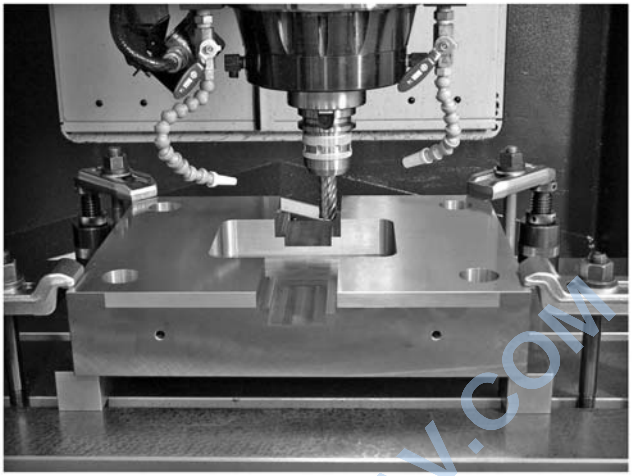


Machine	: YBM 660N (Rough Machining)
Work Piece	: Mold Base
Material	: S50C
Work Piece Dimensions	: 400×300×80 (mm)
Cutting Oil	: Water Miscible Cutting Fluid (Emulsion)

High speed machining with YASDA HAS-1 system					
Machining Process	**Cutting Tool**	**Spindle Speed (min^{-1})**	**Feed Rate (mm/min)**	**Cutting Time (min)**	**Total Cutting Time**
Ø35.5 Hole	Ø35 Drill (Indexable Type)	1800	270	2.0	**40Min.**
	Ø35.5 Boring Bar	1300	156	4.0	
Ø8 Hole	Center Drill	1200	120	1.0	
	Ø8 Drill (Guide Hole)	3000	600	1.5	
	Ø8 Long Drill	2800	560	2.0	
Cavity	Ø25 High Speed Radius Mill (Indexable Type)	3000	7500	22.5	
	Ø20 Square End Mill	1000	650	7.0	

Figure 3-24

HIGH SPEED HIGH PRECISION MACHINING WITH YASDA YBM 950V

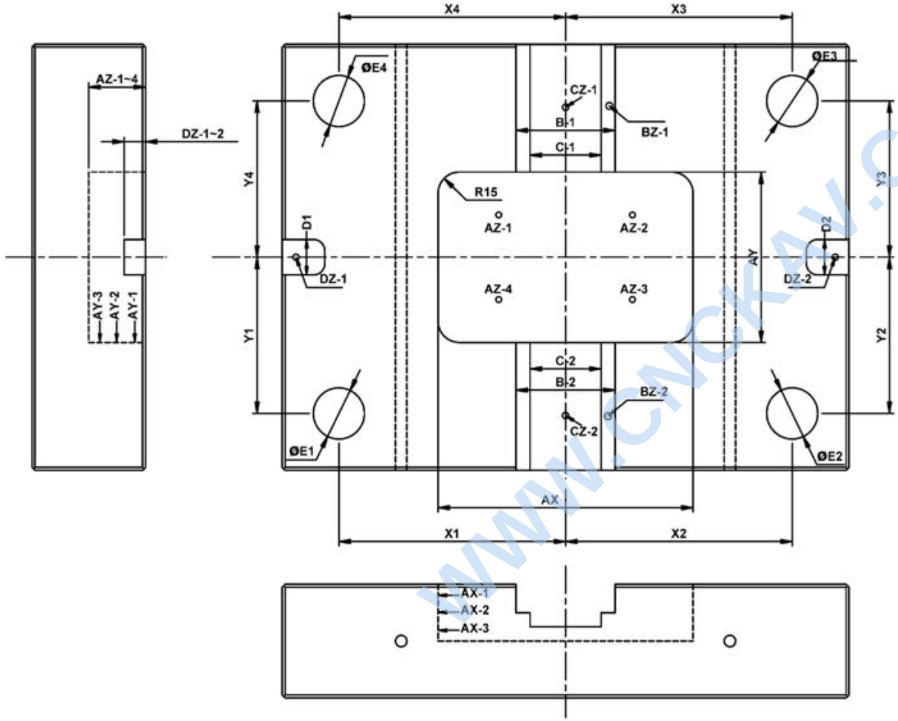


Machine	: YBM 950V (Finish Machining)
Work Piece	: Mold Base
Material	: S50C
Work Piece Dimensions	: 400×300×80 (mm)
Cutting Oil	: Water Miscible Cutting Fluid (Emulsion)
	Ø17 CBN With Oil-mist

High speed machining with YASDA HAS-3 system					
Machining Process	**Cutting Tool**	**Spindle Speed (min^{-1})**	**Feed Rate (mm/min)**	**Cutting Time (min)**	**Total Cutting Time**
25mm Width Pocket (Rough)	Ø10 Square End Mill	3000	300	3.5	**46Min. 30Sec.**
25mm Width Pocket (Finish)	Ø10 Square End Mill	3000	300	4.0	
Ø36Hole (Semi-Finish)	Ø35.9 Boring Bar	1330	110	4.0	
Ø36Hole (Finish)	Ø36 Boring Bar	1330	110	4.0	
Cavity (Semi-Finish)	Ø20 Square End Mill	1000	650	7.0	
Cavity Side Face (Finish)	Ø17 CBN End Mill	11000	2400	19.5	
Cavity Bottom Face (Finish)	Ø17 CBN End Mill	5000	1000	4.5	

Figure 3-24 (Continued)

Measuring Equipment	: Leitz PMM 12 10 6
Date	: 2004 . 9 .21



	Dim.	Target	Actual	Error
WIDTH	AX-1	$180.000^{+0.010}_{0}$	180.0070	0.0020
	AX-2		180.0073	0.0023
	AX-3		180.0079	0.0029
	AY-1	$120.000^{+0.010}_{0}$	120.0056	0.0006
	AY-2		120.0055	0.0005
	AY-3		120.0059	0.0009
	B-1	70.000 ± 0.005	70.0052	0.0052
	B-2		70.0046	0.0046
	C-1	50.000 ± 0.005	50.0046	0.0046
	C-2		50.0042	0.0042
	D-1	25.000 ± 0.005	25.0037	0.0037
	D-2		25.0047	0.0047
PITCH	X1	160.000 ± 0.005	159.9982	-0.0018
	X2		160.0009	0.0009
	X3		159.9990	-0.0010
	X4		160.0014	0.0014
	Y1	110.000 ± 0.005	109.9991	-0.0009
	Y2		109.9978	-0.0022
	Y3		109.9980	-0.0020
	Y4		109.9990	-0.0010
DIA.	ØE-1	$\phi\, 36.000^{+0.010}_{0}$	36.0095	0.0045
	ØE-2		36.0092	0.0042
	ØE-3		36.0082	0.0032
	ØE-4		36.0079	0.0029
DEPTH	AZ-1	$40.000^{+0.010}_{0}$	40.0090	0.0040
	AZ-2		40.0092	0.0042
	AZ-3		40.0090	0.0040
	AZ-4		40.0081	0.0031
	BZ-1	$20.000^{+0.010}_{0}$	20.0094	0.0044
	BZ-2		20.0064	0.0014
	CZ-1	$30.000^{+0.010}_{0}$	30.0092	0.0042
	CZ-2		30.0083	0.0033
	DZ-1	$15.000^{+0.010}_{0}$	15.0025	-0.0025
	DZ-2		15.0020	-0.0030

Figure 3-24 (Continued)

Table 3-1: Sample List

No	Number	Work Piece	Material (AISI)	Hardness	Machine	Process Time
3-5	TC0SE4-089E	Sample piece	Cemented Carbide G5	HRA88	950V	10hr. 8min.
3-6	TC0SE5-032E	CVJ Tripod Die	DRM2 (Matrix HSS)	HRC62	640V	2hr. 27min.
3-7	TC0SE4-095E	Bearing Retainer	DC53 (D2)	HRC60	950V	2hr. 1min.
3-8	TC0SE3-031E-CBN	Bevel Gear Die	DC53 (D2)	HRC60	640V	2hr. 28min.
3-9	TC0SE4-031E-2	Punch	SKD11 (D2)	HRC60	640V	1hr. 14min.
3-10	TC0SE1-027E	Sample Plate	ARK1 (D2)	HRC60	950V	2hr. 45min.
3-11	TC0SE5-084E	Watch Cavity	DC53 (D2)	HRC60	640V	2hr. 58min.
3-12	TC0SE5-072E	Electric Toothbrush Die	8420 (420 mod.)	HRC55	640V	7hr. 24min.
3-13	TC0SE5-005E	Mating Sample Piece	STAVAX (420 mod.)	HRC52	950V	Upper: 12hr. 56min. Lower: 12hr. 3min.
3-14	TC0SE4-093E	Lens Mold	STAVAX (420 mod.)	HRC52	950V	6hr. 22min.
3-15	TC0SE1-095E-YMC	Sample Piece-Tooth	HPM38 (420 mod.)	HRC52	325	49min./tooth
3-16	TC0SE3-002E	Button of Mobile Phone	STAVAX (420 mod.)	HRC52	640V	8hr. 12min.
3-17	TC0SE5-090E	Buckle Cavity	STAVAX (420 mod.)	HRC52	950V	5hr. 10min.
3-18	TC0SE3-037E	Insert-Die-casting	SKD61 (H13)	HRC47	640V	6hr. 37min.
3-19	TC0SE5-095E-2	Tail Light Lens Mold	NAK80 (P21)	HRC40	640V	4hr. 37min.
3-20	TC9SE9-018E-01	YASDA Letters	NAK80 (P21)	HRC40	640V	9hr. 17min.
3-21	TC0SE5-036E-2	Gear Cavity	NAK80 (P21)	HRC40	640V	4hr. 17min.
3-22	TC0SE2-093E	Filter Mold	NAK80 (P21)	HRC40	325	24hr.
3-23	TC0SE2-099E	Damper Core	STAVAX (420 mod.)	HRC33	950V	8hr. 45min.
3-24	TC0SE4-060E	Mold Base	S50C (1050)	ÐÐ	660N 950V	Roughing: 40min. Finishing: 47min.

Conclusion

YASDA's machines cost more than standard-grade machines due to the special design features and assembling techniques mentioned above. However, the higher initial investment is offset within a short period of time, by savings in cutting tool costs, longer machine and spindle bearing life, and greater accuracy.

Chapter 4

Roku-Roku

By Danny Haight, Roku-Roku Product Manager
MC Machinery Systems, Inc.

MC Machinery Systems, Inc., is the North American importer and support network for the Roku-Roku line of high-speed vertical machining centers. Roku-Roku has set the standard for machine quality and rigidity through its one-piece, box-style cast base, mono-block, and crossbeam support. It delivers accuracy and rigidity in high speed and precision machining. Further, MC Machinery has built a reputation as a world-class manufacturer of EDM systems. MC's equipment is backed by industry-leading customer service and the most extensive dealer network in the field.

A Mitsubishi Corporation company, MC Machinery knows that providing the best solutions means much more than just providing the right equipment. This perspective provides their focus on building and supporting customer relationships, leveraging decades of experience to help customers stay in step with the industry and achieve success.

What Is High-Speed Machining and Hard Milling?

High speed machining is a total approach to a process. It combines a milling machine, CAD/CAM system, tool holders, and cutters. It is a proven metal-removal process involving high spindle speeds and feed rates coupled with light cuts. It is *not* simply conventional milling with a higher RPM.

The Roku-Roku Difference

Roku–Roku has been designing and building machine tools in Japan for more than 100 years. They've known for a long time what everyone knows now—that the most important feature in achieving great results with the high speed and hard milling is in the construction of the machine.

Roku-Roku's machining centers are handcrafted and solidly built to jig-borer standards of quality and accuracy. The company still hand-scrapes mating surfaces, thus eliminating additional vibration. With rigidity firmly in mind, Roku-Roku computer-designs its machine bases with a three-point leveling system.

Hybrid Machines

Roku-Roku was the industry leader in graphite/steel technology machining centers when, several years ago, they realized that many customers did not want to, or could not afford to, purchase two high-end machines, one for graphite and one for hard milling. Consequently Roku-Roku combined their graphite technology machine and their steel technology machine, creating what is now the industry's leading hybrid machine, the HC-658 (see Figures 4-1 and 4-2). These hybrid machines

Figure 4-1 The hybrid machine: HC-658

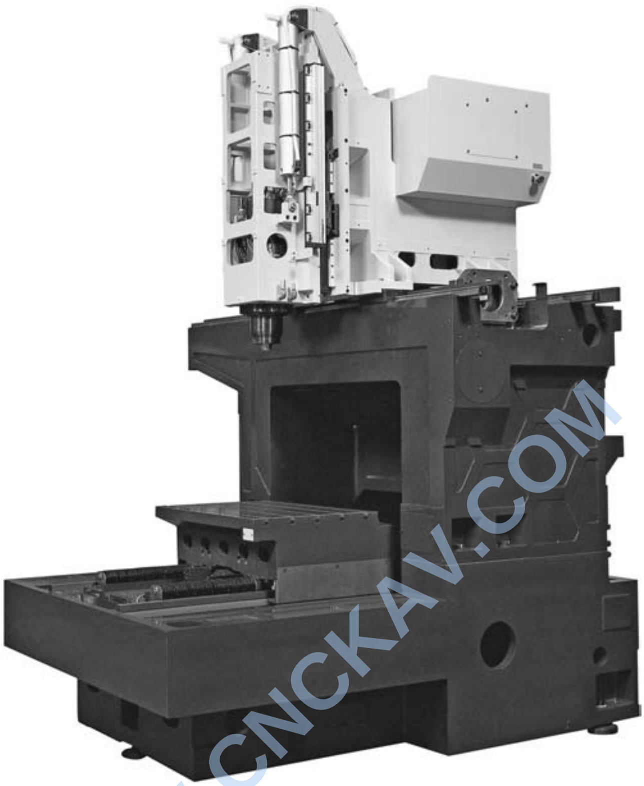


Figure 4-2 Castings for the HC-658

combine graphite machining and hard milling of mold materials, enabling high-speed precision machining.

Anyone can put a flange on the back of a machine and claim to have a graphite package. However, Roku-Roku machines originally were designed with the damaging effects of graphite dust in mind—they were designed with double-covered ball screws and guide ways. Because this style of machine was introduced in 1988, not one ball screw has had to be replaced in a Roku-Roku machine, a testament to the success of Roku-Roku's innovative design.

Solid History of Success

Because Roku-Roku has always used the latest technology available to give their machines a competitive edge, the company has come to expect that kind of success.

Coupled with the Fanuc 16iMB controller and Roku's Super PC III, Roku-Roku machining centers optimize velocity and acceleration/deceleration by using a 64-bit, high-speed RISC processor and AI Nano high-precision contour control. Their combination of high-speed calculation, smooth action linear guides, and read-ahead control minimizes geometric errors during high-speed contouring of continuous, small-motion commands, providing a smoother finish than other machines can.

The Super PC III can be set to one of three different modes—High Precision, Standard or High Speed—to meet any shop's machining requirements. The Roku-Roku line of equipment also features Fanuc's Digital Intelligent Servo System with five-place decimal input and high-resolution glass scale feedback. This combination results in unsurpassed speed and accuracy, even in complex, three-dimensional contours comprising short consecutive line segments or arcs.

Heavy Bridge

In addition, Roku-Roku's bridges are constructed of Meehanite GC in both the base and bridge casting material. This material provides excellent shock and vibration dampening as well as minimal thermal distortion in normal working environments. The machine's bridge construction reduces the distance from spindle center to the Z-axis guide ways, minimizing the opportunity for thermal distortion and simultaneously producing extreme rigidity.

The HC-548's bridge construction also eliminates the X-axis table overhang commonly associated with C-frame construction (see Figures 4-3 and 4-4). The head and guides are mounted on top of the bridge rather than on the face, which eliminates sag and distortion along the X-axis; in other words, it's more accurate.

Z-axis pneumatic counter-balancers provide smooth and accurate movement during high velocity contouring and drilling. The use of counter-balancers also reduces Z-axis motor and ball screw load, resulting in less heat generation. By minimizing heat generation, thermal distortion can be controlled. They also extend the life of the Z-axis ball screw.

High-Performance Spindles

Roku-Roku does not use off-the-shelf spindles; rather, they design their own. As the leading designer of PC-board drilling machines in Japan, they design spindles that spin at up to 250,000 RPM. Feed rates

Figure 4-3 Roku-Roku® HC-548EX

and speeds ultimately will be determined by the types of cutters you use and the surface feet per minute (SFM) your tools can handle without burning up.

Roku-Roku-designed spindles use the latest angular-contact ceramic bearing technology. This special, long-life spindle design uses two large bearings at the bottom and two large bearings at the top of the integral motor.

In the “dry” machines, the spindle has sealed, grease-lubricated spindle bearings, completely eliminating oil contamination of the graphite from dripping, mist-type lubrication. The “wet,” or flood, machines use an oil mist-lubricated bearing system.

Both types of machines come standard with an oil chiller that maintains a ±1.0 degree F operating window. The surrounding jacket of oil stabilizes the spindle temperature. This process minimizes Y/Z-axis

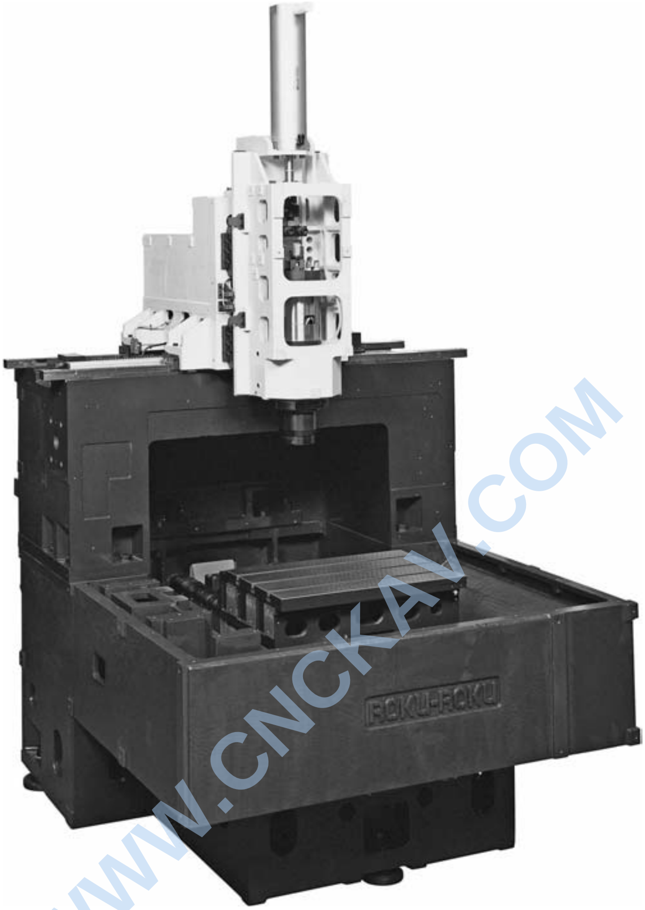


Figure 4-4 Castings for the HC-548EX

thermal deformation commonly caused by high RPM and extended run times.

Hard Milling: What Are We Talking About Here?

Hard milling is the precise result of combining several factors:

1. Rigid machine tools
2. Proper cutter technology
3. Rigid spindles
4. Up-to-date CAD/CAM software

If you are lacking any of these ingredients, your success in hard milling will be limited.

Tests

Positive air-pressure **Linear Scales** are included as standard equipment. Actual measured examples on the static accuracy of the HC-658 are as follows:

Positioning Accuracy	±0.00006” in full stroke
Repeatability	±0.00002”
Circular Cutting (2”. diameter @ 8 IPM)	0.000078”

Support

Roku-Roku machines come with the full support of MC Machinery Systems (Mitsubishi EDM) for all sales, service, and applications needs. The company offers on-site application training as well as seminars at its headquarters in Wood Dale, Ill., and its other facilities in California, New Jersey, Michigan, Ohio and the recently-opened facility in Richmond Hill, Ontario. Most of its customers agree that MC Machinery’s policy of on-site applications training further enhances the personal attention they receive when purchasing a machine tool.

New Milling Products

MC Machinery Systems is constantly working together with Roku-Roku to bring to market machines that meet customers’ needs. For example, customers who want an accurate and reliable graphite machine are introduced to the HC-548EX to meet their budgetary requirements. Roku-Roku has also just introduced a 5-axis machine, the RMX-5, to address the growing medical field (see Figure 4-5).

Customer Testimonials

Service and Support Keeps Customers Loyal

All-American Mold specializes in manufacturing complex tooling for the plastic injection molding industry. The company’s team of experts is dedicated to providing top quality from mold concept and design to finished product in a timely manner.

A loyal Mitsubishi customer since 1992, the company’s emphasis on forming partnerships with their customers is reflected by their

Figure 4-5 The RMX-5, a 5-axis Machine

percentage of repeat business. "About 60 percent of our business comes from existing customers," notes President Mike Veltri. The company's sales team is always recruiting new customers as well, steadily increasing All-American's customer base in markets such as medical, automotive, and electronics.

All-American's 17,000 square-foot, state-of-the-art facility in Rochester, N.Y., houses an array of equipment needed for in-house production machining, custom builds, prototyping, tooling, finishing, and inspecting.

Four Mitsubishi wire EDMs play a crucial role in the precision manufacturing of these custom molds. "They're workhorses. The Mitsubishis are the machines that get the work done, day in and day out; and they deliver the high quality and consistency our business demands," Veltri explains.

"When you get into machining of these high-precision parts, you have to be careful not to compromise accuracy with speed. Mitsubishi maintains consistency at the highest appropriate speed for maximum productivity.

They're extremely robust and haven't lost any accuracy over time," Veltri adds. "We have 100% confidence in them."

In mid-2005, Veltri began looking for a high-speed, high-precision machining solution to increase his shop's efficiency and to expand its production capabilities. He looked at several vertical machining manufacturers and decided on a Roku-Roku HC-658.

"When the service rep came out here for the Roku-Roku installation and training, he left his card and his cell phone number so I could reach him at any time. Making himself available to us 24-7 goes above and beyond good customer service."

The new HC-658 was installed in June, 2005, and has been running ever since. The machine's rigid structure helps to ensure part precision, and its extended speed range (200-32,000 RPM) decreases All-American's turnaround time.

"With Roku-Roku's accuracy and repeatability, parts are through quality and out the door faster," Veltri says.

All-American's Roku-Roku has had a great impact on its business. "It has added a whole new customer base to our business because now we can meet the high-speed demands of markets we couldn't compete in before," Veltri says.

Reducing Cut Time by 40 Percent

In a mold-making market in which overseas competition is forcing thousands of American mold shops to close their doors, how is a shop like F&S Tool, Inc., not only surviving, but thriving? In short, it's the mentality shared by the shop owners, the four Faulkner brothers who combine ingenuity and an inventive state of mind.

Co-founded in 1983 by Jim Faulkner and son Mike, F&S Tool has become one of the nation's leading suppliers of precision tooling to the injection molding industry. The Faulkners have spent more than 20 years focusing on the molding industry, constantly developing ways not only to meet, but also to exceed expectations in multiple areas: mold design, prototyping, production, and repair.

Several years later, JD, Tim, and Scott Faulkner bought out their father's share of the company. The shift in management sparked a fresh, innovative examination of the long-term future of F&S Tool. Shortly after, the forward-thinking team began aggressively investing in capital equipment and initiated plans for expansion (see Figures 4-6 and 4-7).

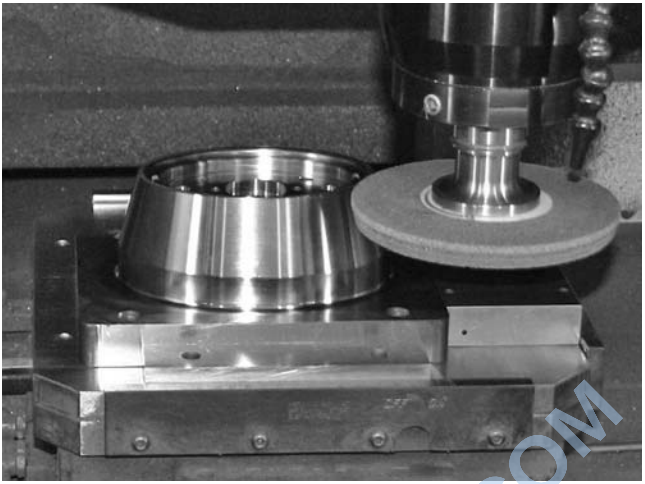


Figure 4-6 Roku-RokuⓈ multipurpose design provides unmatched steel-machining capabilities

Figure 4-7 Roku-Roku combines high-precision and high-speed machining of mold steels

F&S Tool's success can be attributed to a number of factors, but it is the Faulkners' progressive thinking that has helped them maintain a competitive edge. For example, a recent experimental purchase of a Roku-Roku HC-658 turned out to be so successful and profitable that the company purchased an identical machine the very next month.

"Roku-Roku's versatility has noticeably increased our capacity," Vice President of Manufacturing JD Faulker says. "We're trying to make molds as accurately as we always have, but with more modern technology. Our existing machines run in excess of 200 hours per week. The Roku-Rokus have reduced our cut time by 40 percent."

The twin HC-658s run 24 hours per day, hard-milling with inspectors on-site throughout the day, and cutting electrodes unattended overnight. In just 10 weeks, F&S Tool ran $1 million worth of material across the new Roku-Rokus.

F&S Tool has earned a long list of repeat and new customers with their reputation for meeting quick turnarounds with high-quality production. The company uses the traditional plastic injection molding process in production because it produces excellent quality and consistent results.

Wanting to maintain a competitive edge, the company began experimenting with compression molding in 2002. Compression molding is an appealing alternative for injection molding because it eliminates the hot-runner manifold and cuts cooling time in half. There are several limitations on the process, however, including shape geometry, part thickness, and size.

However, F&S found that compression molding allowed them shorter cycle times and higher production rates. With such parts as 35-mm film canister tops and dairy caps, F&S can produce 550-plus caps per minute on a 32- station machine and 1,000-plus on a 64-station unit.

Finding the balance between tradition and innovation has allowed F&S Tool to prosper. "Two years ago, compression molding was zero percent of our business," Vice President of Sales & Marketing Jim Dinger noted at the end of 2004. "Going into 2005, it will be 20 percent of our total business."

F&S Tool continually strives to increase its efficiency and broaden its capabilities, which has resulted in more business and several expansion projects. For example, one recent project, a Product Development Center, was completed in early 2004.

F&S Tool's in-house capabilities eliminate the need for outsourcing, allowing the company to meet more aggressive lead times when speed to market is of the essence. For example, when a manufacturer of disposable medical components anticipated an FDA regulation change, they contacted F&S Tool for solutions to their design issues. The company's most critical issue was speed to market, knowing their success would be determined by how quickly they could supply product to national distribution centers and beat their competition.

The goal was to design and build four multi-cavity tools in 18 weeks and meet predetermined cycle times. By week eight, F&S had design reviews and approvals on all four tools. Not only did the final tools meet the predetermined cycle times, but each actual cycle time came in five to 10 seconds faster than those dictated by the customer.

Chapter 5

Johnford Machines

By Steve Ortner
President of Absolute Machine Tools, Inc., Lorain, OH

Hard Milling Done Right: 10 Keys to Success in Your Shop

In recent years, hard milling technology has helped many manufacturers eliminate EDM operations and benchworking time for more profitable part making. However, some smaller shops may be concerned by the capital equipment costs of "high-end" hard milling/HSM equipment. The reality is that hard milling and HSM technology aren't that far out of reach for small shops. The key to a successful and economical transition is putting together the right mix of machine, tooling, programming, and suppliers. Doing so lets end users gain high-end machining performance without paying high-end price tags.

Understanding Hard Milling and HSM

Definitions for hard milling and HSM are different from company to company and from application to application. A simple way to think of hard milling/HSM is feeding as fast as possible with high accuracy. If it's not accurate, it's not hard milling/HSM, and your final product will be worthless.

A more conventional way of defining hard milling/HSM is machining material 45-64 Rc at spindle speeds of 10,000 RPM and higher. The depth of cut is typically 0.2 mm or less in both radial and axial directions.

Such light, fast cuts produce thin chips that carry heat away from the cutting zone—a major advantage when compared to conventional milling methods. These light cuts also decrease cutting forces to minimize stress and distortion of the work piece and prevent tool deflection that can mar surface finishes and destroy cutting tools.

Hard milling delivers tight dimensional tolerances and excellent surface finishes in relatively short machining times, which is why the process is replacing EDM in certain applications. For instance, moldmakers using EDM typically have a four-step process:

1. Milling steel to about 0.015 in. of a mold's final form
2. Heat treating the milled steel
3. EDMing any remaining stock
4. Hand polishing the mold

In contrast, hard milling is a one-step process that makes complex parts such as molds/dies to net shape (or near net shape) with minimal scrap (see Figures 5-1 through 5-5). It also reduces run time in the cavity

Figure 5-1 The right combination of high-speed machining center, HSK tooling, and CAD/CAM programming ensures quick turnarounds and quality results in demanding mold and die applications.

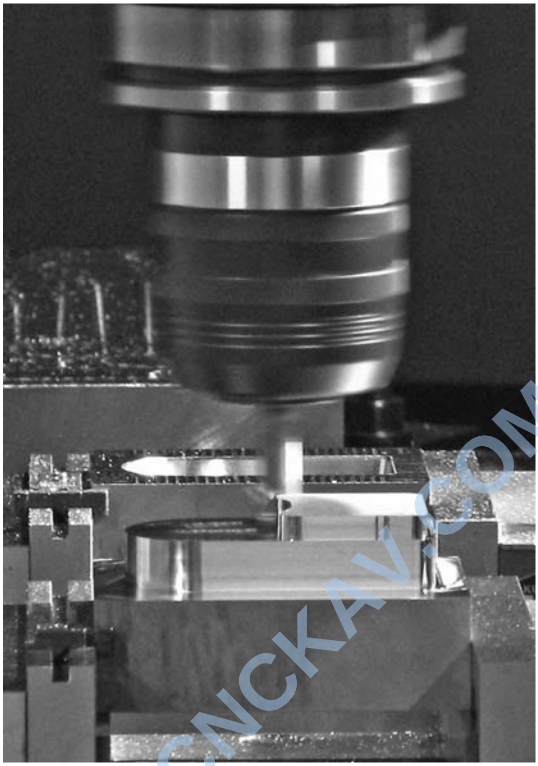


Figure 5-2 In this moldmaking application, a Johnford Hi-Net DMC-1500HN double-column machining center cuts a complex mold core and cavity for a bracket from 52 Rc H-13 steel. Machining time was 2.5 hours.

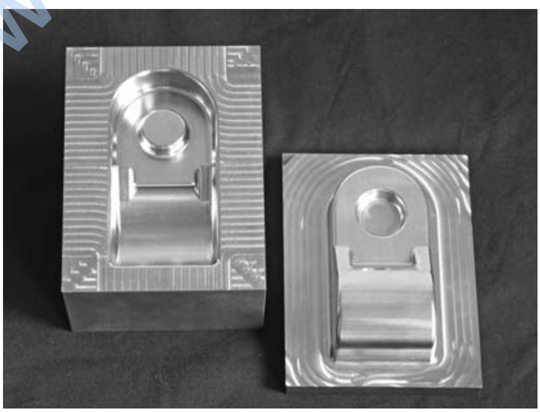


Figure 5-3 This mold cavity (left) and core for a bracket were machined from a 4Óx 3Óx 3Óblock of H-13 steel (52 Rc) in 2.5 hours on the Johnford Hi-Net DMC-1500HN double-column machining center.

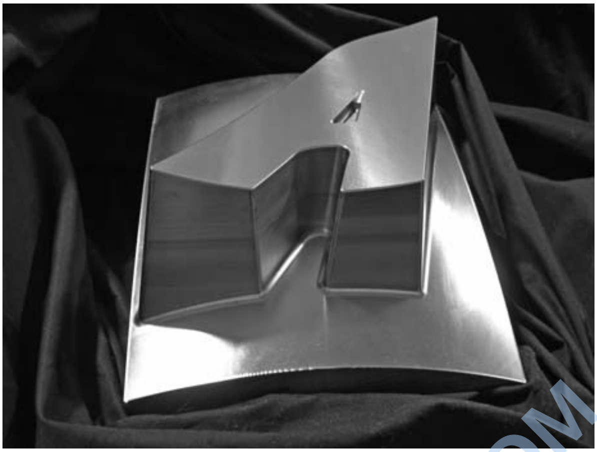


Figure 5-4 Two Johnford Hi-Net machining centers were used to machine this 60 Rc D-2 steel workpiece. The final product measures 8Óhigh X 10Ódeep X 8Ówide. **Roughing:** Johnford Hi-Net DMC-2100H machines in 9 hr; Sent out for heat treating. **Finishing:** Hi-Net SHV-1000 hard milled in 2 hr 45 min.

Figure 5-5 A Johnford Hi-Net SHV-1000 Super Vertical machining center performed rough cutting and finishing of this XX Rc D-2 steel shoe mold. The final product measures 1Óhigh X 5Ódeep X 12Ówide. **Roughing:** X hr; **Finishing:** X hr X min.

and eliminates machine marks that require polishing. Mold shops, among others, are regularly using hard milling techniques to minimize per-piece costs while extending mold/die life.

Obviously, hard milling can't completely replace EDM, which is still necessary to make features such as internal corners and deep grooves. However, it can significantly reduce production time and cost.

Ten Keys to Success

So what are the 10 keys to successful hard milling? The first five focus on what is arguably the most important element—the machine tool. It's critical that shops seek out machines specifically designed for hard milling, which generally share the same qualities as high-speed machining (HSM) centers.

1. Machine Rigidity

Foremost is an extremely rigid structure. Besides damping vibration, machines with heavily ribbed, cast iron construction provide stiffness and resist flexing even under high acceleration rates. All these ensure long tool life and excellent surface finishes.

2. Machine Structure

Basic machine design also has a huge impact on milling performance. Take the differences between C-frame machines and double-column systems. The C-frame design—typically found on small/medium-sized machines where table loads rated below 1,500 lb—has a base, a column, and a head that slides up and down the column. This configuration places the *X* axis on top of the *Y* axis, which makes the two axis loads variable. That's because two axes are impacted as table loads change, which makes machines difficult to tune and control for variable loads.

On a C-frame machine, the table may be fully supported by the saddle, but the saddle is never fully supported by the base casting. This leads to inherent instability that is unacceptable for hard milling/HSM.

By contrast, the double-column bridge is ideal for medium-size and larger machines (see Figure 5-6). In this configuration, the *Y* and *Z* axes are fixed loads, and the table load is the only variable. This allows the machine to be tuned in very tightly in *Y* and *Z* as the axis load and inertia never change, except for unnoticeable differences in the weights of the cutting tool and holder.

Figure 5-6 A double-column (or bridge-type) vertical machining center is ideal for hard milling large parts. For example, the double-column configuration of this Johnford Hi-Net DMC-2100 ensures the Y and Z axes are fixed loads. This allows the machine to be tightly tuned in these axes because the axis load and inertia never change.

The bridge design of the double column also features a long base casting that fully supports the table to the extreme levels of the machine. This configuration eliminates imbalance or pitch and yaw.

3. Moving Elements of the Machine

A machine's slides, way systems, ballscrews, and counterbalancing are also crucial to hard milling performance. Although the machine itself should be heavy, moving parts on it should be as lightweight as possible without sacrificing rigidity. Lightweight and stiff slides permit the fastest acceleration rates and reduce total cut time.

As for way systems, the application determines whether or not to use machines with box ways or linear ways. Linear ways are well-suited for small- to medium-sized machines with low-torque spindles. Medium to large machines with high-torque spindles call for box ways. Although either system works with high-RPM spindle machines that make light cuts at blindingly fast speeds, box ways do have a slight advantage in vibration dampening.

So which should shops choose? The answer may be both (see Figure 5-7). For example, some builders employ linear ways in the *X* axis and box ways in the *Y* and *Z*. The linear ways bear the weight of the table load. This minimizes axis inertia even under widely variable table loads. With a box way system, the amount of torque needed to move the table over and overcome stick-slip becomes widely variable and hard to tune.

One of the most important structural elements of any machine tool, but often overlooked, are the ballscrews. Shops want large-diameter, beefy ballscrews that prevent flex and vibration. Flimsy, lightweight ballscrews simply won't get the job done. In addition, a machine with pre-tensioned ballscrews (stretched under load) eliminates thermal deformation

Figure 5-7 According to Absolute Machine Tools, its Johnford Hi-Net DMC-1500HN is a double-column machining center with linear ways in the X axis and box ways in Y and Z. This configuration allows the linear ways to bear the weight of the table load and ensures accurate positioning of even the heaviest work pieces.

Figure 5-8 Bigger is better for any machining, particularly hard milling applications. A comparison between ballscrews from comparable vertical machining center shows a 1.57Ódiameter ballscrew (top) versus a 1.25Ódiameter ballscrew. The larger ballscrew also has a double nut arrangement, which minimizes play to boost machine tool accuracy.

and growth, and promotes axis rigidity. If a machine structure can't support pretensioned ballscrews, the ballscrews must be cooled by a circulating fluid, which, in turn, creates maintenance issues.

A machine without pretensioned ballscrews must have scales for accuracy, but may still lack axis rigidity. Long-travel machines with long ballscrews should have fixed screw/rotating-nut arrangements to prevent screw whip, and servomotors should directly couple to ballscrews with a rigid coupling. Servomotors not directly coupled (for example, using pulleys and a belt) suffer from lost motion and lost rigidity, which, ultimately, sacrifice accuracy and finish.

Because of the high acceleration rates in hard milling/HSM, counterbalancing with counterweights is not feasible. Therefore, the machine should use a large servomotor with no counterbalance or a hydraulic-counterbalance system.

4. Motion Control

Look for machine tools using controls, servo drives, and motors made by the same manufacturer. This ensures the elements of the motion system are engineered to work together for optimum speed and reliability. Some other considerations to keep in mind:

- **Control speed –** The control's capability to process blocks of three-axis-movement information, execute them through the servo system, and get closed-loop feedback. In particular, look for the following: 3-axis simultaneous blocks (*XYZ* data in each block), absolute coordinate programming (not incremental), cutter compensation on, and tool length compensation on.
- **Block look-ahead –** The number of blocks the control is looking ahead in the program for vector changes so that it can adjust feedrates to avoid over-shooting and gouging. The faster the control, the more blocks of look-ahead are required.
- **Automatic acceleration/deceleration –** When combined with block look-ahead, the automatic acc/dec before interpolation mode automatically reduces feed rates to maintain contour accuracy and integrity.
- **Mass program storage and an Ethernet interface –** Cutting at high speeds requires mass program storage in the control. Seek out a hard-disk drive or ATA card. RS-232 DNC modes are just not fast enough.
- **Powerful servo motors and drives –** Hard milling/HSM machining centers need large AC digital servo motors and drives to quickly start and stop the machines.
- **High-resolution feedback –** Encoders or linear scales are a must. They keep track of where the machine is, where it has been, and where it's going.
- **Servo tuning –** Proper tuning of the servos is also crucial to match machine-axis-inertia changes as table loads change. The control must be tuned for various levels of precision versus speed.

5. Machines with Integral HSM Spindles

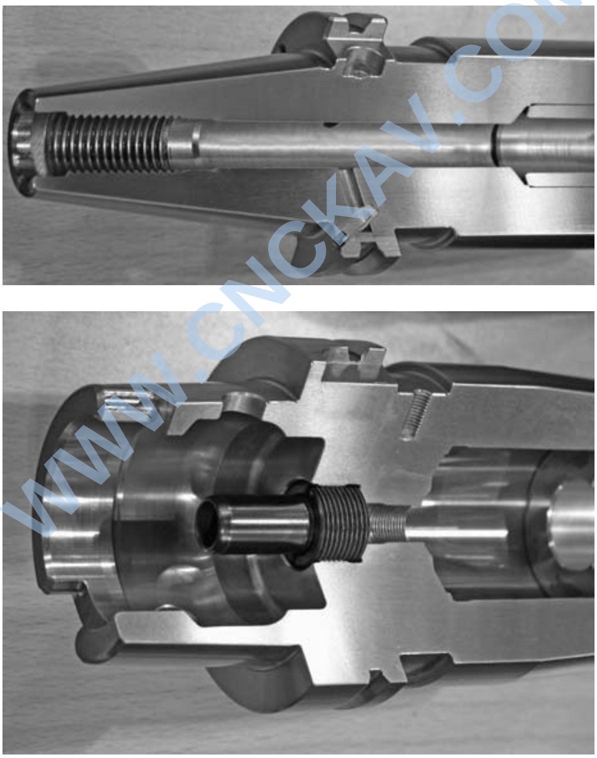
The spindle is the heart of any machine tool. Although there are a number of spindle types available, including gear box and direct drive spindles, the best bet for hard milling/HSM applications is the integral or motorized spindle.

Integral spindles combine the motor and spindle—essentially, the spindle shaft is the rotor and the spindle housing is the stator. They're ideal for high speeds and fine finishes. A good rule of thumb is to look for machines with spindles that deliver speeds from 15,000 to 40,000 rpm.

Although integral spindles can be expensive with high repair costs, they deliver excellent thermal stability with little deformation, exceptional acceleration/deceleration, and adequate cutting torque. All these are critical in hard milling/HSM applications.

6. HSK Tooling

Moving from machines to tooling, end users should invest in HSK tooling for hard milling and HSM work. Resist the temptation to buy cheaper tooling; it only ends up costing more in the long run. Without HSK, shops will never reap all the benefits of their hard milling/HSM machines (see Figures 5-9 and 5-10).



Figures 5-9 and 5-10 A comparison between V-taper (Figure 5-9 Top) and HSK tooling (Figure 5-10 Bottom). HSK is preferred in high-speed machining applications because of its shorter shank and more precise taper. It also provides dual contact (on the spindle face and taper), which prevents the spindle from ÒstickingÓ in the spindle. **Tooling photos courtesy of Haimer USA, LLC, Villa Park, IL.**

What's wrong with CAT/BT systems? They don't hold up well under high RPM. That's because they depend only on spindle-taper contact for rigidity. As spindle speeds increase, centrifugal force can open their pull-stud holding systems.

At high speeds, spindle mouths expand slightly due to centrifugal force, causing conventional toolholders to move further into the spindle because of constant drawbar pulling pressure. This cutter pull-back changes *Z*-axis dimensional accuracy and can cause tools to "stick" in the spindle.

So why not MCAT/BBT systems? They improve rigidity because of dual contact between the machine spindle face and the toolholder-flange face, as well as contact with the spindle taper. This contact reduces machine vibration at high speeds and fretting corrosion between the machine spindle and toolholder tapers. However, MCAT/BBT tooling has the same pull-stud-holding arrangement as CAT/BT systems and runs into the same problems with centrifugal force.

Unlike conventional shanks, HSK shanks are hollow. Their clamping mechanisms operate from the inside, making the holders impervious to centrifugal forces. Also, because of HSK short tapers, spindle bearings are placed closer to the spindle nose for improved rigidity.

It's a good idea to work with machine tool suppliers to select the best HSK system for a particular machine and applications. HSK-A systems are ideal for high-torque cutting at speeds to 24,000 rpm. HSK-E holders, on the other hand, do not have the drive slots of A-type systems and, thereby, improve balance at high speeds. This type is great for low-torque finishing operations at high spindle speeds.

A general rule of thumb is to use large HSK-100A for heavy cutting at speeds to 15,000 rpm, medium-sized HSK-63A for medium to fine cutting at speeds to 24,000 rpm, and small HSK-50E holders for high-speed finishing.

7. Coated Cutting Tools

It's no surprise that cutting tools have a huge impact on the hard milling process. Cutting tool selection is one area where many manufacturers make their biggest mistake. Choosing the right tool can save big bucks; the wrong tool will lead to more scrap. Unfortunately, many manufacturers buy tools based on their price rather than their performance.

Select tools that can withstand high cutting speeds and high temperatures. Shops should select high quality TiAlN-coated carbide tools, and the more coating layers, the better. Ultra-fine carbide grades are also preferred.

It's a good idea to work with cutting tool manufacturers that have a reputation for high quality tooling specifically engineered for hard milling. These companies should work closely with machine tool suppliers. That ensures they can provide the appropriate cutting tools for specific hardened materials, cutting strategies, and machine tools.

Because hard milling generates a lot of heat, flood coolant is not recommended. The coolant can cause thermal shock that negatively impacts the cutting tool (edge chipping, premature wear). Therefore, shops should look to run dry or use either compressed air or air-oil mist to cool the cutting zone and evacuate chips.

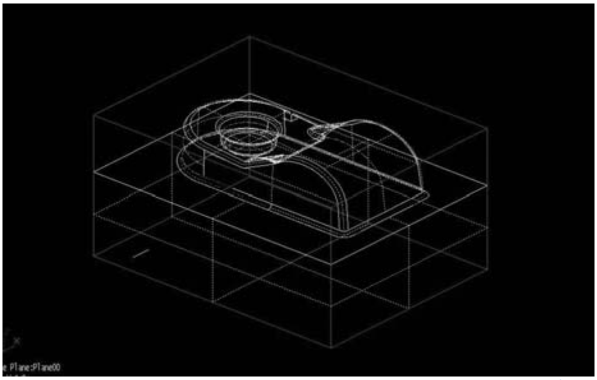
8. CAD/CAM Programming for Hard Milling/HSM

Hard milling success requires CAD/CAM programming that's optimized for hard milling and HSM applications. However, many shops overlook this crucial element. Instead they use conventional programming techniques.

Keep in mind that the difference between hard milling and conventional machining goes beyond simply faster, lighter cuts. Because of the high feed rates involved, it's important to protect the cutting tool from sudden changes in cutting forces. One way to do this is by using Z-level machining, which machines one vertical layer after another in a spiral pattern. Such a tool path ensures a constant load on the tool.

Unfortunately, shops commonly apply the same programming software and methods used for conventional machining to hard milling and HSM work. But they'll get superior part quality and better overall results using software optimized for the process. Shops will also get consistent results in unattended operation—machining a part from start to finish with multiple tools without interruption. In addition, end users can go from rough to semi-finish machining without intermediate cutting if their programming software accurately recognizes remaining stock from previous operations.

Today's advanced CAM systems have several features that are musts for successful hard milling/HSM. Of utmost importance is having software that cuts true to the surface data. Many systems lay a triangulated mesh over the surface to create the machining program. Unfortunately,



Figures 5-11 Part programming was done using CAM-TOOL software from Graphic Products North America Inc., Windsor, Ontario. Programming time took approximately 2 hours. This series of images shows a 3D CAD wireframe of the mold core. **Screen shots courtesy of CAM-TOOL/Graphic Products North America, Inc.**

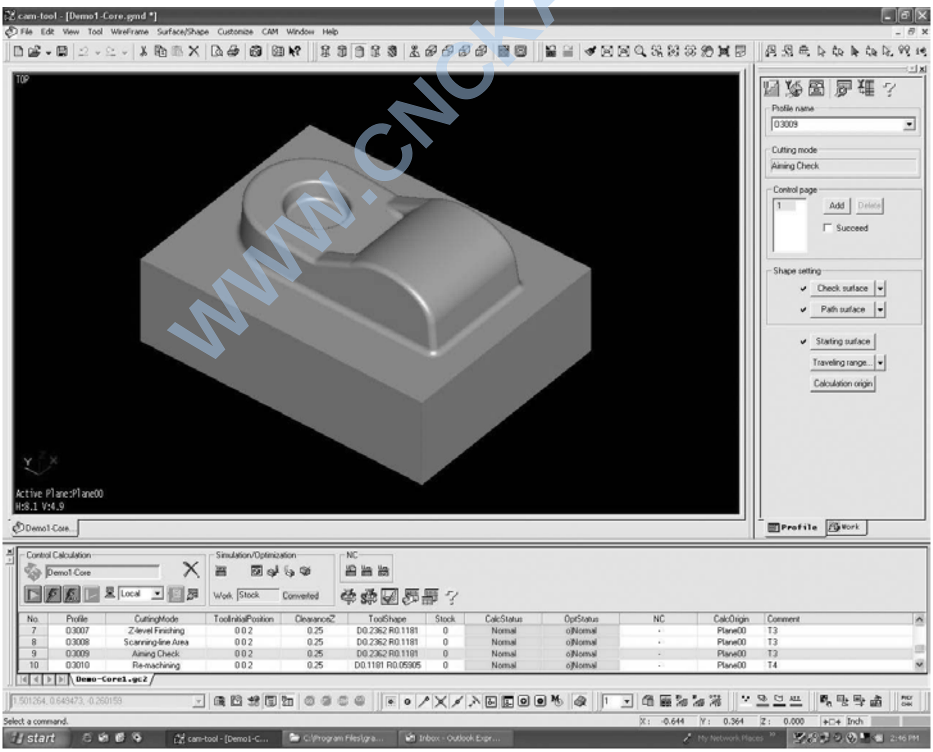
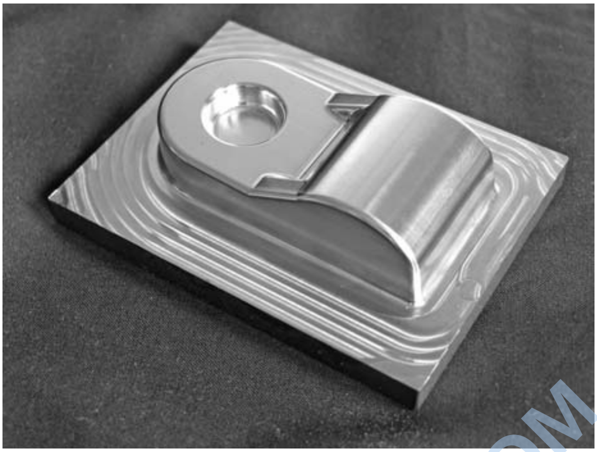


Figure 5-12 A shaded model with tool path information. **Screen shots courtesy of CAM-TOOL/Graphic Products North America, Inc.**



Figures 5-13 The finished core produced by the Johnford Hi-Net DMC-1500HN. **Screen shots courtesy of CAM-TOOL/Graphic Products North America, Inc.**

all of these tiny triangles laid on the surface are not true surface data; ultimately, this type of software will compromise surface finish and accuracy during machining. Other key CAM features to look for include trochoidal roughing routines, Z-level offset machining, and automatic stock recognition and re-machining.

9. Excellent Service and Technical Support

Finding the right machine tool partner is just as crucial to the hard milling process as securing the right machine. Machine tool suppliers should be able to help companies engineer solutions that deliver outstanding and consistent results for their hard milling applications.

Therefore, look for machine tool suppliers that work closely with tooling manufacturers and software developers. This is the only way to guarantee that tooling and software truly optimizes machine performance. Otherwise, a shop may end up with a costly machine that doesn't produce as promised. In many cases, the machine isn't the problem—it's the tooling or programming.

In addition, avoid suppliers that simply sell machines. Instead, seek out partners that focus on application assistance. Such suppliers have a wealth of invaluable information gathered from test cuts. This knowledge can only help shops push the limits of their design and machining capabilities to create more complex parts with finer finishes in significantly shorter lead times. These suppliers can also help shops reap the benefits of unattended machining to be even more competitive on price.

10. Suppliers Offering a Diverse Range of Products

Shops should seek out suppliers with a diverse product line rather than a "one size fits all" mentality. Therefore, look for suppliers that offer a range of working envelopes, table choices, axis configurations, and options such as pallet changers and part probes. These suppliers have expertise beyond any one shop's application experience and may be able to help shops gain the flexibility to take on new jobs.

Obviously, smart shops want plenty of "bang for their buck" versus costly, and sometimes unnecessary, bells and whistles. However, watch out for cheap solutions—standard machine tools modified with high-speed options. Such systems do not have the rigidity, accuracy, and speed needed for hard milling and will end up costing more in the end.

A Final Word

Remember that the right machine is the foundation to successful hard milling. Machine tools specifically designed for the process generally share the same qualities as high-speed machining (HSM) centers: extremely rigid structures that damp vibration, advanced motion systems optimized for high-speed machining and hard milling, and high-speed spindles that can handle hard milling.

Keep in mind that tooling, programming, and technical support play crucial roles in successful hard milling operations. Therefore, seek out machine tool suppliers that have the expertise to put together the optimal package for specific hard milling applications. The end result of all this will be outstanding and consistent hard milling operations, along with a huge competitive advantage.

Hi-Net High Speed Machining Centers for Every Application

Hi-Net high speed machining centers by Johnford are specifically designed for hard milling and high speed, net shape machining of complex surfaces. These machines feature FEA proven rock solid machine construction, world-class high speed spindles and Fanuc CNC controls. The resulting machines compete at the highest level at an affordable cost. In mold machining applications, these machines produce precisely accurate molds that require little or no hand work with the fastest cycle times. Other applications include dies and aerospace.

Hi-Net machining centers are available in a variety of sizes and configurations to meet any need. The SV-33, SV-41 and SV-48 are box way C-frame machines that have been specifically designed for high speed machining. These machines can handle small to medium size workpiece requirements and are available with 18,000 or 24,000 RPM HSK-63A spindles. The DMC series machines are double column (bridge mill) designs made to handle medium to large size workpieces and heavy table loads. They employ box ways in Y and Z and roller type linear ways in X. They are available in 15,000 RPM HSK-100A and 24,000 or 18,000 RPM HSK-63A spindles.

The Super Hi-Net machining centers are the latest generation of high speed finishing solutions from Absolute Machine Tools. Common features of the Super Hi-Net machine are no counterbalance in Z, implementation of Schneeberger roller type linear ways on all three axes, and HSK 63A spindles only. The machine designs have been modified for rigidity and accuracy at ultra high speeds. Currently, there are four models available. The SHV-1000 is a ram head type of vertical machine that features a light weight ram for the Z axis for increased acceleration (see Figure 5-14). The DMC-909, 912, and 915 are double column machines with improved cutting speeds over the standard Hi-Net double columns.

All Hi-Net machining centers are equipped exclusively with Weiss spindles manufactured in Germany. These spindles provide the speed, power, rigidity and reliability necessary to meet today's high speed machining requirements. For heavy cutting and fine finishing all in one spindle, the 15,000 RPM HSK-100A spindle is the answer. It produces 56HP and 300 ft./lbs. of torque at only 1,000 RPM, providing the best of both worlds. For medium roughing and high speed finishing, the 18,000 RPM or 24,000 RPM spindles are the best choice. The 18,000 RPM spindle produces 29HP and 68ft./lbs. of torque at 2,300 RPM while the 24,000 RPM spindle produces 31HP and 53ft./lbs. of torque at 3,000

RPM. The HSK tooling system is used exclusively to provide the balance, rigidity, and accuracy necessary to produce the best results.

The Fanuc 18iM-B control with AI NANO HPCC is the fastest control available and is the only control offered on the Hi-Net machines. The 18iM-B uses NANO technology for the ultimate in precision and speed. The control is mated via fiber optics to the new Fanuc Alpha i servo system features high response and high torque servo motors equipped with 1,000,000 pulse encoders. The AI NANO HPCC (high precision contour control) delivers 150,000 block/min. processing with a 600 block look ahead to navigate radical vector changes without violating the surface being machined. The control is standard with an ethernet connection and 640MB built-in ATA card for large program storage.

Figure 5-14 The Super Hi-Net SHV-1000 is a Super Vertical that combines speed, rigidity, and precision in a machine designed specifically for high speed mold machining. Its features are not found on competitive machines at any price. It has Schneeberger roller type linear ways on all axes with large diameter pre-tensioned ballscrews, and a state-of-the-art integral spindle for the extraordinary finishes. The Y axis features 4 ways for unparalleled support and accuracy. The Z axis is a ram type head with no counterbalance for increased acceleration and smooth operation. Rapid rates are 944Ó/min in all axes.

ABSOLUTE MACHINE TOOLS, INC.
Hard Milling & HSM Products

Super Hi-Net SHV-1000 Vertical Machining Center by Johnford

The Super Hi-Net SHV-1000 is a Super Vertical that combines speed, rigidity and precision in a machine designed specifically for high speed mold machining. This machine has features not found on competitive machines at any price. It features Schneeberger roller type linear ways on all axes with large diameter pre-tensioned ballscrews, and a state-of-the-art integral spindle for the very best finishes. The Y axis features 4 ways for unparalleled support and accuracy. The Z axis is a ram type head with no counterbalance for increased acceleration and smooth operation. Rapid rates are 944"/min in all axes. As in any high quality machine tool, the SHV-1000 is made from heavy Meehanite FC-30 castings. Cast iron has the strength and vibration dampening characteristics necessary for excellent surface finishes and long cutting tool life. The accurate positioning is carried out by large diameter, pretensioned ballscrews (1.77") and powerful servo motors. The servo motors are directly coupled to the ballscrews via rigid couplings.

List the machines made for this process.	Johnford Super Hi-Net SHV-1000 VMC
List of machines, linear, roller and or box ways.	Schneeberger roller type linear ways on all axes
Are these options part of a hard milling and high speed package?	Yes

Controller Options.	
Type of controller options	Fanuc 18iM-B
Storage size ability	• 256K standard memory • 640 MB ATA Card (built-in type) for mass program storage
Data transmit options, Ethernet and RS232.	Ethernet/network connection
Options like Macro B, Helical interpolation and HPCC (high speed turn on).	• AI NANO high precision contour control (600 blocks look ahead/150,000 blocks/min processing) with 64 bit RISC processor • Custom Macro B
Max feed rate	787 IPM
Number of axis ability	• Controlled axis: 3 axis standard (up to 6 axis optional) • Simultaneous Controllable axis: 3 axis standard (up to 4 axis optional)

Heat compensation options.	
How does your heat compensation work?	A Thermistor sensor is placed inside the spindle and another to the machine headstock casting. The headstock sensor is placed as far away from any heat sources as possible. The internal spindle temperature is compared with the ambient casting temperature. We compare the gradients and process the information with a proprietary algorithm that is used in conjunction with the capabilities of the Fanuc control to provide behind-the-scene compensation, effectively eliminating spindle growth issues.
Is the option part of the price?	Yes
Chiller description	High capacity refrigerated oil chiller keeps spindle cooling fluid at a constant temperature to ambient temperature.

Work envelope options.	
Table size X Y Z.	Travels in X,Y,Z: 41.3" X 24" X 20" 47.2" X 23.6" table working surface

Spindle options	
Spindle RPM max	• 24,000 RPM Weiss spindle (medium roughing/fine finishing) • 18,000 RPM Weiss spindle (medium roughing/fine finishing)
Spindle Chillers	Standard Large Capacity Spindle Cooler
Holder option	HSK-63A for both spindles
Horse power	• 24,000 RPM Weiss spindle – 31 HP high torque • 18,000 RPM Weiss spindle – 30 HP high torque

Coolant Capabilities	Flood coolant system with programmable air blast
Air	Standard
Air Oil	MQL optional
High Pressure	Up to 1,000 PSI available as an option
Oil	NO

Machine environment requirements.	18,700 LB. machine with a 115" X 126" X 100" footprint
How thick should the base pad be?	27"

ABSOLUTE MACHINE TOOLS, INC.

Hard Milling & HSM Products

Hi-Net Super Vertical Machining Centers by Johnford

The Hi-Net Super Vertical machining centers combine speed, rigidity and precision in heavy duty packages. These machines have features not found on competitive machines at any price. They feature square box ways on all axes with large diameter pre-tensioned ballscrews, and large diameter rigid spindles for heavy cutting. The Y axis features 4 box ways for unparalleld support and accuracy. The Z axis is hydraulically counterbalanced for increased speed and smooth operation. Special Turcite and hand scraping allow the machines to rapid at exceptionally high rates in the X and Y axes. As in any high quality machine tool, the Johnford Super VMCs are made from heavy Meehanite FC-30 castings. Cast iron has the strength and vibration dampening characteristics necessary for excellent surface finishes and long cutting tool life. The accurate positioning is carried out by large diameter, pretensioned ballscrews and powerful servo motors. The servo motors are directly coupled to the ballscrews via rigid couplings.

List the machines made for this process.	Hi-Net SV-33 Super Vertical Machining Center	Hi-Net SV-41 Super Vertical Machining Center	Hi-Net SV-48 Super Vertical Machining Center
List of machines, linear, roller and or box ways.	Square box ways on all axes		
Are these options part of a hard milling and high speed package?	Yes		

Controller Options	
Type of controller options	Fanuc 18iM-B
Storage size ability	• 256K standard memory • 640 MB ATA Card (built-in type) for mass program storage
Data transmit options, Ethernet and RS232.	Ethernet/network connection
Options like Macro B, Helical interpolation and HPCC (high speed turn on).	• AI NANO high precision contour control (600 blocks look ahead/150,000 blocks/min processing) with 64 bit RISC processor • Custom Macro B
Max feed rate	472 IPM
Number of axis ability	• Controlled axis: 3 axis standard (up to 6 axis optional) • Simultaneous Controllable axis: 3 axis standard (up to 4 axis optional)

Heat compensation options.	
How does your heat compensation work?	A Thermistor sensor is placed inside the spindle and another to the machine headstock casting. The headstock sensor is placed as far away from any heat sources as possible. The internal spindle temperature is compared with the ambient casting temperature. We compare the gradients and process the information with a proprietary algorithm that is used in conjunction with the capabilities of the Fanuc control to provide behind-the-scene compensation, effectively eliminating spindle growth issues.
Is the option part of the price?	Yes
Chiller description	High capacity refrigerated oil chiller keeps spindle cooling fluid at a constant temperature to ambient temperature.

Work envelope options			
Table size X Y Z.	Travels in X,Y,Z: 33.5" X 24" X 24" 39.4" X 23.6" table working surface	Travels in X,Y,Z: 41.3" X 24" X 24" 47.2" X 23.6" table working surface	Travels in X,Y,Z: 48" X 28" X 24.8" 51.2" X 27.6" table working surface

Spindle options	
Spindle RPM max	• 24,000 RPM Weiss spindle (medium roughing/fine finishing • 18,000 RPM Weiss spindle (medium roughing/fine finishing)
Spindle Chillers	Standard Large Capacity Spindle Cooler
Holder option	HSK-63A on both spindles
Horse power	• 24,000 RPM Weiss spindle – 31 HP high torque • 18,000 RPM Weiss spindle – 30 HP high torque

Coolant Capabilities	Flood coolant system with programmable air blast
Air	Standard
Air Oil	MQL optional
High Pressure	Up to 1,000 PSI available as an option
Oil	NO

Machine environment requirements.	17,600 LB. machine with a 94.5" X 126" X 100" footprint	18,700 LB. machine with a 115" X 126" X 100" footprint	20,900 LB. machine with a 122" X 144" X 122" footprint
How thick should the base pad be?	27"		

ABSOLUTE MACHINE TOOLS, INC.

Hard Milling & HSM Products

Hi-Net Double Column Machining Centers by Johnford

The Hi-Net series of high performance double column machining centers are designed for high speed machining of complex 3-D shapes. The Hi-Net concept was developed to meet the needs of high speed, net shape machining in mold, die, and aerospace machining. Simply put, these machines are built to machine shapes in a variety of materials at high feedrates and with high accuracy. To accomplish this task, it takes a very well built machine. We start with a heavy weight cast iron machine frame. The machine design features a moving table and fixed column for maximum rigidity. A rugged 90 degree bridge with offset Y axis ways and a wide saddle keeps the spindle center line extremely close to the bridge for rigidity. The columns and bridge are a one piece casting for the best rigidity. The massive Z axis head and Y axis saddle feature square box ways coated with Turcite and have been designed with diagonally arranged ribs that will help reduce the amount of distortion that is caused by years of continued service. The X axis table traverse is accomplished via heavy duty Schnerberger roller linear ways for accurate positioning of heavy work pieces. Accurate positioning is carried out by large diameter, pre-tensioned ballscrews and powerful servo motors that are directly coupled to the ballscrews via rigid couplings.

List the machines made for this process.	Hi-Net DMC-900 HN	Hi-Net DMC-1200 HN	Hi-Net DMC-1500 HN
List of machines, linear, roller and or box ways.	Square box ways in Y and Z; Heavy duty roller type linear ways in Y		
Are these options part of a hard milling and high speed package?	Yes		
Controller Options.			
Type of controller options	Fanuc 18iM-B		
Storage size ability	• 256K standard memory • 640 MB ATA Card (built-in type) for mass program storage		
Data transmit options, Ethernet and RS232.	Ethernet/network connection		
Options like Macro B, Helical interpolation and HPCC (high speed turn on).	• AI NANO high precision contour control (600 blocks look ahead/150,000 blocks/min processing) with 64 bit RISC processor • Custom Macro B		
Max feed rate	472 IPM		
Number of axis ability	• Controlled axis: 3 axis standard (up to 6 axis optional) • Simultaneous Controllable axis: 3 axis standard (up to 4 axis optional)		
Heat compensation options.			
How does your heat compensation work?	A Thermistor sensor is placed inside the spindle and another to the machine headstock casting. The headstock sensor is placed as far away from any heat sources as possible. The internal spindle temperature is compared with the ambient casting temperature. We compare the gradients and process the information with a proprietary algorithm that is used in conjunction with the capabilities of the Fanuc control to provide behind-the-scene compensation, effectively eliminating spindle growth issues.		
Is the option part of the price?	Yes		
Chiller description	High capacity refrigerated oil chiller keeps spindle cooling fluid at a constant temperature to ambient temperature.		
Work envelope options.			
Table size X Y Z.	Travels in X,Y,Z: 35.4" X 35.4" X 30" 39.4" X 33.5" table working surface	Travels in X,Y,Z: 47.2" X 35.4" X 30" 51.2" X 33.5" table working surface	Travels in X,Y,Z: 59.1" X 35.4" X 30" 63" X 33.5" table working surface
Spindle options			
Spindle RPM max	• 15,000 RPM Weiss spindle (heavy cutting) • 24,000 RPM Weiss spindle (medium rough and high speed finishing) • 18,000 RPM Weiss spindle (medium rough and finishing)		
Spindle Chillers	Standard Large Capacity Spindle Cooler		
Holder option	• 15,000 RPM spindle – HSK-100A • 24,000 RPM spindle – HSK-63A • 18,000 RPM spindle – HSK-63A		
Horse power	• 15,000 RPM Weiss spindle – 56 HP high torque • 24,000 RPM Weiss spindle – 31 HP high torque • 18,000 RPM Weiss spindle – 30 HP high torque		
Coolant Capabilities	**Flood coolant system with programmable air blast**		
Air	Standard		
Air Oil	MQL optional		
High Pressure	Up to 1,000 PSI available as an option		
Oil	NO		
Machine environment requirements.	**26,400 LB. machine with a 177" X 118" X 148" footprint**	**26,400 LB. machine with a 186" X 118" X 148" footprint**	**33,000 LB. machine with a 196" X 118" X 148" footprint**
How thick should the base pad be?	27"		

Hi-Net Double Column Machining Centers by Johnford *(continued)*

List the machines made for this process.	**Hi-Net DMC-1600 HN**	**Hi-Net DMC-2100 HN**	**Hi-Net DMC-2100 SHN**
List of machines, liner, roller and or box ways.	Square box ways in Y and Z; Heavy duty roller type linear ways in Y		
Are these options part of a hard milling and high speed package?	Yes		

Controller Options.			
Type of controller options	Fanuc 18iM-B		
Storage size ability	• 256K standard memory • 640 MB ATA Card (built-in type) for mass program storage		
Data transmit options, Ethernet and RS232.	Ethernet/network connection		
Options like Macro B, Helical interpolation and HPCC (high speed turn on).	• AI NANO high precision contour control (600 blocks look ahead/150,000 blocks/min processing) with 64 bit RISC processor • Custom Macro B		
Max feed rate	394 IPM		
Number of axis ability	• Controlled axis: 3 axis standard (up to 6 axis optional) • Simultaneous Controllable axis: 3 axis standard (up to 4 axis optional)		

Heat compensation options.			
How does your heat compensation work?	A Thermistor sensor is placed inside the spindle and another to the machine headstock casting. The headstock sensor is placed as far away from any heat sources as possible. The internal spindle temperature is compared with the ambient casting temperature. We compare the gradients and process the information with a proprietary algorithm that is used in conjunction with the capabilities of the Fanuc control to provide behind-the-scene compensation, effectively eliminating spindle growth issues.		
Is the option part of the price?	Yes		
Chiller description	High capacity refrigerated oil chiller keeps spindle cooling fluid at a constant temperature to ambient temperature.		

Work envelope options.			
Table size X Y Z.	Travels in X,Y,Z: 63" X 43/51" X 31.5" 66.9" X 43.3" table working surface	Travels in X,Y,Z: 80.7" X 43/51" X 31.5" 86.6" X 43.3" table working surface	Travels in X,Y,Z: 82.7" X 70" X 31.5" 86.6" X 59" table working surface

Spindle options			
Spindle RPM max	• 15,000 RPM Weiss spindle (heavy cutting) • 24,000 RPM Weiss spindle (medium rough and high speed finishing) • 18,000 (medium rough and finishing)		
Spindle Chillers	Standard Large Capacity Spindle Cooler		
Holder option	• 15,000 RPM spindle – HSK-100A • 24,000 RPM spindle – HSK-63A • 18,000 RPM spindle – HSK-63A		
Horse power	• 15,000 RPM Weiss spindle – 56 HP high torque • 24,000 RPM Weiss spindle – 31 HP high torque • 18,000 RPM Weiss spindle – 30 HP high torque		

Coolant Capabilities	**Flood coolant system with programmable air blast**		
Air	Standard		
Air Oil	MQL optional		
High Pressure	Up to 1,000 PSI available as an option		
Oil	NO		

Machine environment requirements.	**45,000 LB. machine with a 218" X 130" X 150" footprint**	**52,000 LB. machine with a 255" X 130" X 150" footprint**	**52,000 LB. machine with a 255" X 130" X 150" footprint**
How thick should the base pad be?	27"		

Hi-Net Double Column Machining Centers by Johnford *(continued)*

List the machines made for this process.	Hi-Net DMC-3100 HN	Hi-Net DMC-3100 SHN	Hi-Net DMC-4100 HN
List of machines, linear, roller and or box ways.	Square box ways in Y and Z; Heavy duty roller type linear ways in Y		
Are these options part of a hard milling and high speed package?	Yes		
Controller Options.			
Type of controller options	Fanuc 18iM-B		
Storage size ability	• 256K standard memory • 640 MB ATA Card (built-in type) for mass program storage		
Data transmit options, Ethernet and RS232.	Ethernet/network connection		
Options like Macro B, Helical interpolation and HPCC (high speed turn on).	• AI NANO high precision contour control (600 blocks look ahead/150,000 blocks/min processing) with 64 bit RISC processor • Custom Macro B		
Max feed rate	394 IPM		
Number of axis ability	• Controlled axis: 3 axis standard (up to 6 axis optional) • Simultaneous Controllable axis: 3 axis standard (up to 4 axis optional)		
Heat compensation options.			
How does your heat compensation work?	A Thermistor sensor is placed inside the spindle and another to the machine headstock casting. The headstock sensor is placed as far away from any heat sources as possible. The internal spindle temperature is compared with the ambient casting temperature. We compare the gradients and process the information with a proprietary algorithm that is used in conjunction with the capabilities of the Fanuc control to provide behind-the-scene compensation, effectively eliminating spindle growth issues.		
Is the option part of the price?	Yes		
Chiller description	High capacity refrigerated oil chiller keeps spindle cooling fluid at a constant temperature to ambient temperature.		
Work envelope options.			
Table size X Y Z.	Travels in X,Y,Z: 120" X 43/51" X 31.5" 130" X 43.3" table working surface	Travels in X,Y,Z: 122" X 70" X 31.5" 130" X 59" table working surface	Travels in X,Y,Z: 157.5" X 43/51" X 31.5" 165" X 43.3" table working surface
Spindle options			
Spindle RPM max	• 15,000 RPM Weiss spindle (heavy cutting) • 24,000 RPM Weiss spindle (medium rough and finishing) • 18,000 (medium rough and finishing)		
Spindle Chillers	Standard Large Capacity Spindle Cooler		
Holder option	• 15,000 RPM spindle – HSK-100A • 24,000 RPM spindle – HSK-63A • 18,000 RPM spindle – HSK-63A		
Horse power	• 15,000 RPM Weiss spindle – 56 HP high torque • 24,000 RPM Weiss spindle – 31 HP high torque • 18,000 RPM Weiss spindle – 30 HP high torque		
Coolant Capabilities	**Flood coolant system with programmable air blast**		
Air	Standard		
Air Oil	MQL optional		
High Pressure	Up to 1,000 PSI available as an option		
Oil	NO		
Machine environment requirements.	**59,000 LB. machine with a 333" X 130" X 150" footprint**	**72,160 LB. machine with a 323" X 157" X 150" footprint**	**66,000 LB. machine with a 412" X 130" X 150" footprint**
How thick should the base pad be?	27"		

ABSOLUTE MACHINE TOOLS, INC.
Hard Milling & HSM Products

Super Hi-Net Double Column Machining Centers by Johnford

The DMC-909, 912, and 915 are double column machines with improved cutting speeds over the standard Hi-Net double columns.

List the machines made for this process.	Super Hi-Net DMC-909	Super Hi-Net DMC-912	Super Hi-Net DMC-915
List of machines, linear, roller and or box ways.	Heavy duty roller type linear ways in all axes		
Are these options part of a hard milling and high speed package?	Yes		

Controller Options.	
Type of controller options	Fanuc 18iM-B
Storage size ability	• 256K standard memory • 640 MB ATA Card (built-in type) for mass program storage
Data transmit options, Ethernet and RS232.	Ethernet/network connection
Options like Macro B, Helical interpolation and HPCC (high speed turn on).	• AI NANO high precision contour control (600 blocks look ahead/150,000 blocks/min processing) with 64 bit RISC processor • Custom Macro B
Max feed rate	787 IPM
Number of axis ability	• Controlled axis: 3 axis standard (up to 6 axis optional) • Simultaneous Controllable axis: 3 axis standard (up to 4 axis optional)

Heat compensation options.	
How does your heat compensation work?	A Thermistor sensor is placed inside the spindle and another to the machine headstock casting. The headstock sensor is placed as far away from any heat sources as possible. The internal spindle temperature is compared with the ambient casting temperature. We compare the gradients and process the information with a proprietary algorithm that is used in conjunction with the capabilities of the Fanuc control to provide behind-the-scene compensation, effectively eliminating spindle growth issues.
Is the option part of the price?	Yes
Chiller description	High capacity refrigerated oil chiller keeps spindle cooling fluid at a constant temperature to ambient temperature.

Work envelope options.			
Table size X Y Z.	Travels in X,Y,Z: 35.4" X 35.4" X 20" 39.4" X 33.5" table working surface	Travels in X,Y,Z: 47.2" X 35.4" X 20" 51.2" X 33.5" table working surface	Travels in X,Y,Z: 59.1" X 35.4" X 20" 63" X 33.5" table working surface

Spindle options	
Spindle RPM max	• 24,000 RPM Weiss spindle (medium rough and finishing) • 18,000 RPM Weiss spindle (medium rough and finishing)
Spindle Chillers	Standard Large Capacity Spindle Cooler
Holder option	• 24,000 RPM spindle – HSK-63A • 18,000 RPM spindle – HSK-63A
Horse power	• 24,000 RPM Weiss spindle – 31 HP high torque • 18,000 RPM Weiss spindle – 30 HP high torque

Coolant Capabilities	Flood coolant system with programmable air blast
Air	Standard
Air Oil	MQL optional
High Pressure	Up to 1,000 PSI available as an option
Oil	NO

Machine environment requirements.	22,000 LB. machine with a 177" X 118" X 122" footprint	24,200 LB. machine with a 186" X 118" X 122" footprint	30,800 LB. machine with a 196" X 118" X 122" footprint
How thick should the base pad be?	27"		

About Absolute Machine Tools

Absolute Machine Tools, Inc., Lorain, Ohio, is a leading importer and distributor of high-performance CNC machining and turning equipment for production machining, mold/die machining, and production turning. The company represents Johnford machining and turning centers, Argo Seiki drill tap centers, and You Ji vertical turning centers. It also offers a diverse range of previously-owned equipment.

In addition to delivering advanced metalworking solutions, Absolute Machine Tools has built its reputation on innovative preventive-maintenance programs and after-sale technical service. A nationwide network of regional distributors is in place to help North American manufacturers with their production needs.

For more about Absolute Machine Tools, its product lines, and services, visit www.absolutemachine.com or call (440) 960-6911.

Chapter 6

Moore Precision Tools

Data supplied by Ed Lockwood of Moore Precision Tools

FSP300X: High Speed 5 Axis Machining Center

Overview

The FSP300X is a machine of a portal-type nature and has been specifically designed from the ground up for high-speed cutting and maximum dynamic response at the cutting tool (see Figure 6-1). Excessive tool extensions and overhangs common to vertical spindle HSC machines are eliminated with this unique design, thereby improving work piece accuracy, surface finish, and throughput. Five-axis HSC capability is a standard feature allowing maximum utilization and return on investment. The rotary axes feature direct-drive technology for the ultimate in contouring speed and acceleration along with programmable axis clamps for conventional five-sided, three-axis machining. Productivity options for unmanned flexible or serial production are available via robotic part and tool changing systems. Infrared part probes are available optionally.

Machine Architecture

The machine is arranged as follows. The base carries the *Z* and *B*-axis slide and rotary swivel table. The *C*-axis vertical rotary table is in turn mounted to the *B*-axis rotary table. The portal type column and *X*-axis saddle are attached to the rear of the base. The vertical *Y*-axis slide carries the direct drive horizontal milling spindle and is attached to the *X*-axis saddle. The tool change carousel is attached to the base at the extreme left end of *X*-axis travel. Tool changes are carried out by spindle and carousel motion. Tool measurement and compensation are standard

Figure 6-1 The FSP300X High Speed 5-Axis Machining Center

via a Blum laser tool setter mounted to the *Z*-axis slide. Infrared part probes are available optionally.

Machine Structural Components

The base, column, and slides are manufactured from Class 40 Gray Cast Iron (40,000-PSI tensile strength). Precision surfaces are ground or hand scraped for a high degree of accuracy. All structural cast iron components are extra heavy, and ribbed for a high degree of machine stability and vibration damping.

Automatic Tool Changer

A Servo-controlled; random select, Automatic Tool Changer with 24-tool capacity is standard equipment. The HSK40E tools are easily loaded through an access door in the enclosure. The location of the tool changer eliminates tool and work piece interference as well as reducing chip and coolant contamination.

Spindle

The Moore FSP300X features a 10KW, (13.4 Horsepower), vector controlled, HSK40E Taper, Direct Drive, Precision Milling Spindle with power drawbar as standard equipment. The standard speed range for this configuration is 200–30,000 RPM. Temperature stabilization via a re-circulating liquid spindle chiller is provided as standard equipment. Moore Tool also offers HSK 40E spindles with up to 40,000 RPM as a standard option.

Rotary Swivel Table (*B*-Axis Horizontal)

The swivel table is integrated directly into the *Z*-axis slide with 230-degree total movement. The table features a direct drive torque motor with liquid cooling, high-resolution absolute encoder feedback and programmable ring type clamping via a hydraulic system. The rotary table is supported and guided on precision roller thrust and radial bearings.

Rotary Index Table (*C*-Axis Vertical)

The rotary table is mounted to the *B*-axis swivel table. The table features a direct drive torque motor with liquid cooling, high-resolution, absolute encoder feedback and programmable ring type clamping via hydraulics. The rotary table is supported and guided on precision roller thrust and radial bearings. The rotary table is furnished with an Erowa ITS power chucking and pallet system as a standard feature. Other clamping systems, along with conventional tabletops are available as options. Consult your Moore Tool representative with your requirements.

Tool Coolant Systems

The standard flood coolant system features multiple adjustable coolant nozzles that direct coolant on the work-piece at a rate of 10 GPM @ 80 PSI. A 150-PSI coolant through the spindle option is available to supplement the standard manifold mounted nozzles, as is servo-controlled tool coolant. A second 10 GPM pump is supplied as standard for wash down and chip flushing.

Also available are:

1. High power pumps for handling cutting oils
2. Oil/Air mist units for dry cutting
3. Graphite dust extraction systems (consult the factory)

Axes Drives and Way System

High-speed precision ground ball screws and pre-loaded nuts drive the *X*, *Y*, and *Z*-axes. These screw systems are specifically designed for HSC applications and provide excellent stiffness and response with minimal heat generation. Telescoping metal way covers protects the *Z*-axis ways. Armored bellows and roller-type shields protect the *X* and *Y*-axis ways. All axes are driven by a high gain digital servo system featuring brushless motors with ultra high-resolution feedback. All machine slides are guided on over-sized preloaded grease packed linear roller ways using longer, heavy duty bearing trucks, thus providing increased stiffness, damping, and a more rigid connection. The high-gain, closed-loop digital servo system allows for fast positioning feed-rates of 30,000 mm/min. and 1G+ acceleration on all axes.

Machine Cabin and Guarding

The cabin design totally isolates the machining area from the rest of the machine. The spindle nose only protrudes through a two-axis way cover system used for protecting the *X* and *Y*-axes. The cabin seals directly against the base flange, thereby ensuring against leakage. The large slide door can easily be opened and is designed to allow ease of crane access for part loading. Thanks to the short reach combined with available *B*-axis swivel motion, access to the work-zone is optimized for five axis setups. The cabin is standard with work-light and C.E. interlocks.

Control: Siemens 840D

The 840D is a modular control that is ideally suited for high performance 5-axes contouring. It is an all-digital solution including digital interface (parallel bus) to digital drives. The 840D employs an open system PC for HMI, communications, and custom applications. Its real time CNC kernel is its own CPU with a dedicated Pentium processor and housed in a module in the servo rack. The integrated PLC is from the Siemens Simatic family and is compatible with all Step 7 technology. The CNC highlights that follow are relevant to the 840D configuration of the Moore FSP 300X.

1. Number of axes: 6 + vector controlled spindle axis
2. Interpolated axes: 5
3. Spline interpolation
4. Helical interpolation
5. Polynomial interpolation (3rd and 5th degree)
6. Curve table interpolation
7. Standard canned milling and drilling cycles with graphical interface for editing cycle parameters

8. Ability to create custom cycles
9. Position feedback, all axes: absolute scales
10. Feedback resolution: 0.0001mm. Encoder count resolution >4Meg
11. Feedback resolution B & C: 0.0034 Degree
12. Inverse time feed
13. Direct time programming
14. Mechatronics diagnostics for high-speed performance
15. Automatic feed-rate management for stable, optimum cutting performance
16. Jerk limitation
17. Data smoothing
18. Corner rounding
19. Real time compressor function (transforms linear blocks into parametric polynomials)
20. Look Ahead: 300 blocks
21. 10.4" TFT color screen
22. Graphic support for programming and program simulation
23. PC processor speed: 566MHz/1.2GHz optional
24. Hard drive: >10GB
25. User part program memory for direct execution from RAM: 2.5MB
26. Program execution from external hard drive for virtually unlimited program size
27. Operating system: Windows NT/XP
28. Ethernet: built in
29. Real time 5-axes transformation with 5-axes tool compensation, oriented tool retraction (RETTOOL) and remote tool center point (RTCP)
30. Measuring cycles: Optional measuring cycles for work coordinate system alignment to work-piece
31. Advanced coordinate system setting functionality including variables of type "frame"
32. Robust G-code programming language
33. Powerful Basic-like macro language with user-defined variables (nesting 12 deep)
34. User defined macro substitutions (DEFINE Rapid AS G00)
35. Flexible and user-friendly block search

Laser Tool Setter

The FSP300X is furnished standard with a Blum Laser tool-setting system. This system allows non-contact tool length measurement with the spindle running at programmed speed. This system also allows measurement of tool radius, although spindle speed should be limited to under 3000 RPM while measuring. The laser optics are cleaned by compressed air automatically prior to each measuring cycle. Please note that the laser can determine length and diameter only. It cannot measure tool nose configuration.

Two Year Limited Warranty

Moore Tool Company backs its machining center products with a two-year limited warranty. The first year's warranty covers all parts, labor and travel. The second year warranty covers all parts, but excludes labor and travel. Moore Tool service engineers must install warranty parts covered during the second year for the warranty to remain valid. The milling spindle is warranted separately for one year, or 4000 hours, whichever occurs first, given normal and correct usage.

Custom Engineering and Turn-Keys

Moore Tool engineers can work to customize a Moore Machining Center to meet a customer's exacting manufacturing requirements. They can design and manufacture the dedicated tooling and fixturing to machine parts, develop part processing, recommend CAM systems, create the required part programs, and provide special automation and spindle options.

Standard Specifications

BASE	Class 40 Gray Iron
COLUMN	Class 40 Gray Iron
TABLE, SADDLE, SLIDE, ROTARY (X, Y, Z, B, C)	Class 40 Gray Iron
WAY SYSTEM (X, Y and Z)	Heavy preload re-circulating Anti-friction roller-ways
LUBRICATION	Grease
TRAVEL X-AXIS	370 mm : (14.57 inches)
TRAVEL Y-AXIS	320 mm (12.6 inches)

TRAVEL Z-AXIS	310 mm (12.20 inches)
TRAVEL B-AXIS	230° (25 + 180 + 25)
TRAVEL C- AXIS	Infinite
MAXIMUM PART SIZE (SWING)	300 mm Diameter × 200 mm Lg. (9.8Ó× 7.9Ó)
TABLE LOAD CAPACITY (Based upon automation. Consult the factory for higher weights.)	25 kg (55 lbs.)
B-AXIS CENTERLINE TO SPINDLE NOSE (Z- Axis)	100 mm Ð 410 mm (3.94 Ð16.14 inches)
SPINDLE (DIRECT DRIVE)	HSK 40E Nose
SPEED RANGE	200 Ð 30,000 RPM
POWER (VECTOR CONTROL)	10 KW, (13.4 HP)
TORQUE	4.0 NM, (35.4 Inch-LBS.)
LUBRICATION	Grease packed
COOLING METHOD (CHILLER)	Rated 20,000 btu/hr @90 degrees F.
ATC: TOOL CAPACITY	24 Tools
ATC: CHANGE TIME (tool-to-tool)	8 Seconds
ATC: METHOD OF TOOL SELECTION	Random/BI-direction
ATC: MAXIMUM TOOL DIAMETER	16 mm (0.62 inches)
ATC: MAXIMUM TOOL WEIGHT	1.5 kg (3.3 lbs.)
ATC: MAXIMUM TOOL LENGTH	150 mm (5.91 inches)
LASER TOOL SETTER: RED BEAM LASER	1mv/670 nm
MINIMUM TOOL DIAMETER	0.5 mm
REPEATABILITY	< +/– .005 mm (0.0002 Inches)
RAPID FEEDRATE (X, Y, Z axes)	(30,000 mm/Min) 1181 IPM
CONTOURING FEEDRATE (X, Y, Z axes)	(20,000 mm/Min) 787 IPM
MAXIMUM SPEED (B AXIS SWIVEL)	140 RPM
MAXIMUM SPEED (C AXIS ROTARY)	210 RPM
MAXIMUM AXIS ACCELERATION (X, Y, Z AXES)	16.6 m/sec^2 (1.7 G)
MAXIMUM AXIS ACCELERATION (B AXIS SWIVEL)	130 rad/sec^2
MAXIMUM AXIS ACCELERATION (C AXIS WORKHEAD)	300 rad/sec^2
FEEDBACK	Absolute linear scales

ENCLOSURE	CE Mark, includes work-light
PAINT SPECIFICATION	See graphics
FLOOR SPACE (w/Control)	2.7 m × 4.4 m, (8.9f × 14.4f.)
MACHINE HEIGHT	2.6m, (8.6f.)
FLOOD COOLANT	10 GPM @ 80 P.S.I
MACHINE WEIGHT	11,500 POUNDS
VOLTAGE REQUIREMENTS	400V Ð 3ph
POWER REQUIREMENT	55 KVA Maximum
AIR REQUIREMENTS	793 Liters/Minute Maximum

POSITIONING: DIN/ISO 230-2

POSITIONING UNCERTAINTY P: X, Y & Z-AXES	0.004 mm (0.00016 inches)
POSITIONING UNCERTAINTY PA: X, Y & Z-AXES	0.003 mm (0.00012 inches)
POSITIONING UNCERTAINTY P: B & C-AXES	10 Arc Seconds
POSITIONING UNCERTAINTY PA: B & C-AXES	5 Arc Seconds

GEOMETRY:

STRAIGHTNESS: X, Y & Z-AXES	0.005 mm (0.0002 inches)
SQUARENESS: XY, XZ, & YZ-AXES	0.0076 mm (0.0003 inches)

Optional Features

ITEM 002: High Speed Spindle Option HSK 40E

SPINDLE	HSK 40E Nose
SPEED RANGE	200 Ð 40,000 RPM
POWER (VECTOR CONTROL)	10KW, (13.4 HP)
TORQUE	4 NM, (35.4 IN-Lbs.)
LUBRICATION	Air Oil Injection
COOLING METHOD	Liquid refrigeration

ITEM 003: High Capacity Robotic Part Loader

The price is additional to provide a robotic part changing system. The loader will be capable of changing Erowa ITS type part pallets, 148mm diameter. Alternate tooling configurations from System 3R are also available. The loader must be ordered with item #4.

Maximum part storage positions = 18
Maximum part size = 250mm diameter × 200mm height (9.8 in. × 7.8in.)
Maximum part weight = 23Kg (50 lbs.) (Note: The loader can be configured for additional parts depending upon sizes. Custom automation solutions are also available.)

ITEM 004: Automation Ready

The price is additional to supply a power door in lieu of the standard viewing window at the front of the machine. Price includes pneumatic actuator and solenoid valve.

ITEM 005: 44 Position Tool Changer

The price is additional to provide a vertical chain type magazine with fork-type double-ended exchange arm in lieu of the standard 24 position drum unit.

ITEM 006: Infrared Part Probe

The price is additional to provide infrared part probe suitable for HSK 40E tool holder. Price includes all machine and control modifications along with standard Renishaw cycles.

ITEM 007: Credit to Delete Erowa ITS Pallet System from C Axis R/T

A ground steel work-holding disk, complete with centering pilot and attachment holes Ø8.5/M10. is provided in lieu of the chucking system.

Please note that ITS pallet system can be field retrofitted at a later date. Price upon request.

ITEM 008: Pallet ITS 148 (for C Axis Rotary Table)

The EROWA stainless steel pallet with 148 mm diameter base and 40 mm of height includes attachment holes Ø8.5/M10. Centering plates and chucking spigots are already mounted.

Note: Correct function and accuracy of the ITS power chuck is guaranteed only when using this pallet.

Chips/Coolant Options

ITEM 009: High Pressure Coolant

150 P.S.I.: Includes lift-up chip conveyor, full machine enclosure (already included in standard pricing), and a 55-gallon capacity coolant tank.

ITEM 010: Temperature-Controlled Flood Coolant

When seeking to maintain part tolerances equal to, or better than, ±0.0005, it is highly recommended that temperature-controlled flood coolant be considered. A high-powered refrigeration unit is coupled to the flood coolant tank via a wound heat transfer coil. The refrigeration unit is set to an absolute temperature setting and works to maintain a constant temperature within the flood coolant tank. The exact level of temperature stability provided by this system is dependent upon the heat load created during cutting. The temperature control system is sized to the tank capacity and operates as long as power is applied to the electric cabinet of the machine. The system also incorporates overhead coolant nozzles in the work zone for further stabilization of the cutting process. Machine power does not need to be on for the system to be operational.

Note: Must be purchased in conjunction with Item 009.

ITEM 011: Micro-Lubrication System

A special air/oil cutting fluid application system provides a low volume of mist to the work surface. Ideal as a lubricant for hard steel milling.

ITEM 012: Oil Coolant Delivery System

Consists of modifications to the coolant delivery system to enable cutting oil, rather than water-based coolant, to be effectively delivered to the work area.

ITEM 013: Lift Up Chip Conveyor

Consists of modifications to the coolant system to provide lift up chip conveyor. The conveyor will run in the *X*-axis direction and discharge on the left side.

ITEM 014: Mist Collector

Smoke and mist removal: Includes mist collector, mounting, and all machine modifications.

ITEM 015: Graphite Protection Package

Dust and graphite protection includes:

1. Torit Donaldson Model Downflo® high performance cartridge collector complete with the following features:
   - 1290 CFM
   - 3 Ultra-Web™ filter cartridges, factory installed (570 sq. ft.)
   - Arranged for use with 10 gallon pail, (container included)
   - Fractional efficiency: (99.999+% @ .5 micron)
   - Blower & damper with 5 HP TEFC Motor; 208-230-460/3/60
   - Built-in exhaust silencer; collector rated 68 dB(A)
   - 12 gauge construction
   - Minihelic filter cleaning gauge factory installed
   - Automatic downtime cleaning
   - Extra Life pulse-jet cleaning system requires only 60 psig
2. Stainless steel dust box with rotary joint swivels with the *C*-axis rotary table
3. Hose and enclosure modifications
4. Bellows covers for the *Z* axis are provided in lieu of the hard covers

ITEM 016: Transformer

Step-up transformer: 400vac, 60hz to 460vac, 60hz. The transformer is rated for 55 KVA. Mounting location is on top of the electrical cabinet.

Additional Considerations

Delivery

12–16 weeks based upon present commitments and configuration of options. Delivery to be confirmed at time of order.

Training

Moore Tool will supply up to 40 hours of operator and maintenance training, (five days @ eight hours each), free of charge at its facility for up to two people.

Installation

The customer is responsible for installation, leveling, cleaning, and all service connections. Upon completion of installation, a Moore Tool service representative will commission the machine, verify proper function, and provide two days of on-site training to operator and maintenance personnel.

Service and Spare Parts

Available from the Moore Tool Company, Inc., Bridgeport, Connecticut.

Prices Quoted

F.O.B. Moore's Plant – Bridgeport, CT.

Terms and Conditions

Net 30 Days on all payments except down payment.
Progress Payments as Follow:

40% Down payment with order.
50% Upon shipment from Moore Tool.
10% Upon acceptance at Company Name not to exceed 60 days from Shipment.

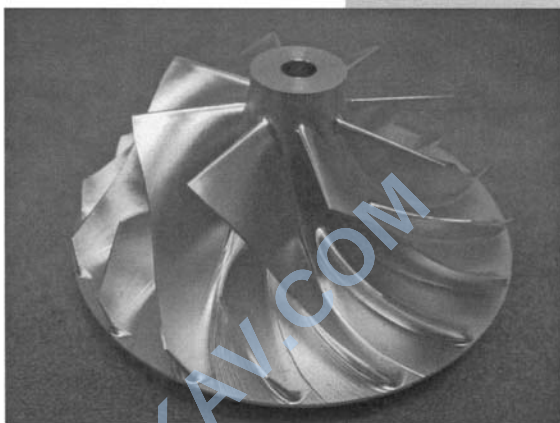
In case of error, bidder reserves the right to re-evaluate quotation. This quotation is valid for 60 days and may be subject to change thereafter.

Case Studies

The remainder of this chapter includes a variety of case studies. Figure 6-2 covers a 108-mm aluminum impeller. Figure 6-3 features a hip. The subject of Figure 6-4 is an aluminum lid-mold for food packaging. Figure 6-5 focuses on an Invar steel precision insert. Figure 6-6 looks at a neck mold. Figure 6-7 covers an aluminum mold for a food container. Figures 6-8 and 6-9 look at a jig and a 10" diameter aluminum impeller respectively. A compressor scroll is the subject of Figure 6-10. Figure 6-11 features a hardened bottle mold. Figure 6-12 focuses on a 120-mm titanium impeller. Finally, Figure 6-13 features a bevel gear forging die.

high-speed machining systems

FSP 300X 5 Axis



Case Study: 108 mm Aluminum Impeller

Material: Forged Aluminum

Operation	Cutter	Spindle Speed	Feed Rate	Op Time
Tool 1	0.125", 2 Flute 10° Tapered End Mill	31,000	216	4 Min.
Tool 2	0.125", 2 Flute 5° Tapered End Mill	39,000	216	32 Min.
Tool 3	0.0625", 2 Flute 5° Tapered End Mill	39,000	216	8 Min.

Total Cycle Time: 44 Minutes

Figure 6-2 108 mm Aluminum Impeller

FSP 300X

specifications

Capacity	
Travel X axis	400 mm (15.74 inches)
Travel Y axis	320 mm (12.60 inches)
Travel Z axis	310 mm (12.20 inches)
Travel B axis	230 degrees (25+180+25)
Travel C axis	Infinite
B axis centerline to spindle nose (Z axis)	100 mm to 400 mm (3.94 - 15.75 in.)
Table Load	27 kg (60 lbs.)
Maximum Swing (C axis rotary)	300 mm (11.81 inches)

Speeds and feeds	
Speed range	200 to 30,000 rpm
Spindle speed	10KW 13.4 HP
Maximum speed (B axis swivel)	140 rpm
Maximum speed (C axis rotary)	210 rpm
Rapid feedrate (X, Y, & Z axes)	30,000 mm/min. (1181 IPM)
Contouring feedrate (X, Y, & Z axes)	20,000 mm/min. (787 IPM)
Maximum axis acceleration (X, Y, & Z axes)	16.6 m/sec^2 (1.7 G)
Maximum axis acceleration (B axis swivel)	130 rad/sec^2
Maximum axis acceleration (C axis workhead)	300 rad/sec^2

Accuracy	
Positioning: DIN/ISO 230-2	
Positional uncertainty P: X, Y, & Z axes	0.004 mm (0.00016 inches)
Positional uncertainty P: B & C axes	10 arc seconds
Positional uncertainty PA: X, Y, & Z axes	0.003 mm (0.00012 inches)
Positional uncertainty PA: B & C axes	5 arc seconds
Geometric: Straightness	
X, Y & Z axes	0.005 mm (0.0002 inches)
Geometric: Squareness	
XY, XZ & YZ axes	0.0076 mm (0.0003 inches)

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Figure 6-2 (Continued)

Figure 6-3 Hip

high-speed machining systems

FSP 300X 5 Axis

Case Study: Aluminum Lid-Mold for Food Packaging

Program ID	Extension	Tool Ball	Taper	Spindle Speed	Cutting Feed
Mold_Roughing	1.75	0.5	0	32,000	330
Semi_Fin_Mid	1.0	0.25	0	35,000	275
Finish	1.0	0.125	0	38,000	275
Moore Logo	1.0	0.125	0	38,000	60

- **Material: 6061 Aluminum Block**
- **Size: 50 mm x 185 mm x 240 mm**

Total cutting time for complete mold:
1 Hours 20 Minutes

Figure 6-4 Mold

FSP 300X

specifications

Capacity

Travel X axis	400 mm (15.74 inches)
Travel Y axis	320 mm (12.60 inches)
Travel Z axis	310 mm (12.20 inches)
Travel B axis	230 degrees (25 + 180 + 25)
Travel C axis	Infinite
B axis centerline to spindle nose (Z axis)	100 mm to 400 mm (3.94 – 15.75 in.)
Table Load	27 kg (60 lbs.)
Maximum Swing (C axis rotary)	300 mm (11.81 inches)

Speeds and feeds

Speed range	200 to 30,000 rpm
Spindle speed	10KW 13.4 HP
Maximum speed (B axis swivel)	140 rpm
Maximum speed (C axis rotary)	210 rpm
Rapid feedrate (X, Y, & Z axes)	30,000 mm/min. (1181 IPM)
Contouring feedrate (X, Y, & Z axes)	20,000 mm/min. (787 IPM)
Maximum axis acceleration (X, Y, & Z axes)	16.6 m/sec^2 (1.7 G)
Maximum axis acceleration (B axis swivel)	130 rad/sec^2
Maximum axis acceleration (C axis workhead)	300 rad/sec^2

Accuracy

Positioning: DIN/ISO 230-2	
Positional uncertainty P: X, Y, & Z axes	0.004 mm (0.00016 inches)
Positional uncertainty P: B & C axes	10 arc seconds
Positional uncertainty PA: X, Y, & Z axes	0.003 mm (0.00012 inches)
Positional uncertainty PA: B & C axes	5 arc seconds
Geometric: Straightness	
X, Y & Z axes	0.005 mm (0.0002 inches)
Geometric: Squareness	
XY, XZ & YZ axes	0.0076 mm (0.0003 inches)

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Figure 6-4 (Continued)

high-speed machining systems

FSP 300X 5 Axis

Case Study: Invar Steel Precision Insert

Program ID	Extension	Tool Ball	Taper	Spindle Speed	Cutting Feed
First Roughing	25.400	6.0	15°	10,000	700 mm/min
Semi Finish Mid	25.400	3.0	0	15,000	600 mm/min
Finish	25.400	1.0	0	35,000	800 mm/min

- **Material: Invar Steel**

Total cutting time for complete insert: *55 Minutes*

Figure 6-5 Invar Steel Precision Insert

FSP 300X

specifications

Capacity

Travel X axis	420 mm (16.54 inches)
Travel Y axis	320 mm (12.60 inches)
Travel Z axis	310 mm (12.20 inches)
Travel B axis	230 degrees (25 + 180 + 25)
Travel C axis	Infinite
B axis centerline to spindle nose (Z axis)	100 mm to 400 mm (3.94 – 15.75 in.)
Table Load	27 kg (60 lbs.)
Maximum Swing (C axis rotary)	300 mm (11.81 inches)

Speeds and feeds

Speed range	200 to 30,000 rpm
Spindle speed	10KW 13.4 HP
Maximum speed (B axis swivel)	140 rpm
Maximum speed (C axis rotary)	210 rpm
Rapid feedrate (X, Y, & Z axes)	30,000 mm/min. (1181 IPM)
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Maximum axis acceleration (X, Y, & Z axes)	16.6 m/sec^2 (1.7 G)
Maximum axis acceleration (B axis swivel)	130 rad/sec^2
Maximum axis acceleration (C axis workhead)	300 rad/sec^2

Accuracy

Positioning: DIN/ISO 230-2	
Positional uncertainty P: X, Y, & Z axes	0.004 mm (0.00016 inches)
Positional uncertainty P: B & C axes	10 arc seconds
Positional uncertainty PA: X, Y, & Z axes	0.003 mm (0.00012 inches)
Positional uncertainty PA: B & C axes	5 arc seconds
Geometric: Straightness	
X, Y & Z axes	0.005 mm (0.0002 inches)
Geometric: Squareness	
XY, XZ & YZ axes	0.0076 mm (0.0003 inches)

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Figure 6-5 (Continued)

Figure 6-6 Neck Mold

high-speed machining systems

FSP 300X 5 Axis

Customer Part: Aluminum Mold for Food Container

Customer cycle time using convention milling machine:

- Hole pattern: setup and machining 1 hour
- Roughing & finishing features: setup and machining 6 hours
- Polishing: 2 hours

Total Time - 9 hours

Moore FSP 300X:

- Hole pattern: Drilled 60 5/8's deep holes in 50 seconds complete.
- Roughing & finishing: 3 hours 4 minutes
- Polishing: 15 minutes

Total Time - 3 hours 20 minutes

Total cutting time for complete mold:
3 Hours 5 Minutes

Figure 6-7 Aluminum Mold for Food Container

FSP 300X

specifications

Capacity	
Travel X axis	400 mm (15.74 inches)
Travel Y axis	320 mm (12.60 inches)
Travel Z axis	310 mm (12.20 inches)
Travel B axis	230 degrees (25 + 180 + 25)
Travel C axis	Infinite
B axis centerline to spindle nose (Z axis)	100 mm to 400 mm (3.94 – 15.75 in.)
Table Load	27 kg (60 lbs.)
Maximum Swing (C axis rotary)	300 mm (11.81 inches)

Speeds and feeds	
Speed range	200 to 30,000 rpm
Spindle speed	10KW 13.4 HP
Maximum speed (B axis swivel)	140 rpm
Maximum speed (C axis rotary)	210 rpm
Rapid feedrate (X, Y, & Z axes)	30,000 mm/min. (1181 IPM)
Contouring feedrate (X, Y, & Z axes)	20,000 mm/min. (787 IPM)
Maximum axis acceleration (X, Y, & Z axes)	16.6 m/sec^2 (1.7 G)
Maximum axis acceleration (B axis swivel)	130 rad/sec^2
Maximum axis acceleration (C axis workhead)	300 rad/sec^2

Accuracy	
Positioning: DIN/ISO 230-2	
Positional uncertainty P: X, Y, & Z axes	0.004 mm (0.00016 inches)
Positional uncertainty P: B & C axes	10 arc seconds
Positional uncertainty PA: X, Y, & Z axes	0.003 mm (0.00012 inches)
Positional uncertainty PA: B & C axes	5 arc seconds
Geometric: Straightness	
X, Y & Z axes	0.005 mm (0.0002 inches)
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XY, XZ & YZ axes	0.0076 mm (0.0003 inches)

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Figure 6-7 (Continued)

Moore 300X & 500 CPWZ

Case Study

This precision jig ground inspection gear is used in the manufacturing process for memory storage devices. The part is manufactured complete at Moore's Precision Manufacturing Center located in Bridgeport.

300X

- Rotary axis used to generate ID's and OD's.
- 5 Axis used for generating tool path on gear teeth.

Time savings: 9 Hours and 20 Minutes.

Machining Center **(Old)** - 10 Hours

Moore 300X **(New)** - 40 Minutes

500 CPWZ

- ID's and OD's jig ground. Tolerances held below 2,0 microns.
- Gear shape ground using Moore Slot Grinder with Moore Variable Speed Dressing Unit.
- Part rotated using a Moore A-Axis Rotary Table.
- Position of teeth held below 5 Arc Seconds.

Figure 6-8 Jig

high-speed machining systems

FSP 300X 5 Axis

Case Study: 10" Diameter Aluminum Impeller

Program ID	Extension	Tool Ball	Taper	Spindle Speed	Cutting Feed
Roughing Shallow	1.75	0.5	0	38,000	282
Reduce Fillet	2.25	0.3125	5	36,000	230
Roughing Deep	2.25	0.3125	5	39,000	225
Blade Semi-Finish	2.25	0.3125	5	24,000	218
Hub Semi-Finish	2.25	0.3125	5	38,000	190
Hub Finish	2.25	0.3125	5	40,000	240
Blade Finish	2.25	0.3125	5	27,000	216

Total cutting time for complete impeller:
2 Hours 55 Minutes

Figure 6-9 10ÓDiameter Aluminum Impeller

FSP 300X

specifications

Capacity

Travel X axis	400 mm (15.74 inches)
Travel Y axis	320 mm (12.60 inches)
Travel Z axis	310 mm (12.20 inches)
Travel B axis	230 degrees (25 + 180 + 25)
Travel C axis	Infinite
B axis centerline to spindle nose (Z axis)	100 mm to 400 mm (3.94 – 15.75 in.)
Table Load	27 kg (60 lbs.)
Maximum Swing (C axis rotary)	300 mm (11.81 inches)

Speeds and feeds

Speed range	200 to 30,000 rpm
Spindle speed	10KW 13.4 HP
Maximum speed (B axis swivel)	140 rpm
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Rapid feedrate (X, Y, & Z axes)	30,000 mm/min. (1181 IPM)
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Maximum axis acceleration (X, Y, & Z axes)	16.6 m/sec^2 (1.7 G)
Maximum axis acceleration (B axis swivel)	130 rad/sec^2
Maximum axis acceleration (C axis workhead)	300 rad/sec^2

Accuracy

Positioning: DIN/ISO 230-2	
Positional uncertainty P: X, Y, & Z axes	0.004 mm (0.00016 inches)
Positional uncertainty P: B & C axes	10 arc seconds
Positional uncertainty PA: X, Y, & Z axes	0.003 mm (0.00012 inches)
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Geometric: Straightness	
X, Y & Z axes	0.005 mm (0.0002 inches)
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XY, XZ & YZ axes	0.0076 mm (0.0003 inches)

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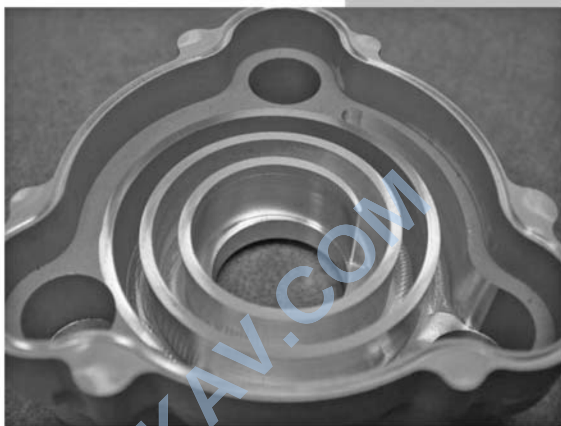
Figure 6-9 (Continued)

high-speed machining systems

FSP 300X 5 Axis



Case Study: Compressor Scroll

Material: 6061-T6 Aluminum

Operation	Cutter	Spindle Speed	Feed Rate	Op Time
Tool 1	3/8", 4 Flute Carbide End Mill	18,000	216	0.9 Min.
Tool 2	5/32", 4 Flute HSSC End Mill	16,500	132	1.8 Min.
Tool 3	1 mm, 2 Flute Carbide End Mill	40,000	56	1.3 Min.
Tool 4	3,2 mm, Carbide Drill	36,000	113	0.34 Min.
Tool 5	5 mm, Carbide Drill	23,000	127	0.26 Min.

Total Cycle Time: 4.6 Minutes

Figure 6-10 Compressor Scroll

FSP 300X

specifications

Capacity

Travel X axis	400 mm (15.74 inches)
Travel Y axis	320 mm (12.60 inches)
Travel Z axis	310 mm (12.20 inches)
Travel B axis	230 degrees (25 + 180 + 25)
Travel C axis	Infinite
B axis centerline to spindle nose (Z axis)	100 mm to 400 mm (3.94 – 15.75 in.)
Table Load	27 kg (60 lbs.)
Maximum Swing (C axis rotary)	300 mm (11.81 inches)

Speeds and feeds

Speed range	200 to 30,000 rpm
Spindle speed	10KW 13.4 HP
Maximum speed (B axis swivel)	140 rpm
Maximum speed (C axis rotary)	210 rpm
Rapid feedrate (X, Y, & Z axes)	30,000 mm/min. (1181 IPM)
Contouring feedrate (X, Y, & Z axes)	20,000 mm/min. (787 IPM)
Maximum axis acceleration (X, Y, & Z axes)	16.6 m/sec^2 (1.7 G)
Maximum axis acceleration (B axis swivel)	130 rad/sec^2
Maximum axis acceleration (C axis workhead)	300 rad/sec^2

Accuracy

Positioning: DIN/ISO 230-2	
Positional uncertainty P: X, Y, & Z axes	0.004 mm (0.00016 inches)
Positional uncertainty P: B & C axes	10 arc seconds
Positional uncertainty PA: X, Y, & Z axes	0.003 mm (0.00012 inches)
Positional uncertainty PA: B & C axes	5 arc seconds
Geometric: Straightness	
X, Y & Z axes	0.005 mm (0.0002 inches)
Geometric: Squareness	
XY, XZ & YZ axes	0.0076 mm (0.0003 inches)

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Figure 6-10 (Continued)

high-speed machining systems

FSP 300X 5 Axis

Case Study: Hardened Bottle Mold

Material: S7 Tool Steel - 52-54 Rc

Operation	Cutter	Spindle Speed	Feed Rate	Op Time
Rough Cavity	10 mm 2 Flute Ball End Mill	7,000	1050	14 Minutes
Semi-Finish	3 mm 2 Flute Ball End Mill	22,000	1540	32 Minutes
Finish	2 mm 2 Flute Ball End Mill	34,000	1530	67 Minutes

Total Cycle Time: 110 Minutes

Figure 6-11 Hardened Bottle Mold

high-speed machining systems

FSP 300X 5 Axis

Case Study: 120 mm Titanium Impeller

Material: Forged Titanium

Operation	Cutter	Spindle Speed	Feed Rate	Op Time
Tool 1	0.1562", 2 Flute Tapered End Mill	14,000	98	39 Min.
Tool 2	0.125", 2 Flute 5° Tapered End Mill	17,500	118	32 Min.
Tool 3	0.125", 2 Flute 5° Tapered End Mill	26,000	160	76 Min.
Tool 4	0.0625", 2 Flute 5° Tapered End Mill	36,000	132	14 Min.

Total Cycle Time: 161 Minutes

Figure 6-12 120-mm Titanium Impeller

FSP 300X

specifications

Capacity

Travel X axis	400 mm (15.74 inches)
Travel Y axis	320 mm (12.60 inches)
Travel Z axis	310 mm (12.20 inches)
Travel B axis	230 degrees (25 + 180 + 25)
Travel C axis	Infinite
B axis centerline to spindle nose (Z axis)	100 mm to 400 mm (3.94 – 15.75 in.)
Table Load	27 kg (60 lbs.)
Maximum Swing (C axis rotary)	300 mm (11.81 inches)

Speeds and feeds

Speed range	200 to 30,000 rpm
Spindle speed	10KW 13.4 HP
Maximum speed (B axis swivel)	140 rpm
Maximum speed (C axis rotary)	210 rpm
Rapid feedrate (X, Y, & Z axes)	30,000 mm/min. (1181 IPM)
Contouring feedrate (X, Y, & Z axes)	20,000 mm/min. (787 IPM)
Maximum axis acceleration (X, Y, & Z axes)	16.6 m/sec^2 (1.7 G)
Maximum axis acceleration (B axis swivel)	130 rad/sec^2
Maximum axis acceleration (C axis workhead)	300 rad/sec^2

Accuracy

Positioning: DIN/ISO 230-2	
Positional uncertainty P: X, Y, & Z axes	0.004 mm (0.00016 inches)
Positional uncertainty P: B & C axes	10 arc seconds
Positional uncertainty PA: X, Y, & Z axes	0.003 mm (0.00012 inches)
Positional uncertainty PA: B & C axes	5 arc seconds
Geometric: Straightness	
X, Y & Z axes	0.005 mm (0.0002 inches)
Geometric: Squareness	
XY, XZ & YZ axes	0.0076 mm (0.0003 inches)

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Figure 6-12 (Continued)

high-speed machining systems

FSP 300X 5 Axis

Case Study: Bevel Gear Forging Die

Material: Tool Steel Hardened to 60 Hrc

Operation	Cutter	Spindle Speed	Feed Rate	Op Time
Tool 1	10 mm, 4 Flute Carbide End Mill	2,800	1,400	16 Min.
Tool 2	8 mm, 4 Flute Carbide End Mill	3,700	1,512	24 Min.
Tool 3	6 mm, 4 Flute Carbide End Mill	5,100	2,100	38 Min.
Tool 4	3 mm, 2 Flute Carbide Ball End Mill	15,000	1,500	32 Min.
Tool 5	2 mm, 2 Flute Carbide Ball End Mill	22,000	2,800	66 Min.
Tool 6	1 mm, 2 Flute Carbide Ball End Mill	39,000	1,900	155 Min.

Total Cycle Time: 5.5 Hours

Figure 6-13 Bevel Gear Forging Die

FSP 300X

specifications

Capacity

Travel X axis	400 mm (15.74 inches)
Travel Y axis	320 mm (12.60 inches)
Travel Z axis	310 mm (12.20 inches)
Travel B axis	230 degrees (25 + 180 + 25)
Travel C axis	Infinite
B axis centerline to spindle nose (Z axis)	100 mm to 400 mm (3.94 – 15.75 in.)
Table Load	27 kg (60 lbs.)
Maximum Swing (C axis rotary)	300 mm (11.81 inches)

Speeds and feeds

Speed range	200 to 30,000 rpm
Spindle speed	10KW 13.4 HP
Maximum speed (B axis swivel)	140 rpm
Maximum speed (C axis rotary)	210 rpm
Rapid feedrate (X, Y, & Z axes)	30,000 mm/min. (1181 IPM)
Contouring feedrate (X, Y, & Z axes)	20,000 mm/min. (787 IPM)
Maximum axis acceleration (X, Y, & Z axes)	16.6 m/sec^2 (1.7 G)
Maximum axis acceleration (B axis swivel)	130 rad/sec^2
Maximum axis acceleration (C axis workhead)	300 rad/sec^2

Accuracy

Positioning: DIN/ISO 230-2	
Positional uncertainty P: X, Y, & Z axes	0.004 mm (0.00016 inches)
Positional uncertainty P: B & C axes	10 arc seconds
Positional uncertainty PA: X, Y, & Z axes	0.003 mm (0.00012 inches)
Positional uncertainty PA: B & C axes	5 arc seconds
Geometric: Straightness	
X, Y & Z axes	0.005 mm (0.0002 inches)
Geometric: Squareness	
XY, XZ & YZ axes	0.0076 mm (0.0003 inches)

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Figure 6-13 (Continued)

Chapter 7

Heartech Precision Inc., Advanced Tooling Systems

By Dave Mann, HPI Sales

What Are the Essentials for Accurate and Rigid Tool Holders?

Taper contact, run out, and balance are essential for tool holders that are accurate and rigid.

Taper Contact

Taper contact is the percentage of contact between the spindle of the machine and the taper of the tool holder. It is the most important element in accuracy and rigidity of the tool holder. Figure 7-1 magnifies the error on the taper.

Figure 7-2 shows a typical taper fitment, including the machine spindle and the tool holder shank. The figure indicates the allowable allowances for both the spindle and the tool. Taper error can be measured by a taper gauge, an air gauge, a roundness tester, and a CMM machine.

Figure 7-3 shows various taper contact percentages, highlighting the contact for AT3.

Run Out

Your target for run out should be 0.0002" or better at the cutter edge (see Figures 7-4 and 7-5).

Balance

Balancing is a critical part of holder manufacturing. Balancing a holder requires some type of material removal like drilling, milling,

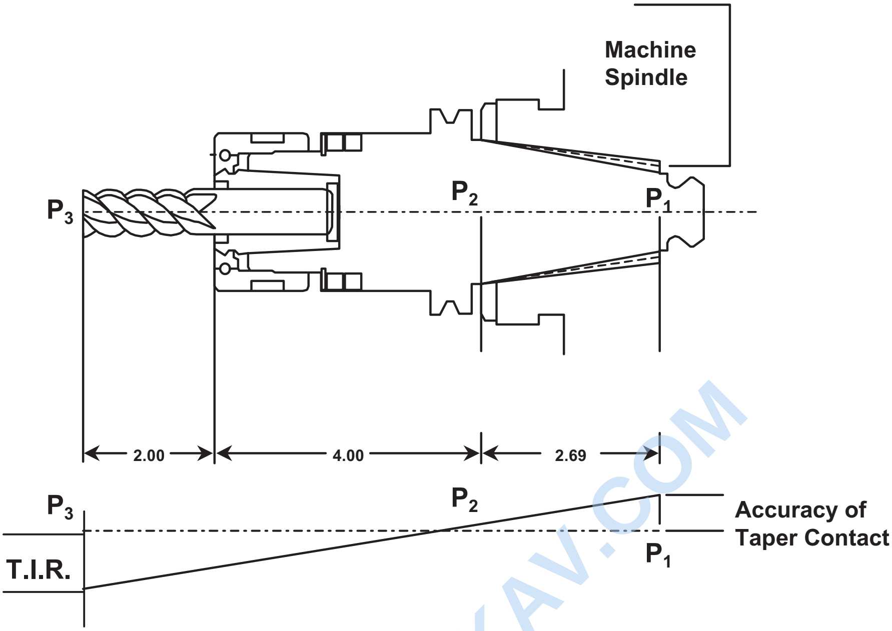


Figure 7-1

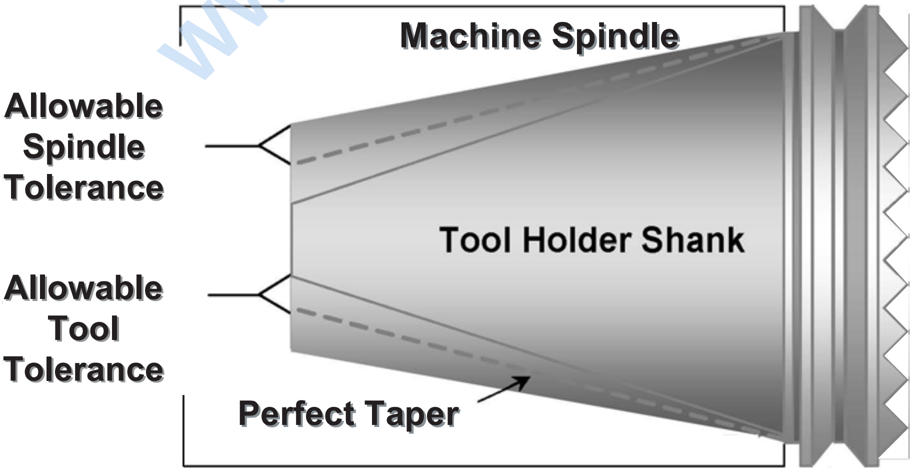


Figure 7-2

Taper	Length	AT1	AT2	AT3	AT4	AT5
30	[1.875Ó]	[.000039]	[.000060]	[.000009Ó]	[.000015]	[.000024Ó]
	47,63mm	0,0010	0,0015	0.0023mm	0,0038	0.0061 mm
40	[2.687Ó]	[.000043]	[.000068]	[.000011Ó]	[.000017]	[.000027Ó]
	68,25mm	0,0011	0,0017	0.0028mm	0,0043	0.0069 mm
45	[3.250Ó]	[.000053]	[.000082]	[.00013Ó]	[.00020]	[.00033Ó]
	82,55mm	0,0013	0,0021	0.0033mm	0,0051	0.0084 mm
50	[4.000Ó]	[.000065]	[.000080]	[.00013Ó]	[.00020]	[.00032Ó]
	101,60mm	0,0017	0,0020	0.0033mm	0,0051	0.0081 mm
60	[6.375Ó]	[.00006]	[.00010]	[.00016Ó]	[.00026]	[.00040Ó]
	161,93mm	0,0016	0,0026	0.0040mm	0,0065	0.0102 mm

Figure 7-3

or grinding. It is a good idea to balance holders that exceed 4000 RPM. By doing this, you will extend the life of your spindle and get better surface finishes. DM

WHAT IS UNBALANCE?

Unbalance is a condition that exists when the mass axis of a rotor does not coincide with the rotational axis (see Figure 7-6). Unbalanced can be caused by three major factors: flaws in the base material, poor tolerances during fabrication, and asymmetrical tool holder design.

Figure 7-4

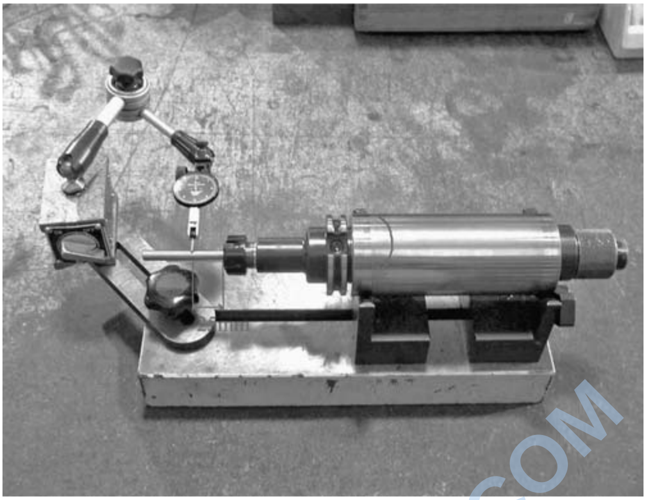


Figure 7-5

Flaws in the base material include pores, seams, and porosity. All of these result in unbalance and structure weakness. Poor tolerances during fabrication represent any machining performed on the tool holder that diminishes the absolute concentricity about the rotational axis. Examples include unmachined portions of the forging, out of roundness, and improper placement of through holes. Finally, any offsetting weight that is not countered by an equal, opposite force can cause unbalance.

Figure 7-7 shows where the holder is out of balance. In this example, the unbalance mass would have to be removed. The basic calculation

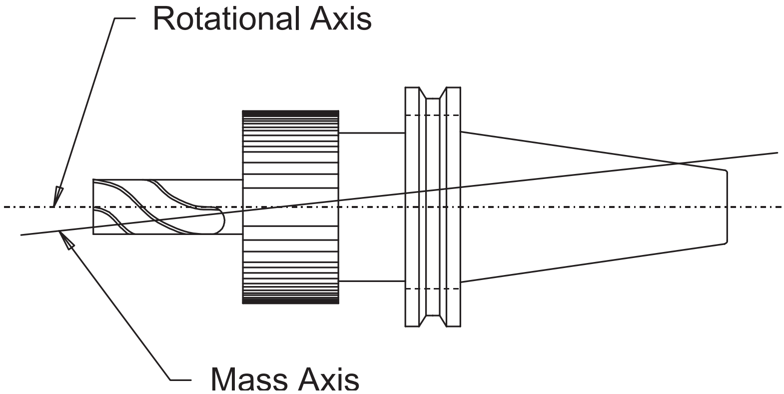


Figure 7-6

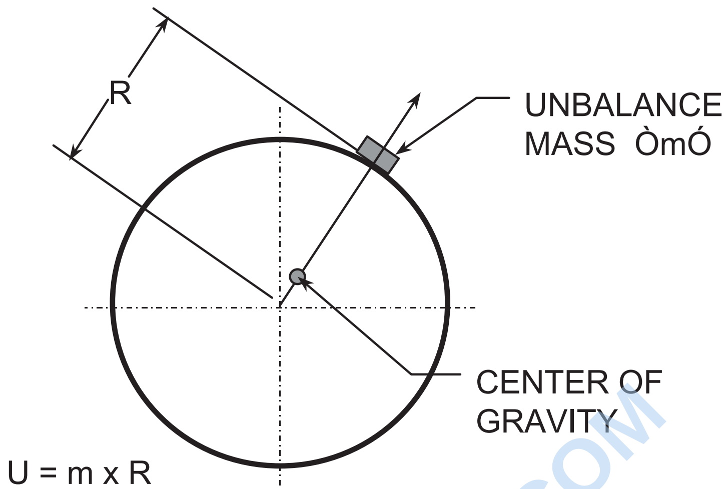


Figure 7-7

for unbalance is U = m * R, where U is unbalance, m is unbalance mass, and R is the radius. For instance, if the unbalance mass m is 1 gram (gm) and the radius R is 1 millimeter (mm), then unbalance is calculated as

$$U = m * R = 1 \text{ gm} * 1 \text{ mm} = 1 \text{ gm-mm}$$

Figure 7-8 considers representative rigid rotors and summarizes their balance quality grades.

Calculating Unbalance: An Example

Suppose we want to calculate the allowable unbalance for a #40 tool taper holder, with assembly at 8,000 rpm and 20,000 rpm. The general expression is:

$$U = \frac{G \times 9549 \times W}{RPM}$$

where:

U is the allowable unbalance in g.mm.
G is the standard for balance quality of rotating rigid bodies. (For machine tool drives it is G 2.5).
W is tool holder assembly weight in (kg). The example chuck has a weight of 2.75 kg.
9549 is a constant.
RPM is our rotational speed.

ANSI S2.1901989

Balance Quality Grades for Various Groups of Representative Rigid Rotors

Balance Quality Grade	Product of the relationship ($e_{per} \times w$)[1), 2)] mm/s	
G4 000	4 000	Crankshaft/drives[3)] of rigidly mounted slow marine diesel engines with uneven number of cylinders[4)]
G1 600	1 600	Crankshaft/drives of rigidly mounted large two-cycle engines
G630	630	Crankshaft/drives of rigidly mounted large four-cycle engines Crankshaft/drives of elastically mounted marine diesel engines
G250	250	Crankshaft/drives of rigidly mounted fast four-cylinder diesel engines[4)]
G100	100	Crankshaft/drives of fast diesel engines with six or more cylinders[4)] Complete engines (gasoline or diesel) for cars, trucks and locomotives[5)]
G40	40	Car wheels, wheel rims, wheel sets, drive shafts Crankshaft/drives of elastically mounted fast four-cycle engines (gasoline or diesel) with six or more cylinders 4) Crankshaft/drives of engines of cars, trucks and locomotives
G16	16	Drive shafts (propeller shafts, cardan shafts) with special requirements Parts of crushing machines Parts of agricultural machinery Individual components of engines (gasoline or diesel) for cars, trucks and locomotives Crankshaft/drives of engines with six or more cylinders under special requirements
G6,3	6,3	Parts of process plant machines Marine main turbine gears (merchant service) Centrifuge drums Paper machinery rolls; print rolls Fans Assembled aircraft gas turbine rotors Flywheels Pump impellers Machine-tool and general machinery parts Medium and large electric armatures (of electric motors having at least 80 mm shaft height) without special requirements Small electric armatures, often mass produced, in vibration insensitive applications and/or with vibration-isolating mountings Individual components of engines under special requirements
G2,5	2,5	Gas and steam turbines, including marine main turbines (merchant service) Rigid turbo-generator rotors Computer memory drums and discs Turbo-compressors Machine-tool drives Medium and large electric armatures with special requirements Small electric armatures not qualifying for one or both of the conditions specified for small electric armatures of balance quality grade G6,3 Turbine-driven pumps
G1	1	Tape recorder and phonograph (gramophone) drives Grinding-machine drives Small electric armatures of precision grinders
G0,4	0,4	Spindles, discs, and armatures with special requirements Gyroscopes

1) $w = 2\pi n / 60 \approx$ if n is measured in revolutions per minute and w in radians per second
2) For allocating the permissible residual unbalance to correction planes, see clause 7
3) A crankshaft/drive is an assembly which includes a crankshaft, flywheel, clutch, pulley, vibration damper, rotating portion of connecting rod, etc.
4) For the purposes of this part of ISO 1940, slow diesel engines are those with a piston velocity of less than 9 m/s; fast diesel engines are those with a piston velocity of greater than 9 m/s
5) In complete engines, the rotor mass comprises the sum of all masses belonging to the crankshaft/drive described in note 3 above

Figure 7-8

Thus, the general expression for G 25 works out to the following:

$$U = \frac{2.5 \times 9549 \times 2.75}{RPM} \quad \text{or} \quad U = \frac{65.659}{RPM} \text{ g-mm}$$

1. Unbalance for G 2.5 at 8,000 rpm gives an allowable unbalance of 8.2 g-mm
2. Unbalance for G 2.5 at 20,000 rpm gives an allowable unbalance of 3.3 g-mm

This shows that as spindle speeds increase the tolerance for allowable unbalance decreases. Ideally, all components should be included during balancing—a matter of good, better, and best.

Machine Tool Spindle Options

This section compares standard CAT tool holders (see Figure 7-9) with BT tool holders and dual face contacts.

CAT vs. BT Tool Holders

Figures 7-10 and 7-11 illustrate a standard CAT tool holder and a BT tool holder, respectively. The key distinctions between the two can be summarized as follows:

1. The BT shank holder calls for a ground I. D. in the retention knob cavity.
2. The BT shank holder is manufactured for symmetry. Both drive key ways have the same width and depth.

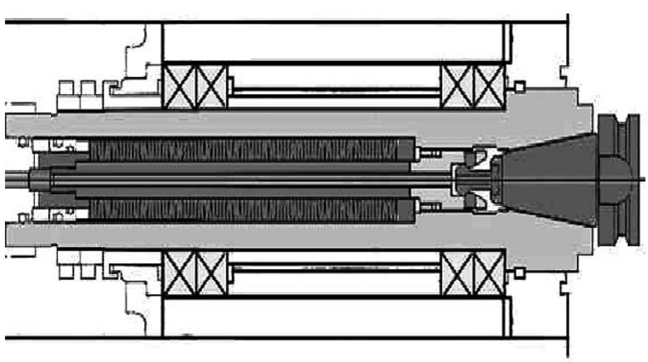


Figure 7-9

ANSI B5.50

CAT40

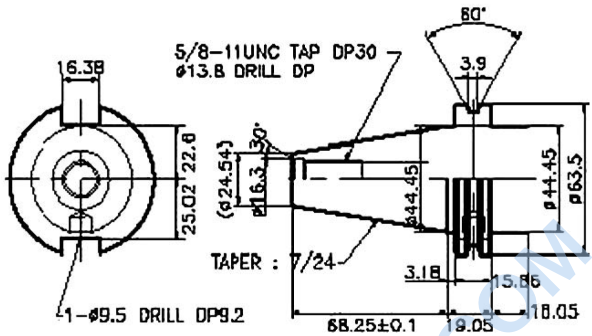


Figure 7-10

3. The CAT shank tool holder is governed by the ANSI standards, which calls for a relief cut under the flange of the tool holder of 5/8” width.
4. All the dimensions on the BT shank tool holder are in metric.
5. The slot in the flange of the BT shank tool holder is offset plus, the flange is thicker. On the CAT shank tool holder, the slot in the flange is centered.

JIS B6339

BT40

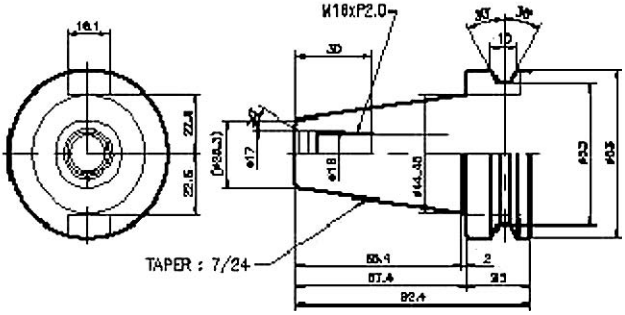


Figure 7-11

Figure 7-12

In both the standard CAT and BT tool holders, there is a gap between the spindle face and the holder flange.

In Figure 7-12, you will see the difference in the length of a BT tool holder (top) and a CAT tool holder (bottom). The CAT is longer because of the extra width needed in the tool change area.

CAT40 vs. Dual Contact CAT40

Figure 7-13 compares the CAT40 with the dual contact CAT 40. Figure 7-14 compares both of these with other tool holders and Figure 7-15 focuses especially on the Dual Contact BT40.

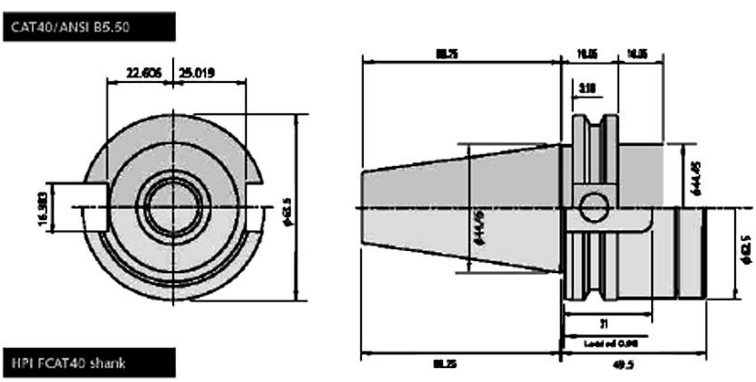
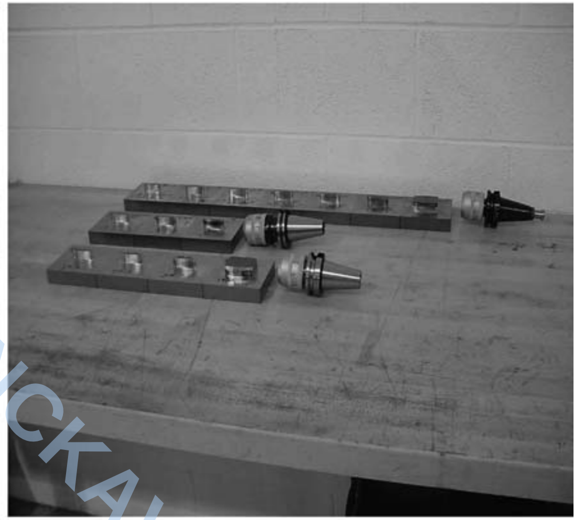


Figure 7-13

Taper Test	CAT/BT/MBT/HSK		
MFG	Shank	Length	Minutes
N	**CAT40**-C3/4 85	3.34	76
N	**BT40**-C3/4 70	2.76	96
N	**MBT40-C3/4-85**	3.34	172
N	**HSK63A-C3/4-95**	3.74	120

MACHINE:	Yasda YBM640V
SPINDLE:	Big Plus
MATERIAL:	A2 60RC 4.00 x 4.00 x 1.5
SOFTWARE:	Cam-Tool
TOOL:	Hitachi EPHT6100 10mm TH Coating
Z-DEPTH:	0.6
STEP-OVER:	0.02
RPM:	3800
FEED:	45
OIL MIST:	On
CYCLE TIME:	25.3



- CAT40

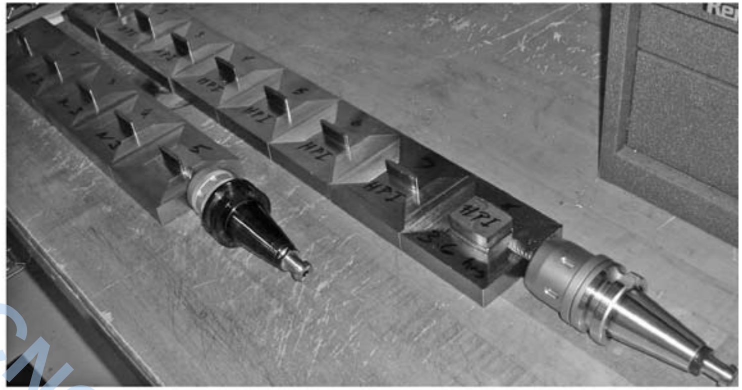
- BT40

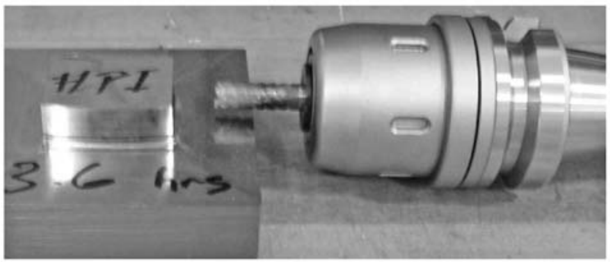
- Dual Contact MBT40

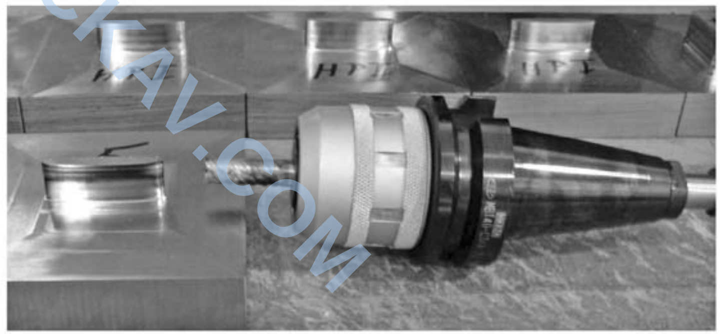
– HSK

Figure 7-14

MACHINE:	Yasda YBM640V
SPINDLE:	Big Plus
MATERIAL:	A2 60RC 4.00 x 4.00 x 1.5
SOFTWARE:	Cam-Tool
TOOL:	Hitachi EPHT6100 10mm TH Coating
Z-DEPTH:	0.6
STEP-OVER:	0.02
RPM:	3800
FEED:	45
OIL MIST:	On
CYCLE TIME:	25.3
FBT40 HMC20-85	216 minutes
MBT40 C3/4-70	140 minutes







- Solid Taper + Floating Flange combination offers rigid and vibration free cutting on HRC60 material.
- This holder saves your cutter, and saves you $.

Figure 7-15

In a standard dual contact, the taper cannot follow the expansion. Thus, it detaches from the machine spindle and maintains only flange contact. With a moveable taper, the taper sleeve follows the expansion and maintains contact with the taper and the flange.

Powerful cutting capability is a result of the balance of the contact ratio at the taper and the flange. Machine spindles expand due to the centrifugal force at the high speed rotation or heat; this is ideal for an extended tool length holder. Figure 7-16 highlights moveable taper construction, which is noted for an internal taper body, grease grooves, a split taper cone, vibration absorption disc springs, and a preload cap.

Moveable Flange Contact Tools

Figure 7-17 looks at HMC, ER, and HFD moveable flange contact tools. The highlights of these follow. Figure 7-18 then looks at how these tools work.

- Better finish
- Faster feed rate
- Vibration-free cutting
- Longer cutter life, up to 400%
- Good for die mold hard milling applications
- Adaptable to regular BT30/40/50 and CAT 40/50 machine spindles
- Available in HMC, ER, and HFD only

Figure 7-16

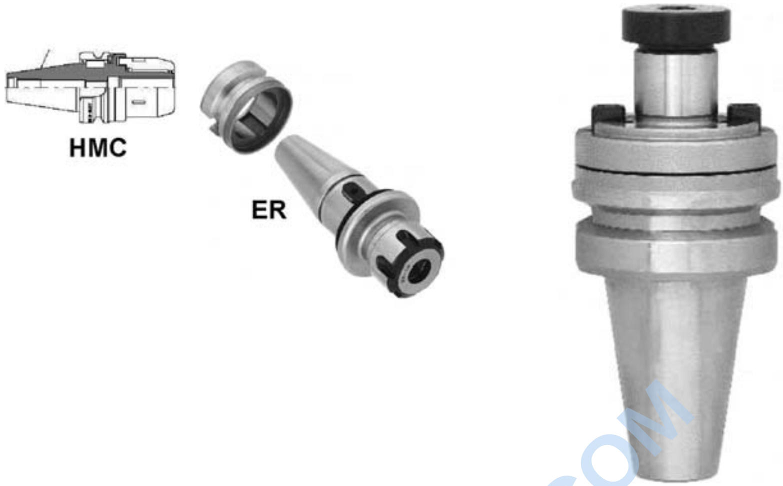
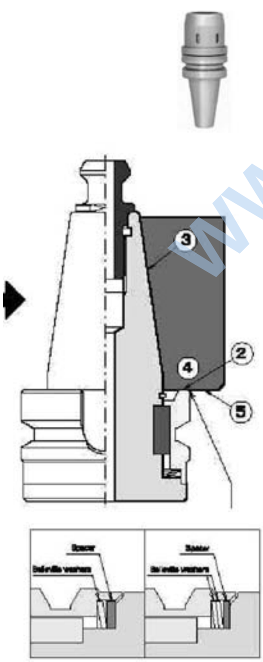
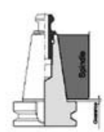


Figure 7-17



How Does It Work?



- As the flange contact tool is pulled into the spindle (#4), the flange (#2) makes initial contact with the flange of the spindle (#5).
- Bevel springs underneath Flange (#2) are compressed and provide extra support to the system while working as a shock absorber to dampen vibrations.
- Finally, the taper (#3) makes contact with the spindle ID, completing simultaneous taper and flange contact.
- Since the taper body is a solid piece, it provides great T.I.R. and rigidity to the whole set up.
- Even under high speed operation, taper contact will not be lost.

Figure 7-18

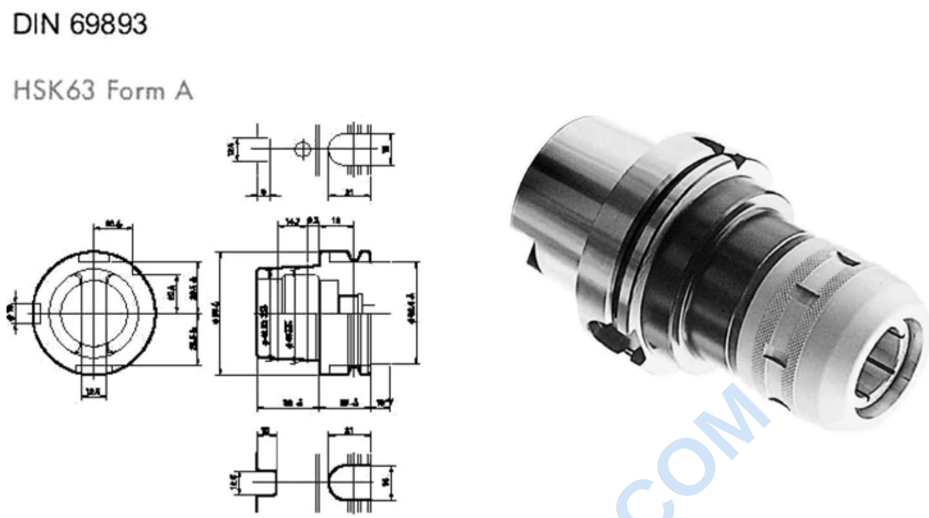


Figure 7-19

Dual Contact—HSK

Figure 7-19 shows the dual contact HSK and Figure 7-20 looks more closely at its tooling systems. The HSK is notable for the following features:

- Short 1/10 taper
- Bearing of machine spindle close to where machining is being done
- Hollow taper allows expansion to maintain taper and flange contact
- Higher static stiffness

Mechanical Milling Chuck

What's Inside the HIP Milling Chuck?

1. The nut/needle roller bearings (four bearings per window to maximize contact area) provides excellent rigidity and grip torque to the cutter shank.
2. Radial grooves help ID to collapse inward evenly. They improve gripping torque, T.I.R., and prevent fretting.

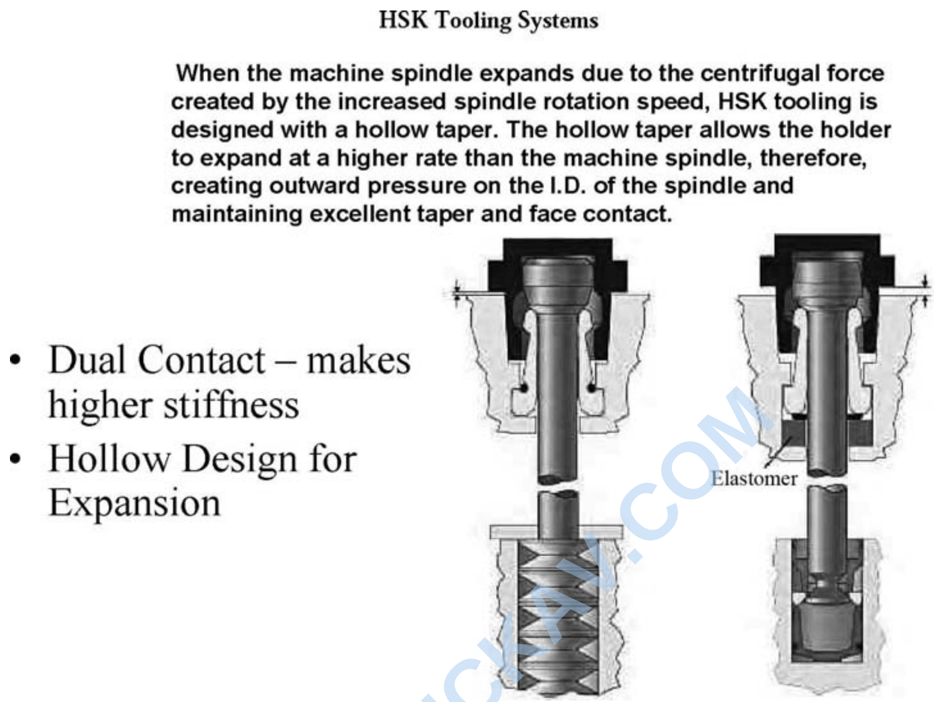


Figure 7-20

3. Axial grooves minimize slipping due to oil on the cutter shank by allowing oil to drain into groove.
4. Straight shank ID is suited for
5. Sub-zero treated body ensures longer, trouble-free tool life. Sub-zero treatment stabilizes material and prevents pittings on the bearing contact surface.

How Does a Mechanical Milling Chuck Work?

It's simple. There are no threads on the HMC milling chuck. Windows on the bearing retainer are slightly tilted (4 degrees). This creates spiral motion as you tighten the nut. As the nut spirals down, the needle roller bearings squeeze the holder body up against the cutter shank. This action provides optimum, mechanical gripping torque capability (see Figure 7-21).

Figure 7-22 illustrates what radial grooves do. Then Figure 7-23 shows how to maintain the parts in only five minutes.

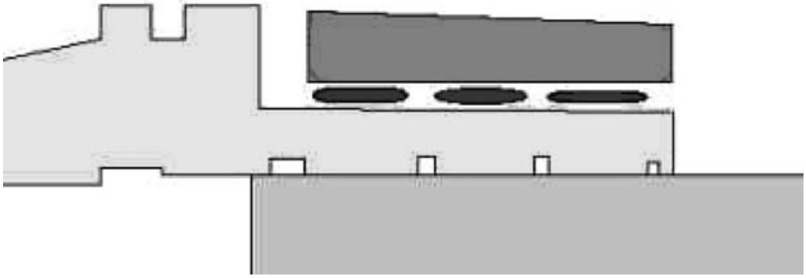


Figure 7-21

Performance Tips

Figure 7-24 shows how to tighten HMC milling chuck. If you do not get TIR on HMC, check the following:

- Nut tighten all the way?
  Back off half a turn. Don't worry, it still has more than enough grip torque.
- Any ding or nick on taper, I.D., or O.D. of cutter?
  Stone any nick or ding from taper.
- Are tool/collet/cutter shank clean?
  Wipe oil/grease/coolant off taper, I.D. hole, collet, or cutter shank.

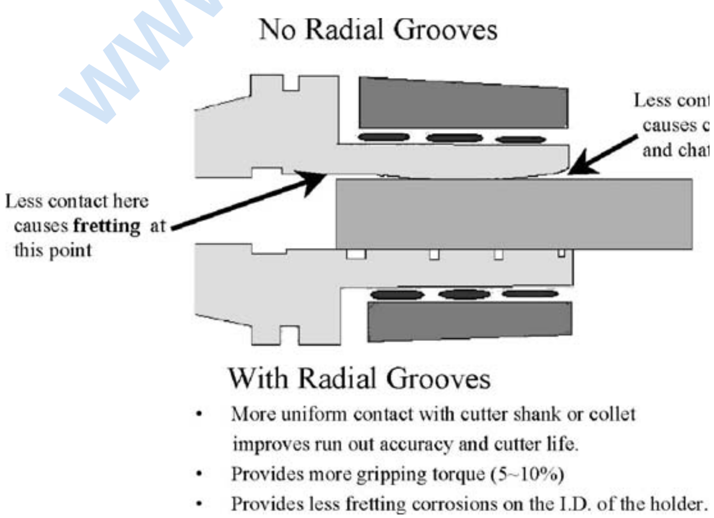


Figure 7-22

5 Minutes Maintenance

Tighten the nut

Take snap ring using two nails

Once the top snap ring is removed, nothing holding the nut.
Nut will come out by turning it Counter Clock Wise

Apply grease on needle bearings inside

Only maintenance required is grease on the needle roller bearings.

Parts view

Figure 7-23

How to Tighten HMC Milling Chuck

- **Heavy Milling:**

  Tighten all the way!
  It will generate MAXIMUM gripping torque.
  Accuracy 0.0004"~0.0008"

- **Finish Cut:**

  Tighten all the way and then, back off ½ (HALF) a turn.
  Make sure that the bottom of the nut is JUST kissing the O-ring. 0.0002~0.0003" accuracy.

Figure 7-24

- Brand new HMC milling chuck?
  Tighten the nut all the way and loosen three times with the cutter shank in the I.D. This helps squeeze out any extra burr in the I.D. hole.
- Check the pullstud?
  Make sure it is not over-tightened.
- Using a collet?
  Align the slots on the collet with the slots on the tool.
- Using weldon shank cutter?
  Use solid shank cutter instead.

Ultra Finishing HMX Collet Chuck

The HMX collet chuck (see Figure 7-25) is the most accuracte one available, with 0.0001" T.I.R. It's easy to use and no heat shrink unit is required. It's suited for higher RPM operations: 12,000 RPM max. for the CAT40-HMX8 and 10,000 RPM max. for the CAT50-HMX8. A hard balance is available to 35,000 RPM. The HMX collet chuck has high

Figure 7-25

gripping torque (8° Collet) and a slim, compact design. It's great for hard milling and high speed finishing applications. Figure 7-26 illustrates HMX mechanics and Figure 7-27 explains the coolant-through system.

Tips for using and maintaining the HMX include the following (see Figure 7-28):

- Torque Rating on Cap Screw.
  For HMX8: 15 ft-lbs
  For HMX12: 20~25 ft-lbs
  There is no need to over-tighten.
  8º taper angle provides sufficient grip torque.
- Make sure to insert the cutter deep into collet.
- Tighten the jam nut all the way.
- 3-mm, 5-mm, and 6-mm key cap bolts are available.
- Check for dings or nicks on the taper, I.D., or O.D. of cutter.
- Keep the tool shank/collet/cutter O.D. clean.
- Refrain from over-tightening the pullstud.
- Use solid shank cutter, and not a weldon shank.
- Extra long protrusions are available upon request.

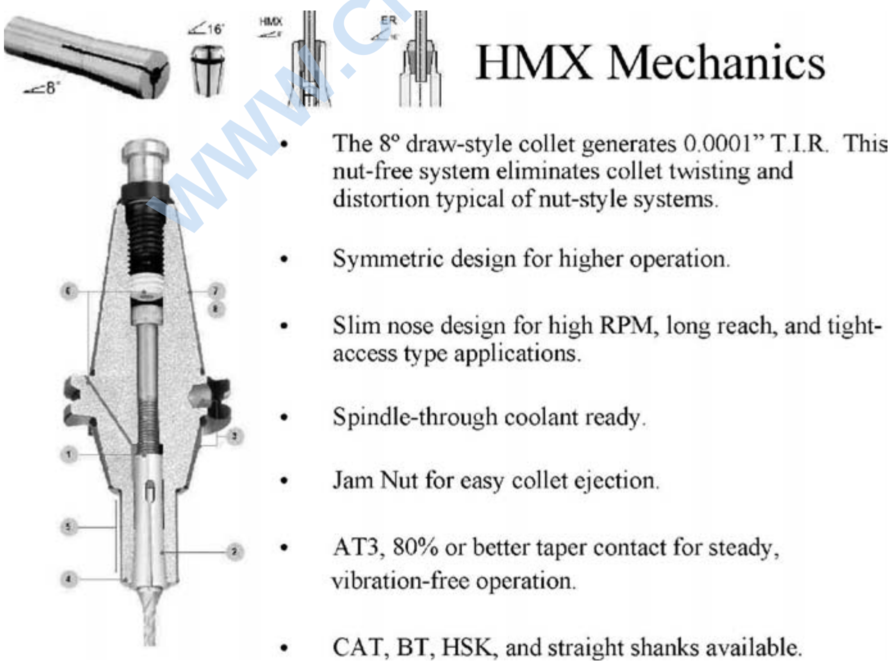


Figure 7-26

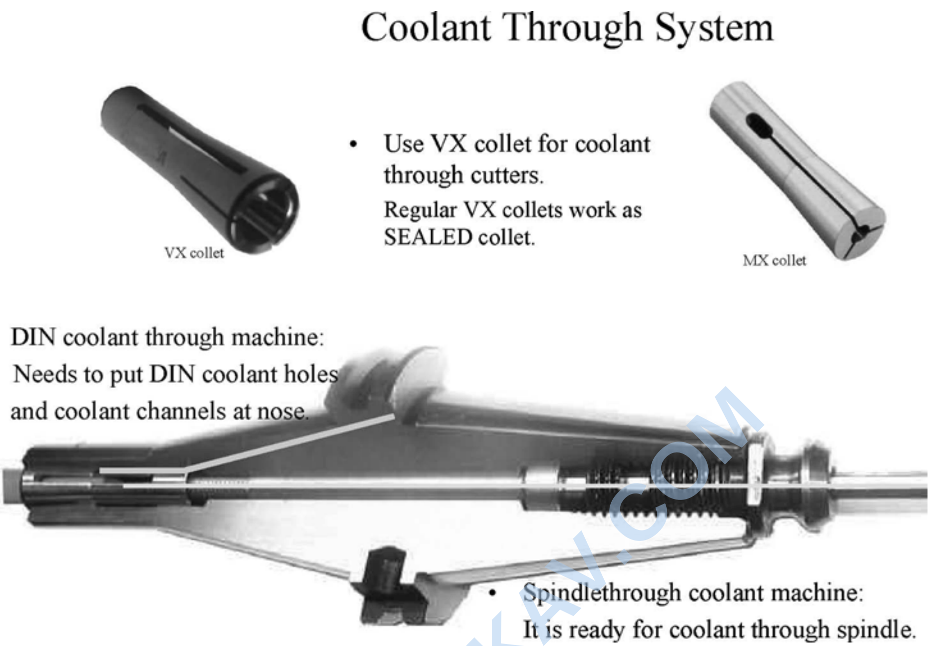


Figure 7-27

Ultra Finishing Shrink Fit Holders

The advantages of shrink fit holders, as pictured in Figure 7-29, include:

- Excellent clamping force
- Excellent concentricity
- Excellent balance characteristics
- Many extended length options
- Small diameter nose
- Short gage length
- Coolant-through ready

The disadvantages include:

- Tool shanks must match holder I.D.
- Requires external equipment (shrink machine)
- Heat may lead to injury

Shrink fit holders increase performance, improve surface finish, extend cutter life, and reduce cost. Figure 7-30 looks at their impact on cutter life.

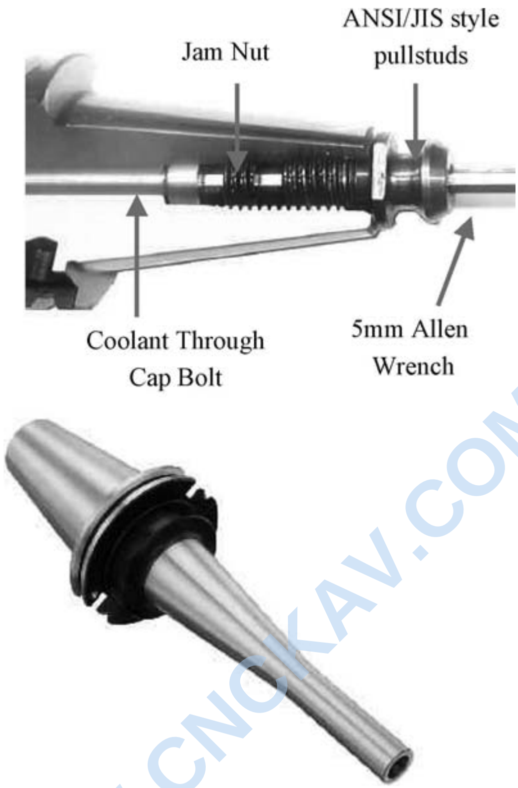


Figure 7-28

Figure 7-29

Heat shrink machines improve productivity in several ways. These include:

- Tool exchanges in 5–6 seconds
- Complete tool cooling in 30 seconds
- Eliminates tooling component and operator variables (collets, nuts, etc.)
- Highest means of repeatable tool clamping and torque transmission
- No machine maintenance
- Safe and automatic operation

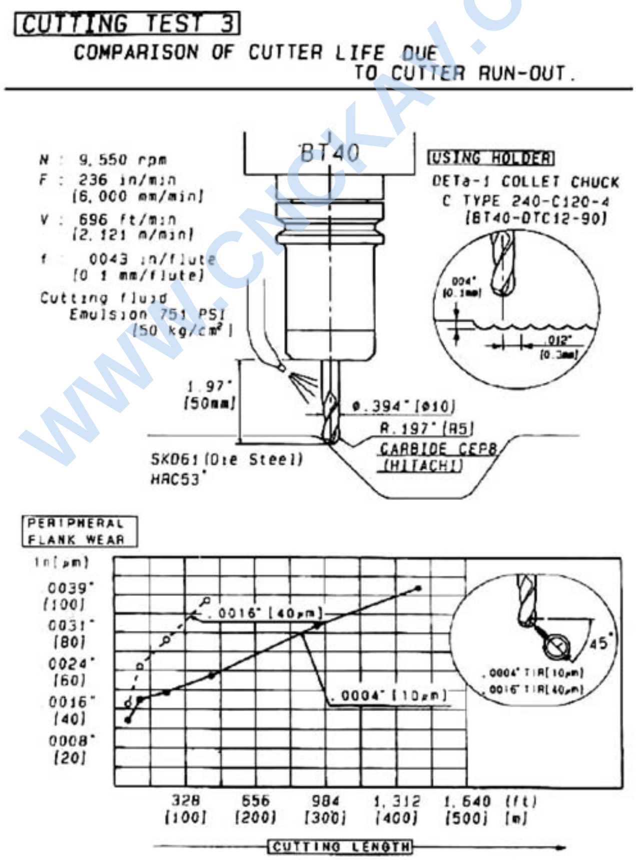


Figure 7-30

Tool Holder Tips

There are several keys to maintaining holder accuracy and life.

Use a Tool Wagon.

Protect the tool shank. Don't leave tools lying around.

Clean Taper, Collet, and Cutter Shank.

Stone any nicks and dents off from the taper. Wipe any grease, oil, and coolant off.

Use Tool Lock.

This is an important step when changing cutters and pullstuds.

Don't Overtighten the Pullstud.

Overtightening will cause a mushroom effect on the tail end of the shank.

Keep Machine Spindle Cleaned.

Once the machine spindle is damaged, it will damage every single tool that goes in it.

Chapter 8

BIG Kaiser: Dual Contact Spindle System Enhances Rigidity and Repeatability

By Jack Burley, Vice President Sales & Engineering,
BIG Kaiser Precision Tooling Inc.

Overview

BIG Kaiser Precision Tooling

BIG Kaiser Precision Tooling, Inc., is a market leader in the development, manufacture, and distribution of high-precision boring tools, modular tooling systems, tool measuring and presetting systems, modular workholding and clamping systems, solid carbide and high-speed steel precision drills, and quality machine tool accessories (Figure 8-1). With brands including Kaiser, BIG Daishowa, Speroni, Unilock, Sphinx, and more, BIG Kaiser's line is focused on extreme accuracy and repeatability.

BIG Kaiser's tooling solutions are designed to produce the highest levels of precision, productivity, and efficiency. From small job shops to the largest manufacturers in the industry, BIG Kaiser is committed to providing high quality solutions and services to all of its manufacturing partners. Its mission is to support North American manufacturers with products that are designed and manufactured to a superior standard. Guaranteed.

BIG Kaiser is a different kind of tooling partner. Its mission is to find the best of the best and deliver it to its customers with a personal commitment to helping them install truly efficient solutions. They have

Figure 8-1 Corporate Office

exceptionally high standards for the products they represent. The result is an all-star line-up of products that deliver true and measurable performance advantages – products that are engineered to exacting standards and then manufactured with materials and craftsmanship that enable superior performance.

BIG Daishowa Seiki

In 2003, BIG Daishowa Seiki, a global total tooling manufacturing company based in Osaka, Japan, formed a strategic alliance with KPT/ Kaiser Precision Tooling, Inc., of Elk Grove Village, IL. This relationship strengthened both company's ability to provide total tooling solutions not only to the North American market, but also to the global market.

Dual Contact

Simultaneous or dual contact spindle systems have many advantages. They permit much higher rigidity by adding contact between the flange face of the tool holder to the spindle face. However, no industry standards have ever guided universal application of dual contact.

Many users have adopted internal methods to create simultaneous fit by using shims attached to the tool holder face and ground-to-specific dimensions, measured to very close tolerances for each specific machine tool spindle. These methods have yielded tremendous improvements in accuracy and rigidity, but costs can be high; the logistics to maintain these setups can bring problems.

The BIG PLUS Spindle System

BIG PLUS, patented world wide by BIG Daishowa Seiki, is a universal simultaneous taper and flange contact spindle system that, for the first time, unifies spindle builders to accept one specification for interchangeable dual contact of tool holder to spindle.

BIG PLUS achieves dual contact by eliminating the gap or space between spindle face and tool holder flange face. This system conforms to current standards for JIS-BT(Japan), DIN69871(Europe), and ANSI B5.50(America). The BIG PLUS system offers simultaneous dual contact between the machine spindle face and the tool holder flange face, and the machine spindle taper and tool holder taper shank.

Simultaneous spindle and flange contact greatly enhances rigidity and repeatability, which yields many benefits in higher metal removal rates, higher accuracy, improved surface finish, and extended tool life. It also minimizes vibration to prevent fretting corrosion; eliminates axial movement during high speed operation; and resists cutter deflection, improving accuracy and finish.

The licensed spindle builders extend the spindle face in the contact area of the tool holder by half the normal gap. For example, CAT40 and CAT50 will normally have a gap of .125”. BIG PLUS spindles reduce this gap to only .04” and .06” respectively, if standard tool holders are used. If BIG PLUS tool holders are used, they reduce the gap to zero, and the close tolerance of the system (normally, less than 5 microns) assures both flange face and taper contact.

The Problems with Conventional Taper Contact Tooling

1. Stable repeatability for close tolerances, especially after repeated and heavy uses, are not achievable, even under the best of circumstances.
2. Repetitive high power cutting such as face milling operations will result in fretting corrosion on both the spindle and tool holder, causing reduced spindle life. Longer tools accentuate the problem.

3. The loss of *Z*-Axis accuracy due to high spindle speed. Centrifugal forces cause the spindle mouth to open, resulting in the tool holder's locating to different *Z*-Axis depths and reduction of taper contact.
4. Stable machining with long tools cannot be accurately predicted.
5. Inaccurate location of retention knobs can cause severe wedge action against the proper fit and run-out of tool holder to spindle.

The Advantages of Dual Contact Systems

1. Higher rigidity of tooling system due to increased contact diameter. Using 50 taper as an example, the contact diameter increases from 2.75" to 3.875", an increase of more than 40%. This increased contact diameter will improve the metal removal rates, especially on face milling operations with long reach applications.
2. Higher accuracy of automatic tool change to within .00004".
3. Minimized vibration to prevent fretting corrosion.
4. Elimination of *Z*-Axis movement due to retention knob clamping or high speed operation. The face contact prevents the tool holder from being drawn back into the spindle.
5. The larger face contact area combined with the taper contact works together to resist deflection. With less cutter deflection, higher machining accuracy and superior finish can be realized.

The Interchangeability of BIG PLUS

The BIG PLUS system provides complete interchangeability with existing tool holders and machine spindles. Standard V-flange tool holders will fit and still operate within existing parameters with taper contact only. Operations that do not require high rigidity, high speed, or high tool change accuracy can be performed using standard commercially available tool holders from any source. Moreover, critical applications demanding face contact can be used at any place in the program without qualification of spindle face location.

The innovative design of the BIG PLUS spindle system delivers the benefits of simultaneous dual contact tooling without the need to discard existing tooling, presetters, tooling fixtures, tooling storage systems, or other associated equipment. To receive the benefit of all technical advantages of the BIG PLUS system, however, one should have a machining center equipped with BIG PLUS spindle and use BIG PLUS tool holders.

Common Machine Types Using BIG PLUS Spindle System

1. Horizontal and vertical machining centers have the widest range of use due to the common spindle interface of CAT, DIN, or BT steep taper tool holders. Taper sizes are 30, 40, and 50.
2. Multi-tasking machines (mill-turn machines) have recently started to shift from proprietary connections to the more standard steep taper shanks. Only by the utilization of BIG PLUS and dual contact can these machines achieve high cutting capacity, especially in the application of static turning tools. The company's new range of MTC tooling systems use BIG PLUS as a standard interface for turning operations.
3. Cutter grind machines have become licensed for BIG PLUS to improve the interchange accuracy required when changing set ups.

Current Machine Tool Builders Licensed for Production

Many of the world's leading manufacturers of machine tools offer the BIG PLUS Spindle System. Some of the machine builders who have produced BIG PLUS spindles are:

- Anca
- Citizen
- DMG
- Dixi
- Enshu
- Fanuc
- G&L
- Honma
- Horkos
- Howa
- Ibag
- Jobs

- Karatsu Iron Works
- Kira
- Kitamura
- Komatsu
- Koyo
- Kuraki
- Makino
- Makino Seiki
- Matsuura
- Mazak
- Mitsubishi
- Mitsui Seiki
- Mori Seiki
- Mori Seiki Hitech
- Motokubo
- Nomura
- NTC
- O–M
- OKK
- Okuma
- Okuma & Howa
- Pama
- Sajo
- Seiko Seiki
- Shoda
- SNK
- Stama
- Sugino Machine
- Toshiba Machine
- Toyo Seiki
- Toyoda
- Tsugami
- Urawa
- Yamasaki Giken
- Yasda

Many of these machine tool builders have standardized production of all spindles manufactured and sold to include BIG PLUS on either all or certain models of equipment.

Customer Testimonials

BIG PLUS is the first universal simultaneous taper and flange contact spindle system to unify spindle builders to accept one specification for interchangeable dual contact of tool holder to spindle. If a machine has a BIG PLUS spindle, utilizing BIG PLUS dual contact tooling can deliver a direct improvement in power transfer from spindle to tool and significantly impact productivity with greater rigidity, repeatability, and accuracy.

Scrap Rate Drops from 50% to 1.5% with BIG Daishowa Mega Micro Chuck

The scrap rate for a precision drilling operation in PVC plastic dropped from 50% to 1.5% after a Silicon Valley machine shop started using a BIG Daishowa Mega Micro Chuck from BIG Kaiser Precision Tooling. Sea-Tek, a high quality CNC machine shop in California's Silicon Valley, was experiencing a 50% scrap rate because of difficulty controlling runout drilling a .047" DIA hole that is 2.170" deep (a length to diameter ratio of 46:1). The drill used in this application is a 6" overall length HSS tool. Sea-Tek is machining a medical product part called a sample housing in which the 2.170" hole accommodates a syringe.

"We use 47 different tools during one hour of previous machining work on this part. When our hole is drilled, it is one of the last operations performed. Hence, we cannot tolerate a wandering hole. If it wanders, the syringe would miss the mating port hole," explains Brian Bradshaw, Sea-Tek Owner/Partner. Bradshaw presented the challenge of improving the manufacturing process to Alex Mosson, Outside Sales Representative with Western Tool & Supply, Santa Clara, CA. Mosson recommended the BIG Mega Micro Chuck for greater accuracy and repeatability, based on previous application experiences at other area machine shops.

The cycle time for the operation on Sea-Tek's Fadal CNC Mill stayed the same after the BIG Mega Micro Chuck was introduced, but the company saved considerable time by virtually eliminating scrap. It takes an hour to complete machining operations on each part. Sea-Tek makes 8–10 parts daily and was losing half of production to scrap. With the BIG Mega Micro Chuck, the scrap rate dropped from 50% to 1.5%.

Each Mega Chuck comes standard with the BIG-PLUS dual contact spindle system to assure the highest rigidity possible in high speed and high metal removal machining operations. BIG-PLUS allows interchangeability with existing tool holders and machine spindles. “The Mega Chuck Series offers the industry’s highest levels of rigidity, gripping force, and runout accuracy to help users achieve better surface finishes, superior precision, and extend tool life,” says David Frank, BIG Kaiser Sales Representative with Next Generation Tooling, Santa Rosa, CA. The shallow taper angle of the collet provides high rigidity combined with “just fit” sizes for perfect runout accuracy and high gripping forces.

The Mega Micro Chuck is ideal for high speed applications in very hard to reach areas with small-diameter cutting tools. It has three collet series that cover a range of 0.018” to 0.236”, with collets available in steps of .004” to guarantee run-out accuracy of .00004” at collet face. Sea-Tek uses the BCV40-Mega3S-2.5T with the NBC3S collet and MGR10 wrench.

BIG Kaiser offers a large variety of collet chuck lengths to optimize tool projection based on application needs. Straight shank types for combination assembly with non-standard tapers or length requirements are also available.

BIG Mega New Baby Chuck Drops Cycle Time 20 Percent and Increases Tool Life 300 Percent

Cycle time dropped 20 percent and tool life increased by three times after a major medical manufacturer introduced the BIG Daishowa Mega New Baby Chuck to a micro drilling and milling operation there. The company had been getting .0002” runout on the precision drilling operation for a medical device. The BIG Mega New Baby Chuck cut runout in half to 0.00009”. Tool life went from 5 holes using carbide drills to an average of 330, with stainless steel and titanium most often being machined.

BIG tool holders and Sphinx micro drills’ superior runout helped drop production from 5.4 to 4.2 minutes per part for the drilling operation, and the company was able to eliminate its centering drill operation. The drill is .0065” diameter by 0.080” deep. The company previously used high speed steel drills because the cost per hole was too high for carbide. These drills only netted an average of 20 holes per drill. After running a test tool, the decision to switch was an obvious one. The tooling was paid off within the first shift.

Each Mega Chuck comes standard with the BIG-PLUS dual contact spindle system to assure the highest rigidity possible in high speed and high metal removal machining operations. BIG-PLUS allows interchangeability with existing tool holders and machine spindles. Because all Mega Chuck toolholders and components are made under BIG Daishowa's strict quality control and all collects go through a 100% inspection, accuracy is guaranteed when assembled together.

The company was running 5.8 parts per hour/12,000 RPM/ 0.00025" peck/1.0 IPM/0.053" deep. Now, with the BIG Mega New Baby Chuck, it runs 240 parts per hour/6,000 RPM/0.0006" peck/2.5 IPM/ 0.053" deep. BIG Kaiser helped this manufacturer achieve a significantly increased tool life with the ability to fixture more parts per machine cycle, and a considerable impact on increasing spindle efficiency. With the dramatic increase in tool life and the predictability of tool failure, the company could anticipate tool failure and load the tool changer with back-up tooling, allowing the company to preset 240 parts under the spindle for 15 hours of unattended production.

Medical manufacturing demands very tight tolerances of +/–0.00005". The Mega Chuck Series offers the industry's highest levels of rigidity, gripping force, and runout accuracy to help users achieve better surface finishes, superior precision, and extend tool life. The exclusive notch-free design of the Mega Chuck Nut eliminates tool vibration at high speeds and reduces whistling noise. The nuts have high precision bearing races to assure lowest friction against the collet when clamping to give no influence against runout accuracy. The BIG Mega New Baby Chuck offers six different size collet series to provide ultra precision for high speed machining with carbide drills, taps, reamers, and endmills. It is offered in all popular styles of shank types, such as CAT, BT, or HSK, and can hold a range of cutting tools from 0.010 to 0.787".

The project was so successful, management at this medical manufacturer gave the machine shop authority to purchase new and replacement tooling wherever it could be justified in cost savings. This company found more than just a tooling solution in BIG Kaiser. With a 20 percent drop in cycle time and a 300 percent increase in tool life, they found a tooling partner.

Runout vs. Tool Life: Runout Key to Toolholder Performance

Big Kaiser's customers indicate they lack objective criteria to consider when making toolholder purchasing decisions. Customers say that every tooling manufacturer claims to have high accuracy, perfect balance, and large clamping forces. With so many choices and very little to distinguish one toolholder from the next, most purchasing decisions are therefore guided by price.

The problem with basing a toolholder purchase decision on price alone is that it overlooks the critical importance of runout to both accuracy and tool life. Many manufacturers are not aware that they could be achieving much better runout than they do. Even if the potential to improve runout is recognized, they are skeptical about how it might impact performance.

BIG Kaiser conducted an informal customer survey on the question, "What is good runout?" The consensus was that good runout is about 0.0005". Averages like this provide useful benchmarks, but no job is average.

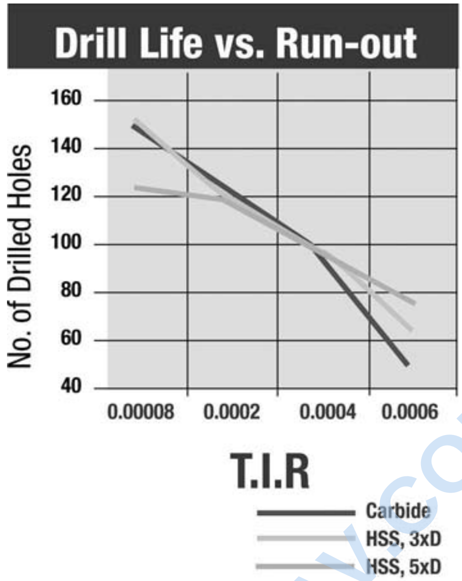
Two important variables in determining what runout should be are tool size and composition. With larger tools (3/4" or more), runout values of 0.0005" may not impair performance and tool life. With smaller tools, we may need to do much better than 0.0005". With tool composition, for example, carbide drills can last much longer than drills made from high speed steel—only if the runout is controlled to a higher accuracy.

To achieve top quality performance, runout must be controlled. Once runout is where it should be, extended tool life will follow. Figure 8-2 shows data from actual drilling tests performed at BIG's Mega Technical Center. Each drill was tested under the same conditions, altering only runout for each value.

As shown, a carbide drill that ran with only .00008" of runout resulted in 148 holes drilled. A second carbide drill ran with .0002" of runout under the exact same conditions, and it resulted in 125 holes. This was repeated two more times with runout of .0004" and .0006". The next test ran these same four runout values on an HSS drill. A third test mirrored the first two, but used a longer drill (5 times diameter) with through tool coolant. In each test, the drill ran until the primary cutting edge measured a wear of .008", at which point the drill's tool life was considered to be expired.

To summarize the results:

- Carbide has the highest sensitivity for lost tool life due to runout. It gains nearly three times more tool life between .0006" and 00008". BIG Kaiser's users believe .0005" is a good, average runout.



Material	1055 Steel
Speed,Carbide	250 SFM
Speed,HSS	90 SFM
Feed	0.004"/rev.
Hole depth, 3xD	.47"
Hole depth, 5xD	.60"
Drill diameter	.118" (3mm)

Figure 8-2 Drill Life and Runout

- HSS materials were slightly less sensitive for lost tool life, gaining 2.3 times more life from .0006" to 00008". HSS materials with coolant through the tool were even less sensitive.

The test results indicate that if the drill is not running concentric to its centerline, higher forces are generated in the radial direction of the highest margin, causing higher wear to one side. Because the test only measures runout up to .0006", users may not realize this value can improve as tool life increases up to three times.

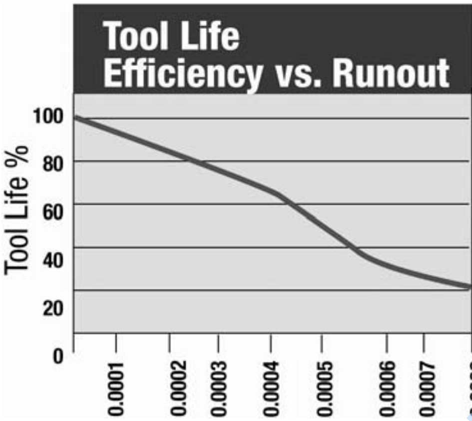


Figure 8-3 Tool Life

From this data, it is possible to plot the tool life efficiency based on runout, whereby theoretical "0" runout is equal to 100% tool life expectancy (see Figure 8-3). If the chart is consulted for .0005", users can expect that they are currently only able to use 50% of the tool's capable life.

Many times users are probably using toolholders to hold drills that allow runout to exceed .001"—for example, the 3-jaw drill chuck. Extrapolating from the data, tool life with .001" runout would be something less than 25 holes for carbide tools, almost six times less than it could be if BIG Daishowa's Mega New Baby Chuck had been chosen over a standard collet chuck purchased strictly on the basis of price.

We can measure cost savings in cost per hole. An average competitive price for the 3mm carbide drill used in our example is $40. With runout of .00008", it's good for 148 holes or $0.27 per hole. With runout of .0006"—considered "good" in the customer survey—the cost per hole triples to $0.80 per hole. Manufacturers willing to accept .0006" runout are passing up an opportunity to cut drilling costs by 66%.

BIG ran similar tests to calculate values for milling, as shown in the chart. Cutting length increased from 528 feet to 693 feet, 1.3 times longer, as runout decreased from .0006" to .00008" (see Figure 8-4). The reason is clear: with runout of only .00008", the cutting forces are evenly distributed on each flute, whereas an excessive force will be applied to only one flute with runout of .0006". Better runout helps stabilize the cutting depth on each flute and results in better surface finish (see Figure 8-5).

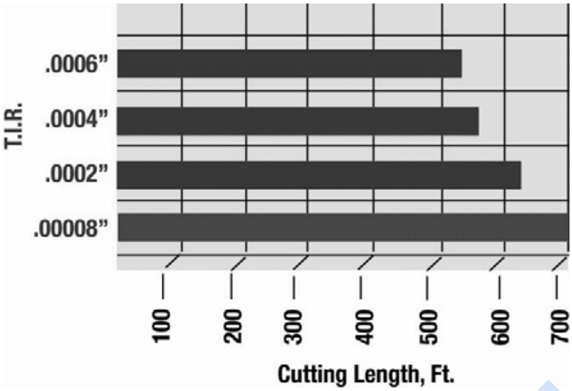


Figure 8-4 Calculating Values for Milling

These tests focus on the relationship between runout and performance. Better runout yields increased output, longer tool life and correspondingly lower costs. It is well worth the effort necessary to improve on good, average runout, according to the tests.

Toolholding is one source that can strongly affect runout. One mold customer, Ideal Tool Co., Meadville, PA, experienced a savings of 30-45 minutes per setup with BIG Daishowa’s HSK-A63 Mega New Baby Chuck. The company was hard milling a stamping die from hardened S7 tool steel, 14 × 8 × 1¾”. Runout had been running .001” to .0015”. With the Mega New Baby Chuck, runout dropped to less than .0005” (see Figure 8-6).

4 Flute Carbide Endmill	
Material	1055 Steel
Cutting Speed	300 SFM
Speed,RPM	2,900
Feed rate	0.004”/flute
Feed	46.4”/min.
Axial depth	.60”
Radial step	0.004”

Figure 8-5 Spindle Taper Test Bar

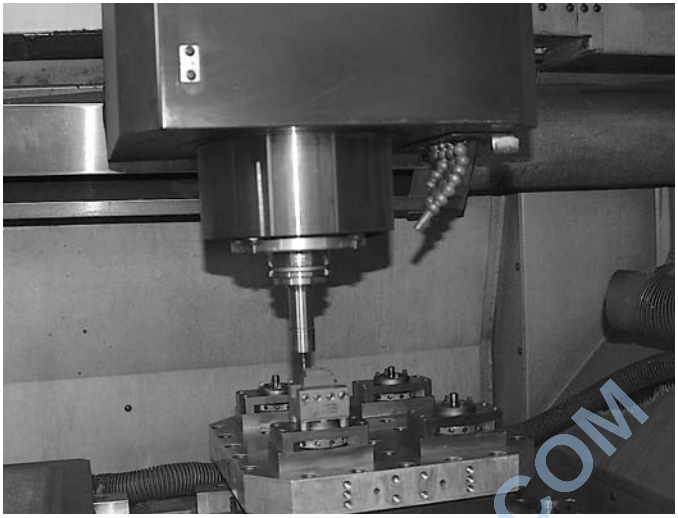


Figure 8-6 Runout was Reduced by 100-200% after Switching to the Mega New Baby Chuck. Photo Courtesy of Ideal Tool Co., Meadville, PA

Changeouts that had taken 5-10 minutes are now completed in 30 seconds. Because the company changes out upwards of 10 chucks per job, the impact on productivity was immediate. The company runs speeds up to 20,000 RPM and feeds up to 150"/minute, using a Makino V55 with HSK-A63 spindle. Like most mold shops, they run many limited production jobs and make many tooling changes.

Allowable TIR of the cutting tool should be based on not just one value, .0005" for example, across the board for any diameter. Figure 8-7 shows the constant relationship between tool diameter and runout as a function of chip load of the cutting tool. The data was made from .0005" TIR as a starting point for a 1/2" diameter tool, from which the allowable TIR could be calculated for smaller tools and their respective chip load. One could imagine that if a 1/16" endmill with 3 flutes is profiling mold steel, the effective chip load of only .0002" for each tooth becomes a highly unbalanced ratio when .0005" runout is applied.

Many factors can contribute to increased runout, so concentrating on the collet chuck alone is not sufficient. Users who recognize the importance of reducing runout need to pay very close attention to several other important influences on runout, starting with spindle accuracy. Even the best collet chuck cannot deliver superior performance in an old

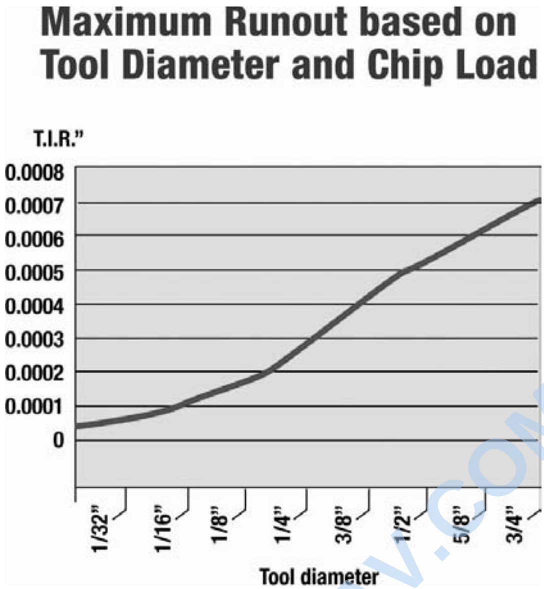


Figure 8-7 Determining Runout

or worn spindle. Start by evaluating the spindle for runout, using a precision gage bar to measure it.

BIG offers two types of inspection gauges for machine spindles (see Figure 8-8). The more popular version is a simple straight bar made to extremely close tolerances and is used by slowly rotating the spindle and measuring run out with an indicator. Less known and equally important is the use of dynamic run-out gauges. When the spindle is rotated at low speeds, centrifugal forces have little or no influence to run out. However, as the spindle speeds increase, centrifugal forces increase exponentially which can cause extreme runout, an important consideration for high speed cutting.

The dynamic run-out gauge has a precise point for accurate measurement of laser alignment tools in the X and Y axis. BIG's recent tests of high speed spindles showed that many machines are very accurate at only 500 RPM, but at 30,000 RPM measured runout exceeds .001".

Other influences on runout include taper into taper contact, the angle of the collet and corresponding clamping range, the quality of the pullstud, and the collet nut. Starting with the insertion of the toolholder into the spindle, BIG Mega Chucks achieve at least 96% taper into taper

Figure 8-8 Runout Test

contact as a result of the superior, sub-micron tolerances and micro-mirror surface finish to which the taper is precision ground on the toolholder.

In a typical collet chuck system, the standard angle of the collet is 16 degrees. With 16 degrees, a single collet can have a clamping range of 1mm (.039”), a feature that most users find very attractive due to the wide clamping range. However, the trade-off to having a 1mm clamping range is less runout control and less clamping force to grip the cutting tool securely.

BIG Mega New Baby Chucks have an angle of 12 degrees, giving them only 0.5mm range but considerably better runout control and clamping force over a standard collet chuck (see Figure 8-9).

Figure 8-9 BIG Mega New Baby Chuck

Figure 8-10 BIG Mega E Chuck

The BIG Mega E Chuck, developed exclusively for holding endmills, has a shallow angle of only 8 degrees, giving it very high clamping force, rigidity, and runout control (see Figure 8-10).

The BIG Mega Micro collet chuck, developed for holding micro cutting tools, also has a shallow taper collet angle (see Figure 8-11). Again, to control runout and maintain good rigidity, collets are available in steps of only .004” on diameter.

For the many cutting tools typically used throughout most users’ machining processes, it is important to select the right toolholders for each application. To obtain the highest accuracy and performance of each tool, the ideal chuck and collet needs to be specified.

With V-flange tool holders, the pullstud used to clamp the toolholder into the spindle should not be considered a cheap, disposable item. BIG Daishowa uses only through-hardened H13 premium tool steel for pullstuds and grinds all features. If you don’t control the accuracy and quality of the toolholder assembly, it will degrade performance and increase runout. A pullstud screwed into a toolholder that does not align

Figure 8-11 BIG Mega Micro Collet Chuck

to the same centerline as the taper and/or retention system will impart lateral forces against the system, and higher runout will result.

HSK users need not worry about pullstuds, but they must monitor the quality of the internal tool retention form. Accuracy and position of this form will affect rigidity, repeatability, and precision of tool changes. In order to hold this form to the strict tolerances of HSK standard, BIG finish machines this form and the drive keys after heat treat, due to the drastic changes that can occur during the heat treatment process.

The collet nut that squeezes the collet and clamps the tool is another key part of the assembly that should be a very carefully engineered, high quality product. The main function of the collet nut is to apply axial pressure against the collet's secondary angle by means of high precision threads. The resulting axial displacement of the collet into the tapered socket of the chuck squeezes the cutting tool and thereby clamps it securely in place.

In the clamping process, the collet engages against the nut's precision ground internal raceway. Two systems are used: bearing nut and friction nut. BIG uses ball bearings between the nut and its inner raceway to assure that there is no friction or lost energy when turning the nut against the collet. In systems using friction nuts, a torque moment or twisting force can be imparted against the collet and cutting tool, adversely affecting runout of the total tool assembly.

BIG guarantees runout no greater than 3 microns (.003mm or .00012") at 4 times the diameter and .00004" at the nose. We can do this only by following very stringent manufacturing and inspection processes for all components. For example, each collet produced by BIG is inspected twice to assure it meets our runout guarantee. The quality control engineers assemble the collet with test bar; they clamp and measure runout at 4 times diameter on specially engineered spindles with virtually no measurable runout. Then, they loosen the assembly, turn it 180 degrees, and repeat the process. If it doesn't meet the 3-micron guarantee, the collet is discarded. BIG conducts this time consuming and painfully difficult quality control procedure on more than 35,000 collets manufactured every month.

Runout is very important. BIG's tests prove it. "Good" runout can usually be improved for a significant improvement in performance and/or cost savings. The manufacturer who thinks a toolholder purchase decision was based on price may very well have chosen the most expensive alternative and sacrificed quality and accuracy.

Chapter 9

Blum Probes and Lasers

Data provided by Blum, Lmt, Inc.

Laser Systems Provide Total Tool Tip Control

Today laser tool setting systems are capable of measuring tools, detecting broken tools, checking for tool wear, and providing tool identification.

The traditional way of measuring tools, which we will refer to as the static method, is performed on machines that are in their static state with a non-rotating spindle. This method includes the use of height gages, gage blocks, manual touch tool setters, and offline tool setters. The achieved measured result using this method relies on the experienced operator skill and intervention.

Today's preferred method of measuring tools is referred to as non-contact tool measuring. This technology was first brought to the market place by Blum-Novotest GmbH in the early 1980s. This method uses a laser beam as a non-contact switch that, when interrupted, can measure tools during spindle rotation.

This ability provides several key advantages over the traditional method. These advantages are the abilities to compensate for spindle run out, tool run out, tool changing error, wrong tool defined, wrong tool offset called, tool wear, tool breakage, and temperature growth of spindle. Temperature growth of you're the spindle is the one thing for which every machine tool builder tries to compensate. This growth can cause serious blending issues from tool to tool. Figure 9-1 demonstrates the spindle growth during thermal expansion. This growth can easily be compensated for when measuring tools while the spindle is rotating at the correct programmed tool path.

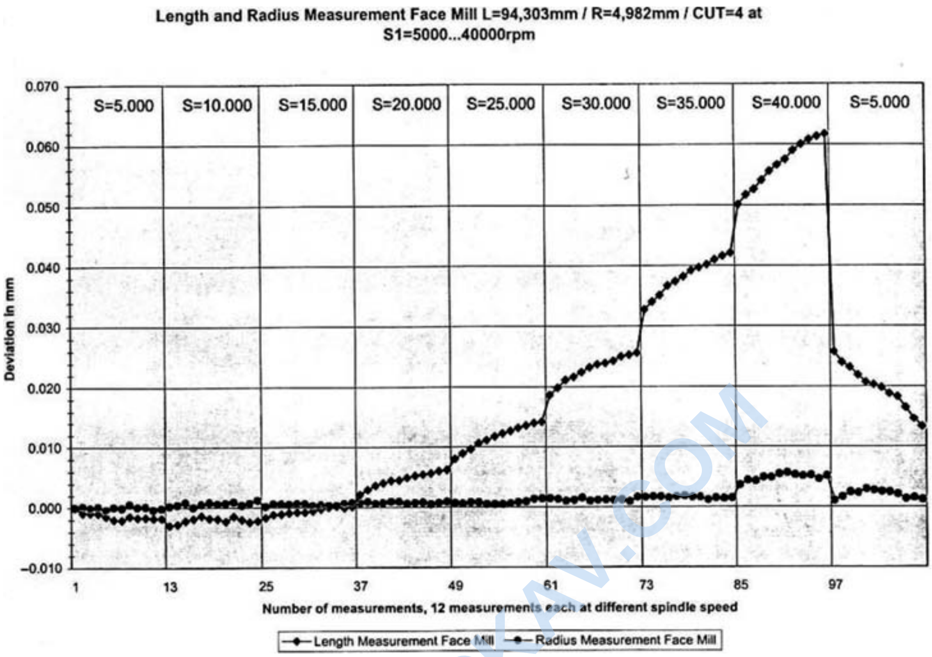
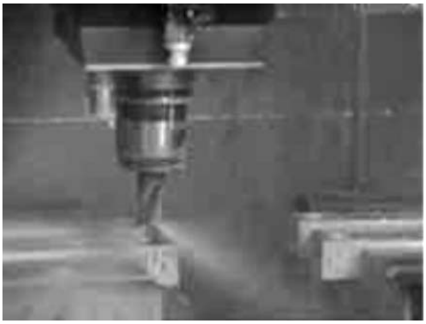


Figure 9-1

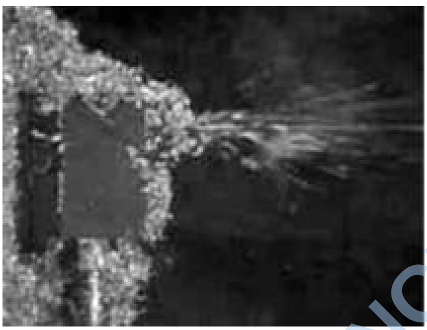
The latest technological advances from Blum-Novotest GmbH, parent of Blum Laser Measuring Technology, Inc., Erlanger, KY, address the critical elements of product and process control in terms of laser tool measuring. Today, not all non-contact laser tool setters are the same. In reality, they are all quite different. It is critical that the correct system is used for the correct application.

Blum-Novotest GmbH uses the best manufacturing methods when building their laser systems. The hardware of the Blum laser control system is designed to work in the harshest environments of today's machining environment. Each laser system with its components is manufactured by highest standards. Each laser system consists of a transmitter and receiver that are designed with a shutter to protect the laser system optics from contamination of coolant or cutting chips. The shutters are controlled through a pneumatic unit that filters air quality debris down to .1 micron filtration. The pneumatic unit, combined with the shutter, provides a superior role in protection (see Figure 9-2).



Problem

Solution



Result

BLUM Pneumatic Unit

Figure 9-2

Blum-Novotest has designed new shutters that dissipate the air flow where the laser beam travels (see Figure 9-3). Air pressure can influence the quality of the beam generation while it travels through this region. When beam quality is affected, absolute measuring accuracy is sacrificed.

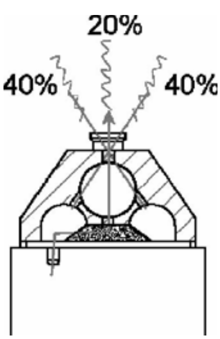


Figure 9-3a Air Dissipation

Figure 9-3b Actual Shutter Inside Air Seal

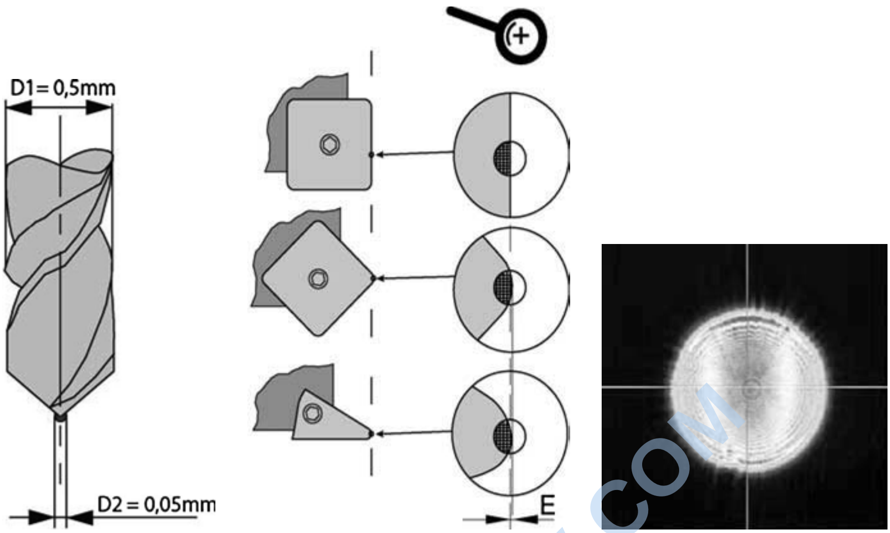


Figure 9-4 Absolute Accuracy with Focused Laser Beam

The Importance of Laser Beam Quality and Focusing the Beam

Not all laser systems are the same. This topic is very important to understand. Some laser systems have a focus beam (see Figure 9-4) and some do not (see Figure 9-5). Blum laser systems are custom focused. Only a focused beam can provide the best accuracy and the capability to measure tools as small as .05mm (.002"). Every laser system has generally good repeatability characteristics, but only a focused beam provides superior *tool-to-tool* accuracy for tool blending of cutters with various tool geometries.

Software

Blum provides software for versions of almost all commercial available control systems (see Figure 9-6). The software is written in a parabolic programming format that includes calibration of the laser system with a qualified master tool, tool length measurement, tool diameter measurement, broken tool identification, defective cutting edge identification, form control scanning for tool wear characteristics, and axis temperature compensation.

Patent technology is built into the laser system that is called *NT* (New Technology). The laser software NT provides improved measuring

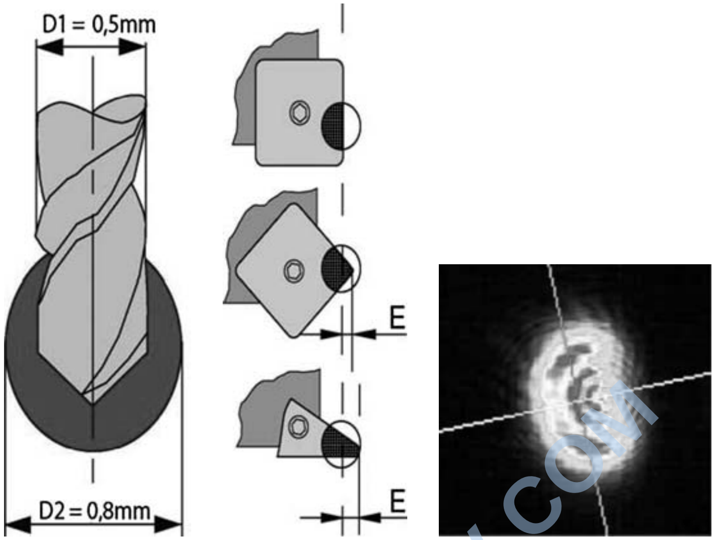
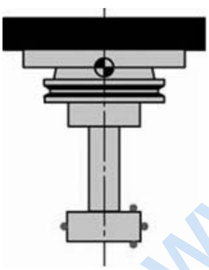
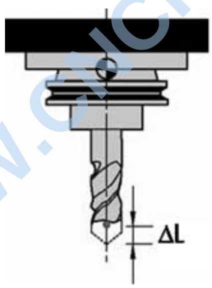


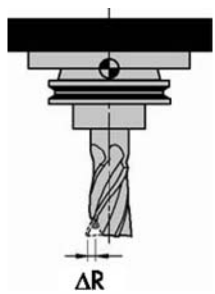
Figure 9-5 Absolute Accuracy with Non-Focused Laser Beam



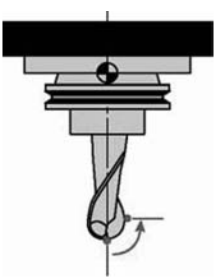
Calibration/Temperature Compensation



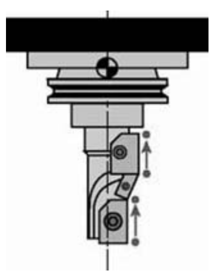
Tool Length Measurement
Tool Breakage Detection



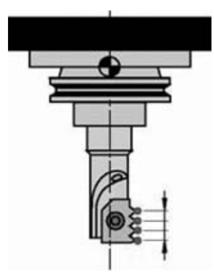
Tool Diameter Measurement
Defective Cutting Edge Identify



Form Control Scanning
Corner Radius Measuring



Edge Scanning



Thread Mill Scanning

Figure 9-6

accuracy, even with coolant and chips present during measuring. At the beginning of laser measurement, coolant and chips caused interference signals that became the main obstacle for the application of optical measuring systems in the machine tool work area. Up to now, this problem was solved by a plausibility check. However, the side effect of this method caused longer measuring times when coolant was increased in the working area.

The solution, presented only by Blum-Novotest GmbH (which received a patent for this technology), is the *NT* measuring method that positions the tool into the laser beam and then measures by moving "out of the beam". This method is used by others, but their ability to measure ABSOLUTE accuracy is greatly decreased. This is due to not having the patent technology *NT*, which has the ability to measure individual flutes at their *outer* edge when positioning the tool "out of the beam" (see Figure 9-7). When the outer edge is not measured, the tool is measured between the flutes. The length is then measured in the core cavity of the tool, causing the tool to be measured shorter than its actual true physical length.

Figure 9-7 Laser System with NT (New Technology) Software

Runout Control

The runout of cutting edges on milling tools is of great influence on production accuracy as well as on economic efficiency of milling operations (see Figure 9-8). The consequences of unacceptable run out are, amongst other things, reduced tool life due to vibrations and different cutting edge load, an increased load of the machine (especially the main spindle), dimensional deviations, and a reduced surface quality of the work-piece.

Static runout of the edges appears on slowly turning or standing milling tools; it is caused by tool-changing errors which may occur through, e.g., dirty surfaces of the tool taper. Additional reasons for static runout can be a cutting edge offset on the tool caused by setting errors of adjustable tools, or production tolerances at monolithic tools, as well as at tools with soldered edges.

Dynamic runout of the cutting edges only appears at higher turning speeds of the milling tools. The reason, therefore, is a deflection of the tool due to its being unbalanced and the resulting unbalanced forces which are mostly independent from the turning frequency. Centrifugal forces during tool setting may cause runout, depending on the rotational frequencies due to widened collets.

Figure 9-8 Safe Runout Detection is Possible Only Directly on the Edge under Nominal Speed

Other reasons for static or dynamic runout may be setting errors due to tolerances of the tool receptacle and also of the chuck, or pollution, in either of these areas. The cause of this error has significant meaning because the resulting setting errors may change after each tool change. This is a serious problem for finish machining on unmanned machine tools.

The dynamic run out which is dependant on the turning frequency of the milling spindle is very significant for fast milling spindles, especially for high-speed milling because the resultant centrifugal forces will increase with the square of the turning frequency.

For the complete recognition of the runout which is important for the machining result, it is necessary to measure the milling tools when they are set under nominal speed.

Today, to control tool changing contact error inaccuracies, proximity sensors are often used. The disadvantage of these proximity sensors is that they can only detect gaps greater than 0.03mm which is, however, not sufficient for many applications. This contact error causes an increase of the effective tool radius of 0.1mm for an HSK63 in combination with a tool length of, e.g., 210mm. This example makes it clear that this type of control is sufficient only to detect rough setting errors which may cause a loss of the tool, but is not sufficient to avoid machining errors.

Another method of detecting the concentricity of tools is to measure the flight circle by means of a laser light barrier. A tool radius measurement is carried out and the measured value is compared with the radial value of the tool compensation memory of the control. If an essential difference is measured, it is a matter of tool changing error. The measuring accuracy, however, depends on the absolute machine accuracy and, therefore, it is strongly influenced by different factors, e.g., thermal axis offset. Also optical restrictions like coolant mist can cause changes of the switching threshold of the laser light barrier.

With this new method (see Figure 9-9), for which the company has applied for a patent, the radius-measuring values are not considered absolutely, but relatively (see Figure 9-10). A measured tool radius is not compared with the value of a tool memory, but with a virtual concentricity measuring value. This measuring value is updated at each concentricity control; deviations are not considered absolutely, but in relation to a previous measurement. Gradual changes such as machine drifts, coolant and swarf build up on the tool tip, tool wear, or switching threshold offset

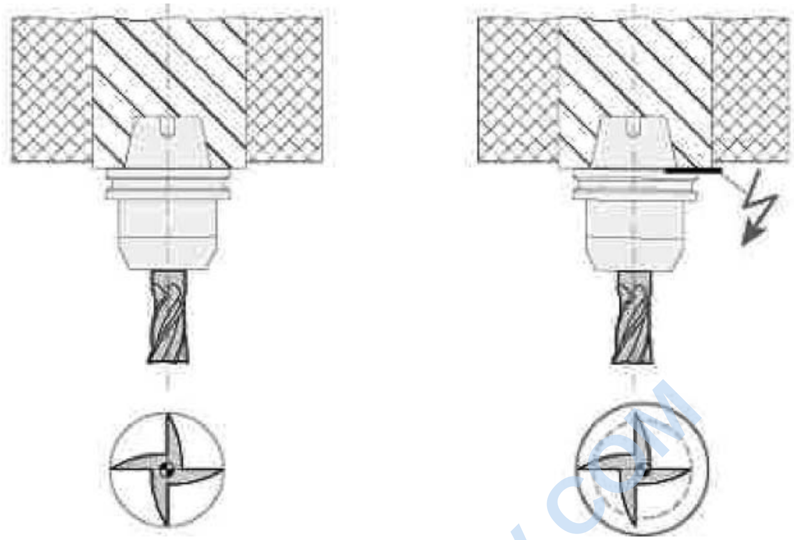


Figure 9-9 Blum Runout Control, Detection of Setting Errors within Seconds

by coolant mist will be ignored. If a tool changing error should occur, it causes a spontaneously-changed measuring value and so it is immediately detected. With this method it is possible to detect runout of a few microns under production conditions.

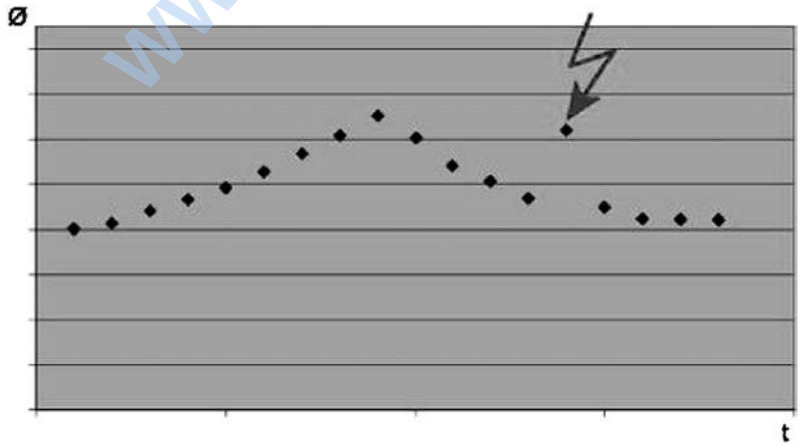


Figure 9-10 The Relative Consideration of the Measuring Values Detects Setting Errors Reliably and Fast

Another advantage of the Blum Runout Control is the reduction of the measuring time. As the expected switching threshold is exactly known, it is possible to choose a very small measuring window which reduces the measuring time to seconds.

New Laser System Laser Control NT-H for Temperature Compensation of the 3rd Axis

The abbreviation *H* in the name of the system means hybrid. In this version, the high-precision laser system by Blum is completed with an integrated mechanical probe (see Figure 9-11). The hybrid laser system NT-H is available in two completely different versions that can fulfill the following measuring tasks:

1. When installed in the beam axis direction, the laser system is capable of monitoring the third axis. With this version, thermal compensation of three axes can be determined for a machining center.
2. When installed at 90° to the laser beam, the hybrid system is used to perfect the absolute accuracy of smallest tools in mold and die production (see Figure 9-12). In this application, the "optical fault" which results from the relative (final) size of the

Figure 9-11 Hybrid Laser for Thermal Compensation of All Machine Axes

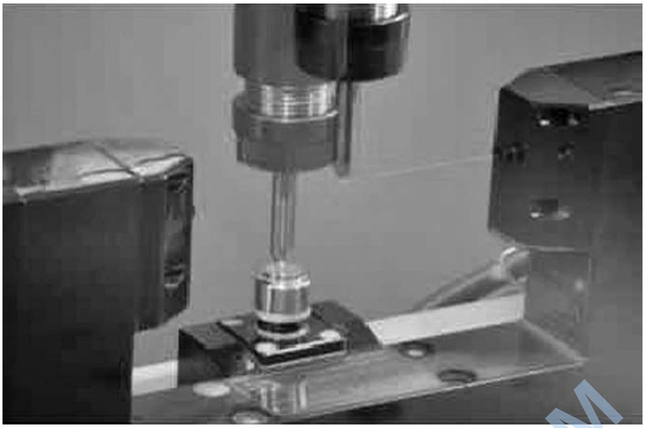


Figure 9-12 Hybrid Laser to Perfect the Absolute Accuracy in Mold and Die Protection

focused laser measuring point to the tool tip will be measured and compensated for by the probe. Both measuring tasks will be supported by the appropriate software cycles from Blum.

Workpiece Probes

The Blum-Novotest TC Probe family offers solutions for precision measurement, fast part, and fixturing location. The BLUM Workpiece Touch Probes are used to determine work piece position as well as tolerance deviations and thermal drift in machining centers. The three probes, models **TC**50, **TC**51 and **TC**51-20, are designed for different application fields, but share some identical characteristics.

- The most significant feature of the new probes is the precise and repeatable trigger generation characteristic in all directions (see Figure 9-13). Conventional probes often use the three-point contact measuring principle. Deflecting the stylus results in electrical or optical changes, finally generating the trigger signal. The disadvantage of this method is its different measuring results, which are—depending on the touch direction—measured in XY. This inaccurate triggering (lobing effect) that is prevalent with conventional probes has been consequently avoided by BLUM for over 20 years with different measuring principles.

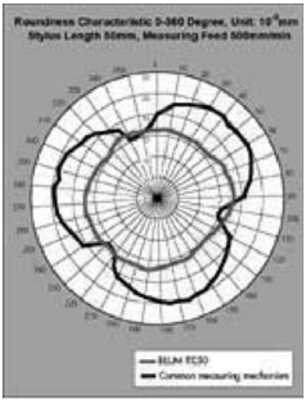


Figure 9-13 Roundness Characteristic at Different Contact Directions

- The signal generation of the TC probes is done with the same non-contact optoelectronic measurement principle as used in all BLUM measuring components. Deflection of the stylus results in shading of the interior miniature light barrier. Because of this non-contact principle, the accuracy of the probe is consistent over lifetime and allows an essential, faster-measuring speed than conventional probes.
- A protective air curtain integrated into the infrared receiver IC55 helps to save the cumbersome installation of an air nozzle in the work area.
- Another characteristic is the common power supply for all probes using a standard 9V block battery with low-energy consumption for up to 100,000 contacts.

Touch Probe TC50/52

With the universal multi-directional probe model TC50, BLUM introduces a new measuring principle. The circular measuring system is in the counter-bearing of the housing and shades; using a movable element, the miniature light barrier operates with a consistent repeatable movement, independently of the deflecting direction of the stylus. The optoelectronic measuring principle provides constant multi-directional touch characteristics in all directions without disadvantageous lobing, as shown in Figure 9-14. Due to its mechanically robust design, the TC50 can withstand fast acceleration and rapid machine movement, without false trigger signals by deflection of the system or mechanical damage.

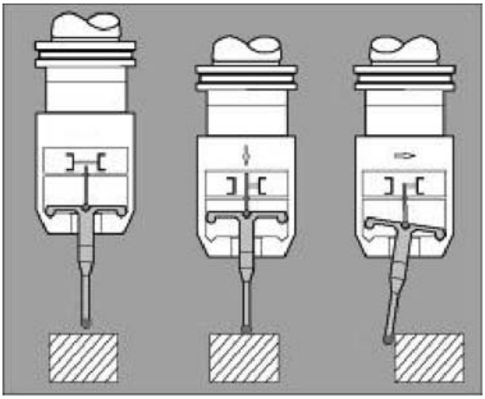


Figure 9-14a Universal Probe TC50

Figure 9-14b Probe with Rotational Symmetric Measuring Principle

The special coating of mechanical parts and the no–wear optoelectronic measurement system guarantee extended probe life and consistent accuracy over lifetime of the TC50.

Highlights:

- precise non-lobing touch characteristics
- robust design
- no-wear, optoelectronic signal generation
- extended battery life
- reliable infrared data transmission
- compatible with BLUM bore gauge BG40 and adjustable boring bar

Touch Probe TC51

The probe model TC51 uses the high-precision, bi-directional measuring principle developed by BLUM (see Figure 9-15). When probing in Z-direction, the stylus is shading a miniature light barrier by axial movement. The second defined probing direction in XY is shading the light barrier by tilting around a fixed turning point. This requires the appropriate spindle orientation of the probe to the work piece.

The advantages of this principle are obvious. It is extremely fast at positioning and measuring, with a measuring speed of up to 8m/min

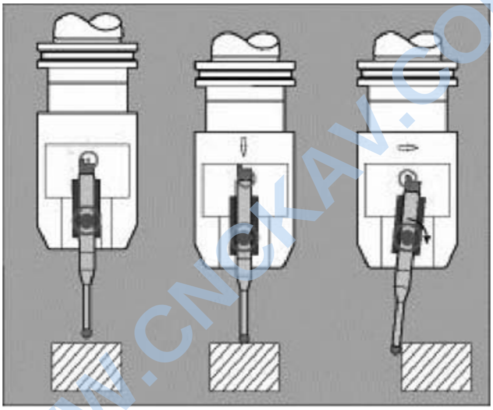


Figure 9-15a Probe with Bi-directional Measuring Principle

Figure 9-15b Probe TC51 for High Productive Applications

and accelerations of up to 10g. The high accuracy of this system is based on the defined stylus deflection, the fast touch speed and avoidance of premature triggering when coolant is present.

BLUM has built this principle into more than 5.000 larger probes. With the compact standard probe model TC51, it is now available for all machines with spindle orientation.

HIGHLIGHTS:

- extremely fast acceleration and measuring speed
- super precision
- touch proof even with coolant
- robust design
- no-wear optoelectronics and signal generation
- reliable infrared data transmission
- compatible with BLUM bore gauge BG40 and adjustable boring bar

TOUCH PROBE TC51-20

The design of the probe model TC51-20 allows the pushing measurement in Z-direction as well as a pulling move for precise measurement of grooves, slots, and shoulders (see Figure 9-16). Due to its extreme speed, the probe is perfectly suited to work on high-speed machine centers where time is of the essence.

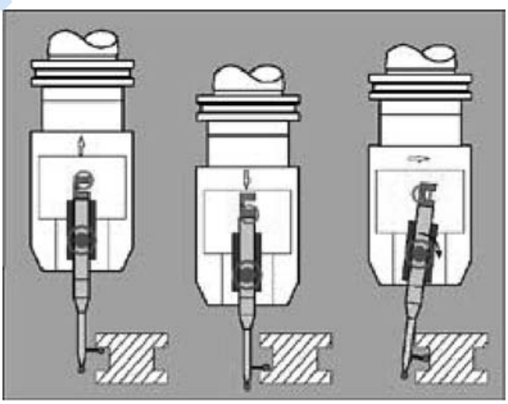


Figure 9-16 Probe TC51-20 with +Z and –Z Measuring Direction

Touch Probe TC52

With a diameter of 40mm and an effective length from spindle nose to stylus tip of only 112mm, the TC52 sets new standards (see Figure 9-17). This system has a completely innovative optoelectronic measuring unit. Compared with a lot of other probes, the TC52 has the same measuring results when probing in various directions. Constant measuring forces at any spindle position allow for precise measuring results. This is especially important for motor spindles as they often have no spindle orientation.

If the stylus touches the work piece, a miniature light barrier is shaded inside. This non-contact trigger principle by Blum, which has already been proven for many years in other applications, is absolutely wear-free and guarantees constant accuracy of the probe. It allows an

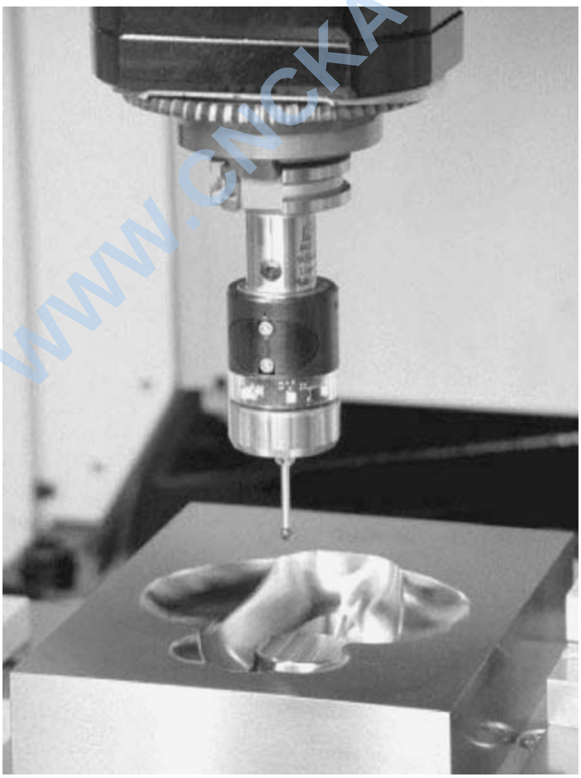


Figure 9-17 Probe TC52

essentially higher measuring speed than other comparable probes. The TC52—with its compact design, extended battery life, and high reliability—can be universally used to determine work piece positions and measurement at a repeatability of 2 Sigma < 1 µm, and is suitable for all types of machining centers. The system is equipped with the latest infrared data transmission technology IC55 by Blum and has an optimized energy consumption for up to 100,000 approaches without battery exchange.

Infrared Receiver IC55

All Blum work piece probes and bore gauges are now compatible with the new fail-safe Infrared Transceiver IC55 (see Figure 9-18). The IC55 is also compatible with the Komet adjustable Boring Bar M042 that enables an economic integration of multiple measuring devices using only one receiver.

Operating Modes

- switch ON/OFF via IR flash·signal
- transmission for TC series
- 16-bit measuring value transmission for bore gauge BG series
- control of active tools
- The integrated air nozzle guarantees signal transmission without interference and wear.

Figure 9-18a The IC55

Figure 9-18b A Standard for All Products

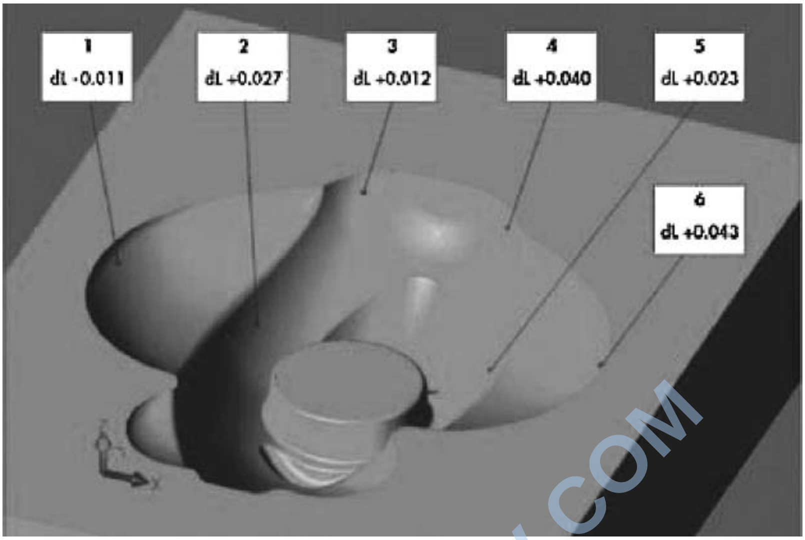


Figure 9-19 Measuring Forms on Machining Centers

Blum's new probe family offers the right solution for a variety of different applications. Probe model TC50 is a universal system for mold and die production as well as for precision machine shops. The probe model TC51 is designed for a high-production environment where time is of the essence. Several accessories, such as self-centering styli for quick exchange and standard software for different controls, are available. The customer's advantage is a precise, faster, more reliable, and, therefore, more economic measuring system.

FormControl

With the FormControl, it is possible to measure forms on machining centers (see Figure 9-19). The advantage is that quick form control can be carried out directly on the machine tool, thereby eliminating time-consuming resetting of the tool onto a measuring machine.

It is possible to rework the work piece in its original position without having to reset it. This saves time-consuming alignment of the work piece and increases the accuracy essentially at the same time.

Thanks to ADIF (Automatic Data Interface), the measuring results are available immediately. There is no faulty manual generation or transfer of measuring programs. The measuring results can be evaluated directly on the screen and then be printed in a clear protocol for documentation purposes.

Chapter 10

Case Studies for Hard Milling and High Speed Machining

By Dale Mickelson

A2 60Rc

Figure 10-1 shows an example of A2 60Rc material. The mold core in this example is being machined today using an advanced hard milling process. In the past, aerospace industry manufacturers have been the largest users of four- and five-axis machining centers. Today, due to the difficult geometries of die and mold parts, multi-axis is more common to growing manufacturers.

Because of the multiple axes available today, software programs are becoming more complex and taking longer to learn. This market requires detailed training to obtain the knowledge needed to create machine code. Therefore, it is critical to purchase products for this process from knowledgeable venders. The people selling this product must know how to educate their customers to use their products in order to obtain maximum efficiency.

The customer for Figure 10-1 was spending over 17 hours producing this part. They were using multiple setups with EDM wire and electrodes. Now they can machine this part in 42 minutes. Due to four-axis capabilities, shops are now able to eliminate multiple processes by using ridged indexing systems.

H13 55Rc Cell Phone Mold

The customer for Figure 10-2 spent over 60 hours per mold using EDM electrodes, soft machining, and polishing. Now the customer can make a mold in less than 3.5 hours.

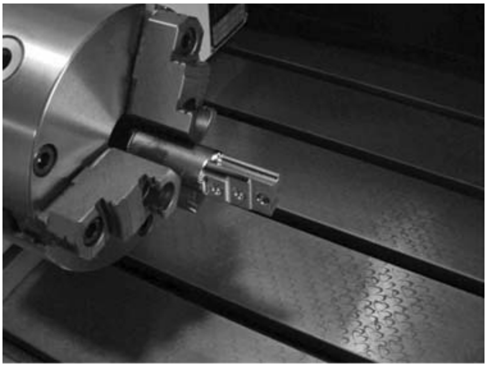


Figure 10-1 A2 60RC with Rotary

H13 is a commonly-used material for plastic injection molds. This material is successfully machined using cutters coated with ALTIN. In this example, the 2-mm cutter is traveling at a feed rate of 70 inches per minute, and a spindle speed of 15,000 rpm. A 3-mm cutter used for roughing this mold was traveling at a rate of 150 inches per minute. Now this cell phone mold can be hard milled in the same time it takes to machine the electrodes needed for the EDM process previously used.

H13 52RC Forming Dies

The customer in Figure 10-3 was soft milling each part in 1.5 hours, then sending the part out for heat treatment and hand finishing. Now the customer can hard mill each part in a little over 18 minutes, with no hand polishing or soft machining process.

Figure 10-2 Cell Phone Mold

Figure 10-3 Forming Dies

CAMTOOL Software

Roughing Tool Path

Figure 10-4 is an example of a roughing tool path applied to a 3D part model. Most software is incapable of recognizing previously machined areas. Due to this, the tool path has a large amount of air cut, which results in extend cycle times.

Optimized Toolpath

Figure 10-5 shows the tool path after it has been optimized to the work piece model. As you can see, it only leaves tool path where the

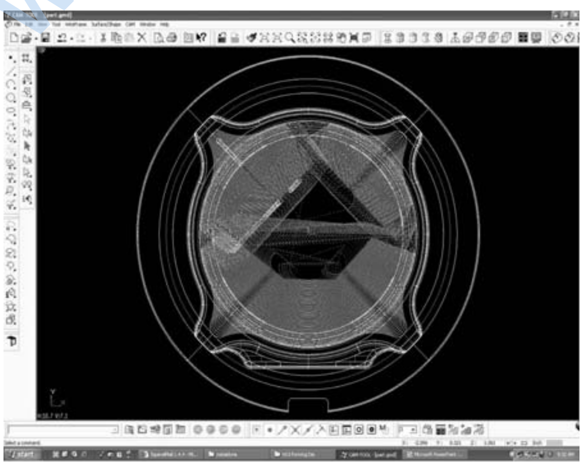


Figure 10-4 Roughing Tool Path

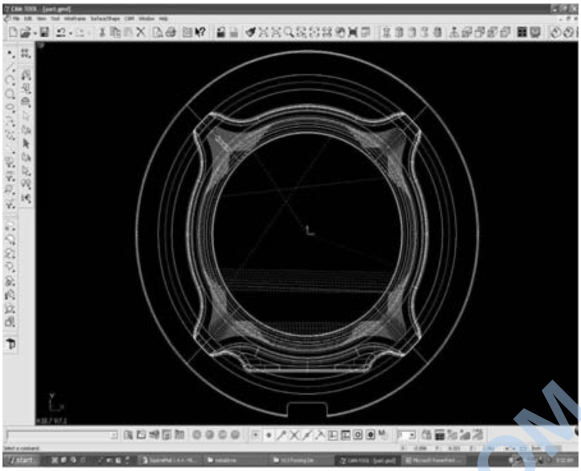


Figure 10-5 Optimized Tool Path

cutter will engage the material. This software makes efficient tool paths, decreasing cycle times. By using inefficient software programs and manually editing the codes, there is a great risk of crashing your machine tools.

Trochoidal Tool Path

A trochoidal tool path is required during the machining of the slot illustrated in Figure 10-6. It is needed to ensure that the tool life is maintained and the part is cut closer to net shape.

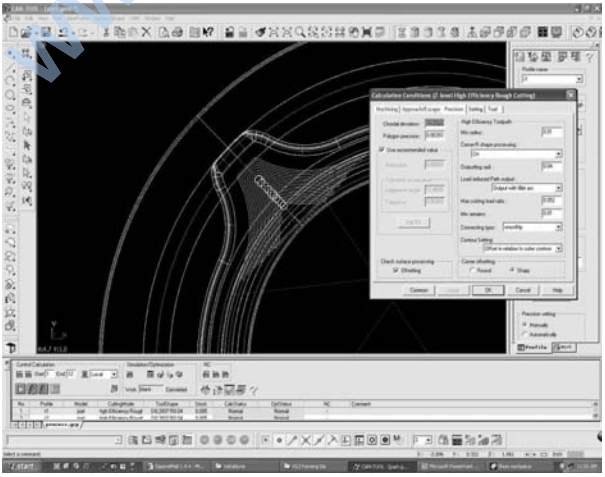


Figure 10-6 Trochoidal Tool Path

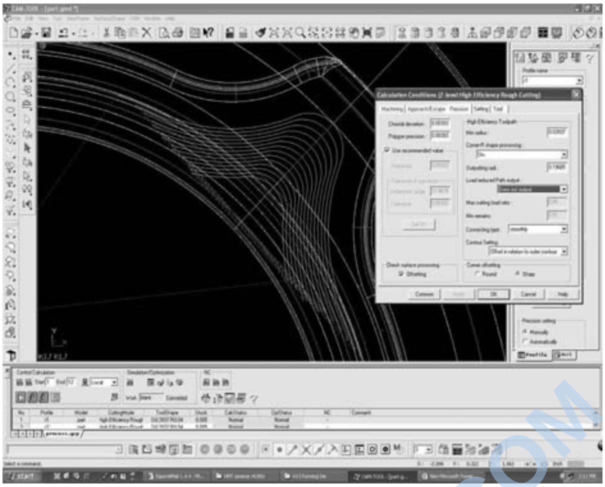


Figure 10-7 Standard Programming

Standard Programming Technique

In Figure 10-7, the slot is made with a standard programming technique. In this copy, notice there is more material in the corners then in the trochoidal example. Without the slot being cut to its net shape, the finishing cutter will now encounter a larger amount of stock,thus shortening its tool life.

NAK80 40RC

Figure 10-8 provides an example of a new cutter on the market for high speed machining and hard milling. The design of this cutter is a two-piece system to help customers save in their consumable costs.

The insert on this tool can be replaced with multiple geometries, thereby allowing the operator to change the insert without pulling the tool out of the machine. During testing, this cutter proved to have consistent tool life in hard and soft steels. The soft milling cycle time was under 9 seconds. Machining in nak80 40RC materials.

D2 58RC

D2 58 Rockwell (see Figure 10-9) can also be machined with the same design as listed in the previous example. This is a test for machining ball locks. Finishing time in this material was 17 seconds.

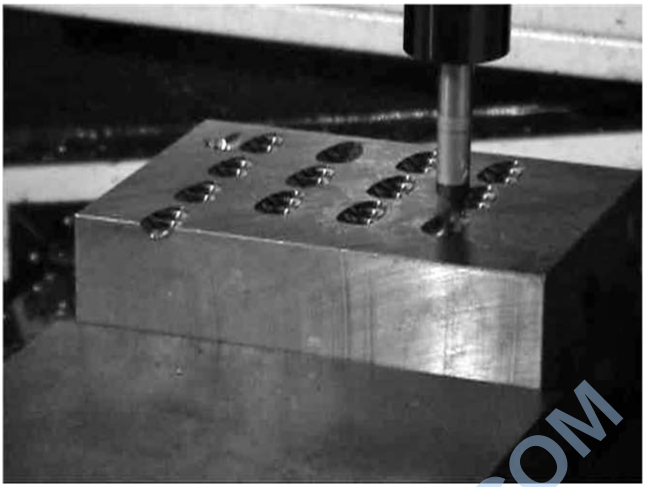


Figure 10-8 Ball Locks Roughed

Figure 10-9 Ball Locks Finished

420SS 52RC

Figure 10-10 shows a safety glass mold that I produced for a customer who was scraping 75% of this style mold. He would machine, buff, and then polish in a super fine finish. While buffing, the operator made flat spots in the mold. After shooting the clear plastic, the inspector

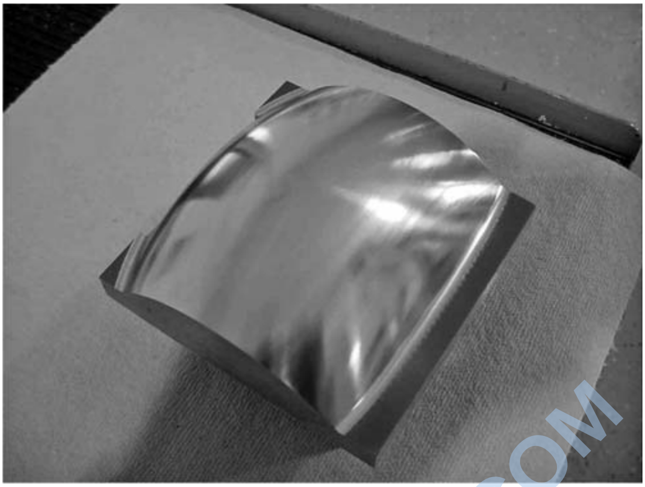


Figure 10-10 Safety Glass Mold

would shine light through the lens and check for a spectrum. This was the reason for the scrap problem. However, with the right machine, program, and tool, the customer was able to eliminate the buffing process, leaving only the diamond polishing. The product is now produced in less than half the time, and with no scrap.

420 Stainless 52 Rockwell

I use two types of holders for finishing: A high-speed collet system and a heat shrink. These two systems have given me the ability to provide high-gloss finishes along with tight accuracies. Figure 10-11 shows a part made with the high-speed collet holder from HPI.

420 Stainless 52 Rockwell Lenses Mold with a Magnet

Magnets are commonly seen in shops today. We use magnets for roughing and finishing molds and for die components. This work holding design, seen in Figure 10-12, gives the machinist the ability to machine the outside as well as the inside of the part. As you cut the material, the chips tend to collect to the sharp corners left over. You will need to use air or coolant to keep the chips clear of the cutter to keep from being re-cut. The chips come off of the part fairly easily when lightly persuaded.

Figure 10-11 Lens Mold

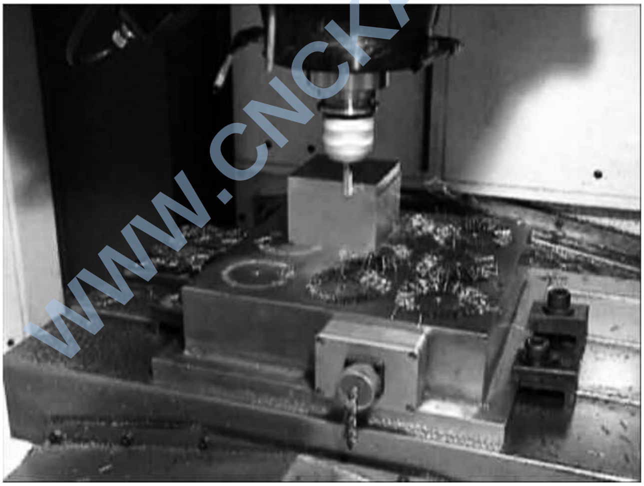


Figure 10-12 Roughing

420 Stainless 52 Rockwell: Roughing Technique

Figure 10-13 shows the roughing technique for making this core. The cutter I am using has its best performance when taking deep axial cuts and shallow radial cuts to create a long thin chip.

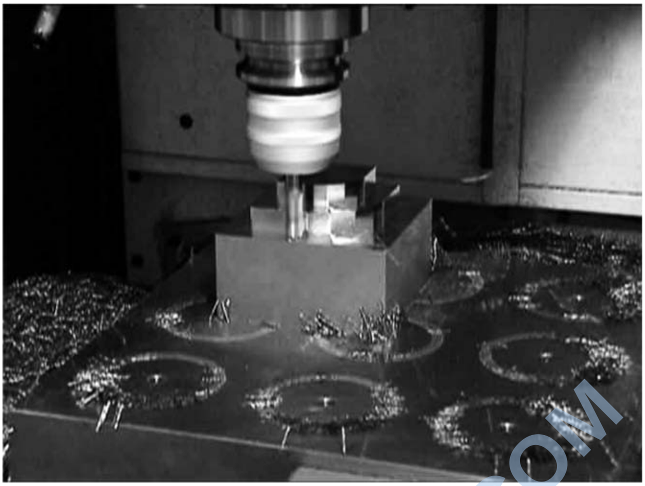


Figure 10-13 Semi-roughing

420 Stainless 52 Rockwell: Small Steps

The next technique I use takes small axial and radial steps to get closer to the core's net shape (see Figure 10-14). This technique is harder on end mills than the full axial example previously described. You will experience more vibration, eliminating valuable tool life. Today, we have a better way of machining this next level. Because of the new cutters

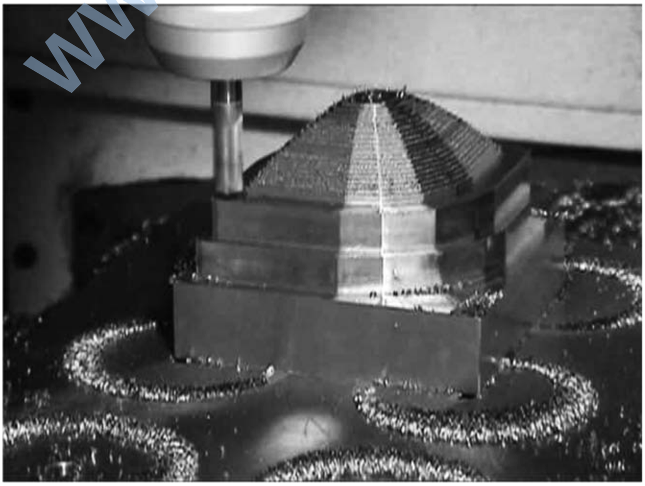


Figure 10-14 Semi-finishing

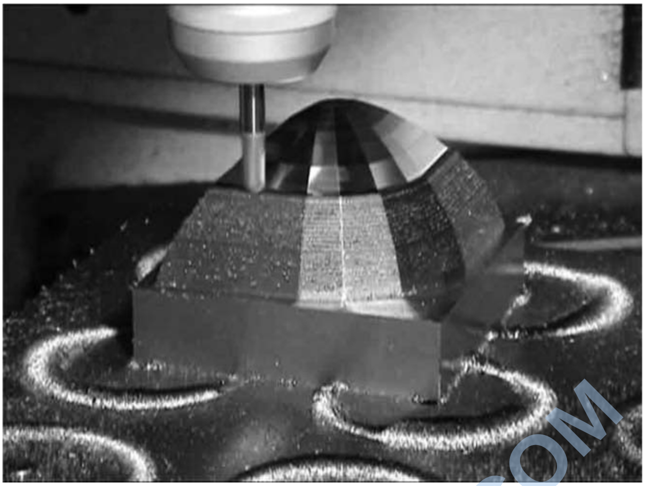


Figure 10-15 Finishing

developed for this process, now we can use high feed cutters with 2-mm and larger corner radiuses as well as the ability to remove material at high rates of speed.

420 Stainless 52 Rockwell: Finishing Cutter

In Figure 10-15, you will see the finishing cutter doing its job. This example shows micro-grained carbide with a special coating made just for stainless materials. As you can see, the finish gives the customer the ability to machine parts with little or no polishing.

420 Stainless Soft: Hitachi ASR Insert Cutter

In Figure 10-16, I am using a Hitachi high feed insert cutter. It will take up to .040 chip load per tooth in soft materials. The holder used for this type of cutter is called a milling chuck. It is an accurate collet style system with the ridged stability to do this type of heavy roughing.

420 Stainless Soft: High Feed Carbide Cutter

In Figure 10-17, you see a high feed carbide cutter running at a feed of 360 inches per minute. The customer had been spending 40 hours making this part using conventional machining. Now, with high speed machining, it is done in 2.5 hours.

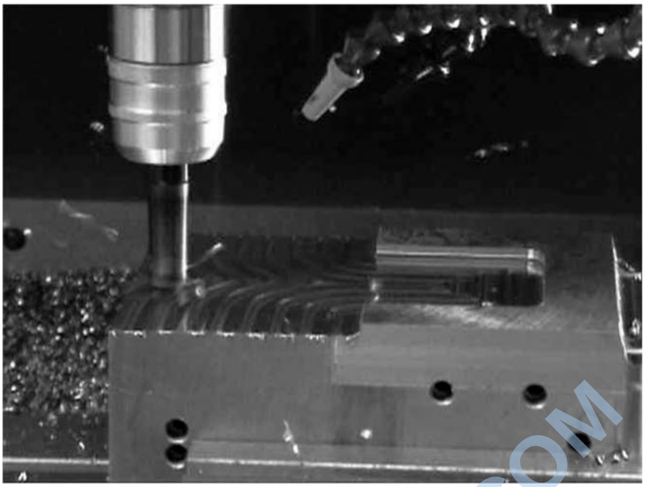


Figure 10-16 High Feed Roughing

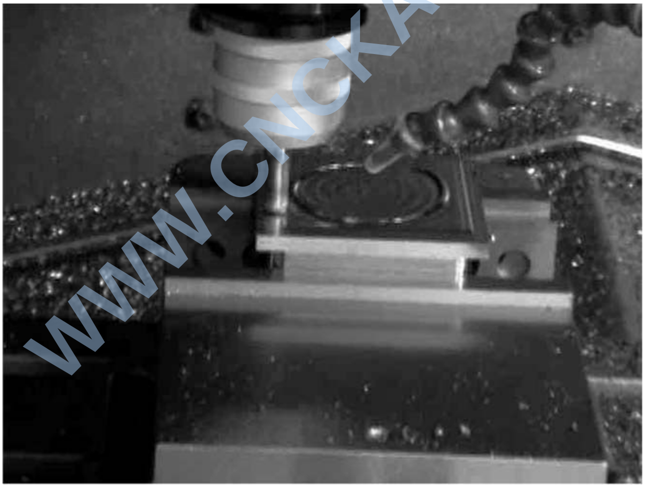


Figure 10-17 High Speed Roughing

.08 Diameter Drill 440C Stainless 60 Rockwell

Figure 10-18 shows an example of a micro-carbide drill making a hole in hard 440C stainless material. Generally this is only done if the part needed to be repaired after the material was hardened or if the tolerance didn't allow for the hole to be put in prior to heat treatment.

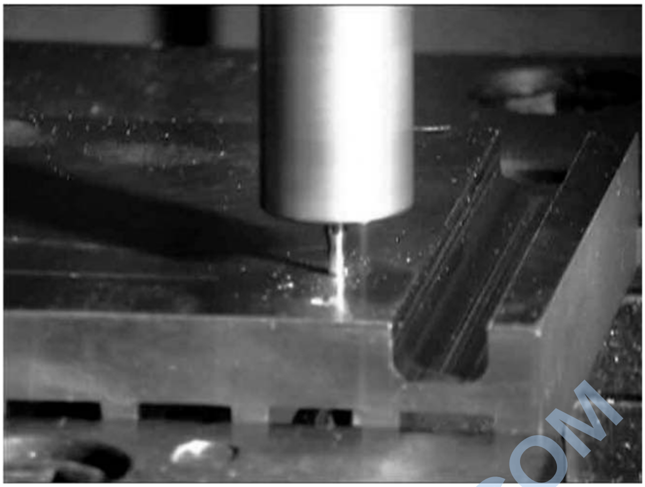


Figure 10-18 Hard Drilling

4-40 Tap 440C Stainless 60 Rockwell

In Figure 10-19, I am taping the hole I drilled in the previous example. We have the ability now to drill and tap extremely hard materials to repair or maintain a specific part tolerance. To do this successfully, you will need to have an option in your machine called ridged taping.

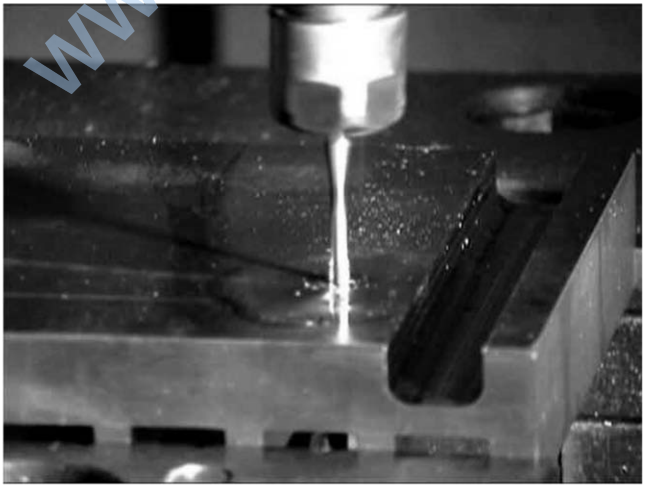


Figure 10-19 Hard Taping

That is where you can program the pitch into the feed and the machine will do all the work. Before ridged taping, we would use spring-loaded taping heads to allow for machine inaccuracies.

440C Stainless 60 Rockwell: Trochoidal vs. Slotting

When the trochoidal technique was first developed in software programs, I tested it to see how it would affect tool life (see Figure 10-20). The first slot in the test was done with the conventional slotting technique. With the recommended feeds and speeds of the cutter manufacturer, the tool burned out at only a quarter-inch deep. Each slot is at a depth of .300. The next nine slots were completed successfully with the same style cutter by only using the trochoidal technique. I ended up with nine times more tool life just by using the trochoidal technique.

440C Stainless 60 Rockwell: 6-mm Ball End Mill

In the example illustrated in Figure 10-21, I tested a chrome-based ball end mill in this hard 440C stainless. It cut ten slots without the tool braking or losing its ability to cut. The geometry of the ball end mill is more efficient at slotting than that of flat-style end mills.

Figure 10-20 Trochoidal vs. Slotting

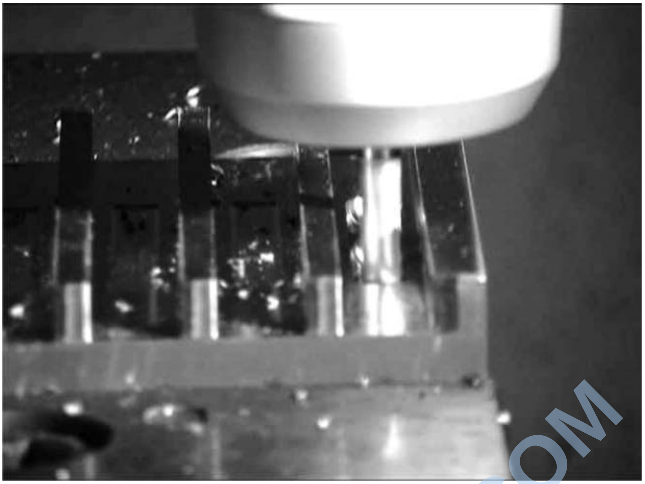


Figure 10-21 Special Cutters

420 Stainless 52 Rockwell

In this test illustrated by Figure 10-22, you will see the same cutter and coating made for stainless. The chrome base on this cutter keeps the material from sticking to it, giving this part its extreme micro-finish.

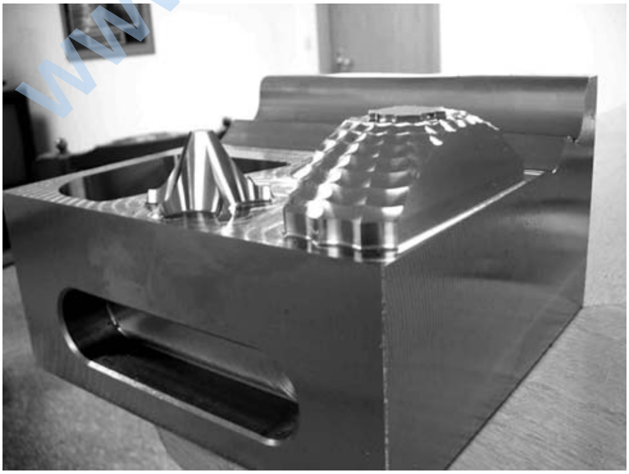


Figure 10-22 Extreme Finishes

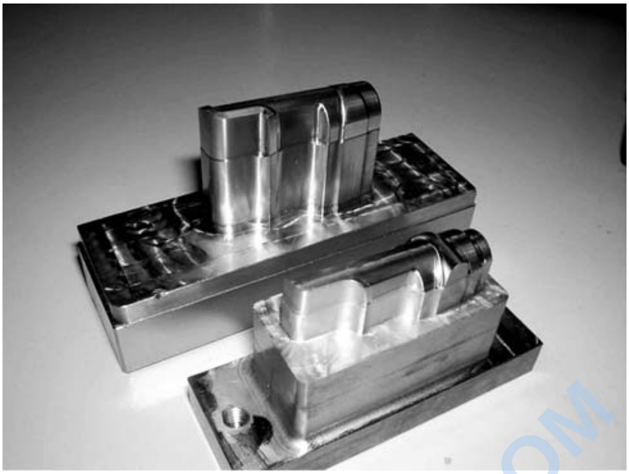


Figure 10-23 Copper Electrodes

Copper Electrodes vs. Graphite

Machining graphite requires special machines with dust collectors, air tight housings, and special cutters with expensive coatings. Because we are replacing more processes with hard milling, the need for graphite machining is shrinking. As you replace your graphite use, you can also start replacing your graphite with copper (see Figure 10-23). This material is machined with the same coolant you use in your steel cutting machines. This material doesn't require high-priced diamond cutters like graphite does. There are special chrome-based cutters on the market for this material that are half the cost of diamond. You can also use standard non-coated carbide if you want and still get the job done.

CPM10V 64 RC

Figure 10-24 shows a test cut between two different coatings in CPM10V. The growing need to cut powdered metals is driving coatings to a new level. The first coating that was tested was ALTIN. In that test, the cutter ran for 1.6 hours before total failure. In the next test, the coating was called TH. That cutter lasted for just under 2 hours, making the TH coating the winner against the powder metal.

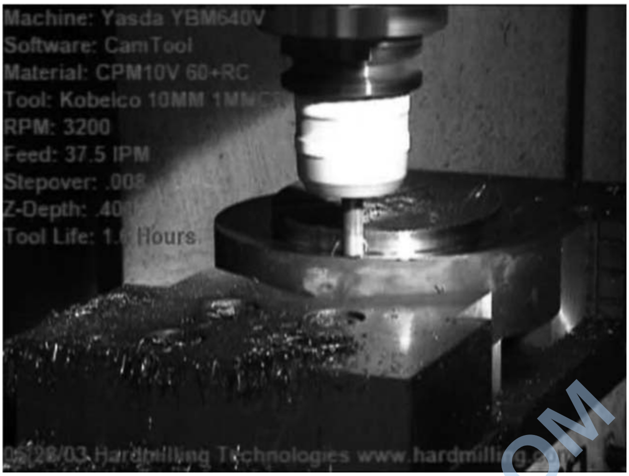


Figure 10-24 ALTIN vs. TH

CPM15V 68RC

Figure 10-25 illustrates an example of someone not believing a job could be done. Here is a powdered metal that is extremely abrasive and has a hardness capability of 68RC. In this test, I had to make a slot down the full length of the part. With all the correct variables in place, this material can be machined in its maximum hardened state by using the best products on the market.

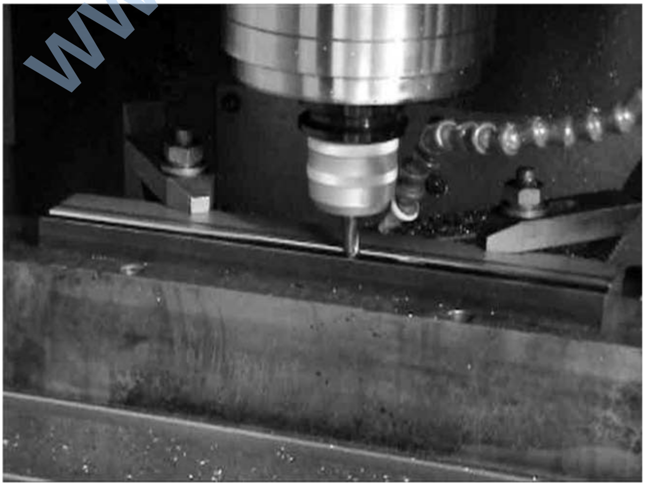


Figure 10-25 Broach Cutting

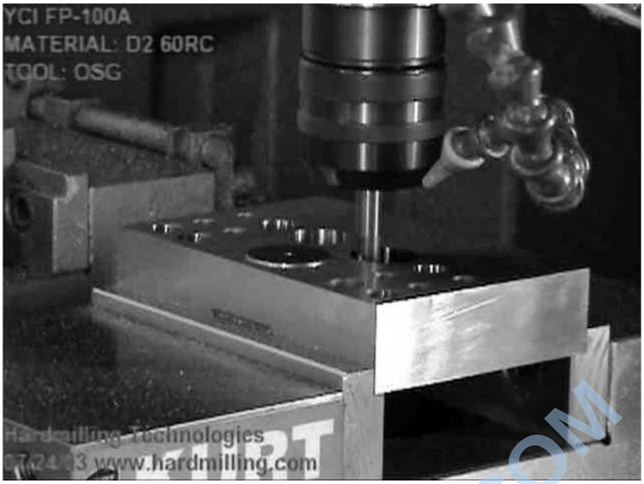


Figure 10-26 Hard Milling Dowel Pin Holes

D2 60 RC

Another lengthy process in the shop today is jig grinding. In Figure 10-26, you see an example of an end mill cutting a dowel pin hole strait, round, and accurate. By using special cutters and accurate holders with a machine that can make a tight circle pattern, you can replace your jig grinding with your high-speed machining centers. Now you can machine a hole in half the time it takes to jig grind it. You can also make a variety of different sizes with the same program and walk away while the machine is cutting them.

Cutting 718 Inconel with Ceramic Inserts

Inconel is used in a variety of aero space applications because of its ability to take heat and stress well. The chemistry data of this super alloy is listed as: aluminum, boron, carbon, chromium, cobalt, copper, iron, manganese, molybdenum, nickel, niobium, phosphorus, silicon, sulphur, and titanium. Because of these hard-to-machine metals included in the structure of this material, companies are always looking for a better way to remove material fast and efficiently. The old way to machine this metal was by using basic carbide inserts. The surface footage for those inserts would range within 50–200 SFM depending on the cutter geometry.

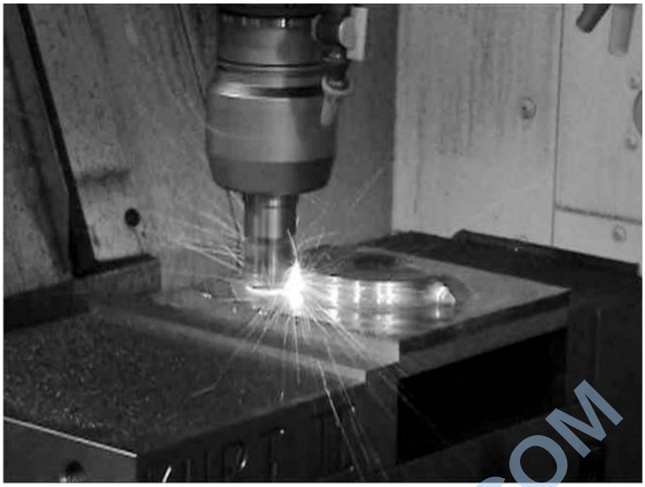


Figure 10-27 718 Inconel Testing

As I found in testing the ceramic inserts, the surface footage was over 3500. Because the ceramic can't take heavy vibration, it uses its ability to take extreme heat while cutting the part. It melts the material during the cutting process, as you can see in Figure 10-27. The best cutting condition for this type of cutter is to stay in the material as long as possible. Moving in and out of the cut results in loss of insert life.

EDM vs. Hard Milling Finish

This is the test result from an EDM finish and a hard milling finish. The two examples on the left in Figure 10-28 are from the EDM surface finish. The two readings on the right are from the hard milled surface. The EDM produced an Ra of 1.10 and Ra of 1.20. The hard milling produced an Ra of .22 on the top of the part and an Ra of .17 on the side. By controlling all the variables in hard milling, you will create hands-free accurate finishes.

Hi Feed Cutter Testing

Hi feed cutters are used just before you finish the part. This style of cutter is very efficient in removing the remaining stock left over from the larger insert cutters. Because there are so many on the market with a large range in price, we decided to find the best one for the money.

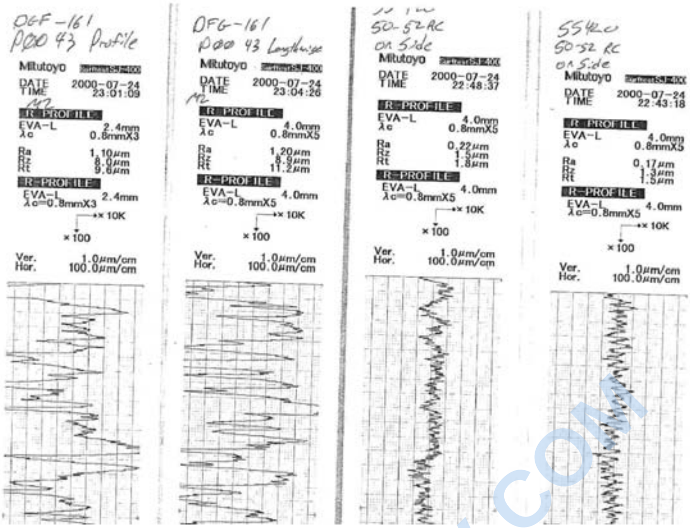


Figure 10-28 Hard Milling Finish Better Than EDM

The price range was from \$370 to \$80.00 for a 10MM diameter. The test material was P20 and the finished result would end in cutter destruction, as seen in Figure 10-29. In the end, a cutter costing a little over \$100 out performed the others and only cost \$16.88 an hour to run at 400 inches per minute.

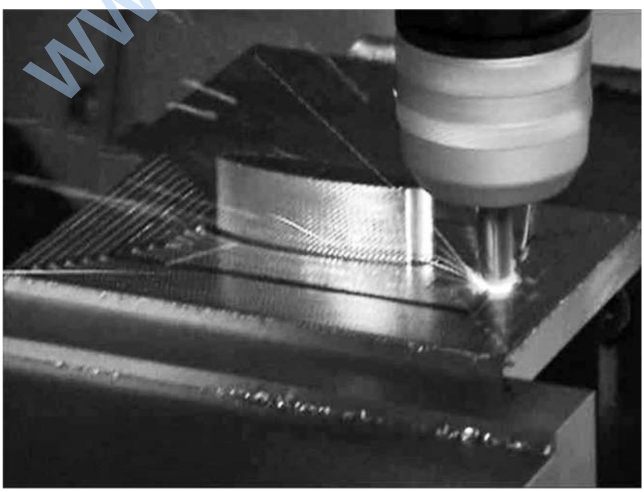


Figure 10-29 High Feed Cutter Test

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To: Randy Nash, President
Graphic Products North America Inc..

From: John Turcotte, President
Granby Mold, Inc.
Date: 5/18/06
Re: CAM-TOOL Software

Randy,

Granby Mold purchased CAM-TOOL Software with the purchase of an Okuma CNC Milling machine. Granby was primarily looking for a new milling machine capable of Hard Milling and High Speed Milling, as well as being very accurate. Dale Mickelson of Gosiger of Michigan (local Okuma and CAM-TOOL distributor) convinced us that we would have greater success with CAM-TOOL. He was right! In a matter of one month Granby Mold became confident in the capabilities of CAM-TOOL. In the 5 months since we purchased CAM-TOOL, we have machined hard die details, cavities requiring little or no benching, very fine detail with 0.5mm cutters, and ribs. We leave the machine running unattended thru the night regardless if we are roughing, semi-finishing, or finishing small details such as ribs. This adds lots of productivity to a small one-shift company like Granby Mold. We have been running lights out for many years with our older equipment and software, but usually not roughing or fine finishing operations.

As a mold-maker accustomed to machining cavities, we are thrilled with the CAM-TOOL's tool-paths to dig out corners. The software always knows what stock is left in the corner and will automatically take multiple passes as required in the corners. This not only reduces the amount of edm work, it also increases cutter life, because the software generates programs for a constant chip load. We have experienced these benefits not only on the new Okuma mill, but on our 10 year old machines as well.

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The automation is not only in the tool-paths, but also starts as soon as the file is imported. CAM-TOOL has excellent surface analysis tools and can usually heal 80-90% of the surface problems automatically. These features quickly increase the programmer's confidence that the tool-paths generated will be error free. The software also takes advantage of the latest computer hardware advances such as dual-core processors. We loaded our CAM-TOOL software on a computer with two dual-core processors. This allows our programmer to have programs running for one job while he is getting another job ready. At night, the CAM-TOOL software generates a large batch of programs using the two processors and dual-core technology to speed things up, and they are ready to review in the morning.

Finally, the training and support from Graphic Products North America and Gosiger of Michigan is outstanding. The attitude of everyone involved with CAM-TOOL is that "the customer must be successful." The training is not only generous, but flexible as well. They want to fit your schedule. They prefer small classes (as small as 2) so they can fit the class to the customer's specific applications. The support that follows is also impressive. The CAM-TOOL personnel want to know about any challenging jobs, or new opportunities that they can help with. That probably has do to the confidence they have in their product.

Thank you,

John Turcotte
Granby Mold, Inc.

Hard Milling Investment Immediate Success

Three years ago I was introduced to Dale Mickelson and hard milling. I was employed by a mold shop where the owner had the foresight to see what was needed to be competitive and succeed in today's rapidly changing marketplace.

My position there was to program and machine graphite electrodes to be used to EDM various mold components. The opportunity to learn a new process and the challenges it offered was something that I readily accepted. It was exciting to be able to learn and use new software and a completely new machining process that few other people were using. Little did I know at the time where this opportunity would take me.

Learning the hard milling process required learning new programming and machining techniques, as well as understanding machine construction, the different types of tool holders, and end mills, and how they apply to the process. With Dale's help we were able to make the hard milling investment a success almost immediately.

In today's market place customers are demanding lower costs for their tooling as well as shorter lead times. Shop owners, on the other hand, are faced with higher operating costs, everything from raw materials to employee benefits. Foreign competition is another concern to shop owners. With hard milling and high speed machining, I have seen the time to produce a quality mold reduced greatly and company profits rise at the same time, all while satisfying customer demands. Also, with hard milling the need to machine costly electrodes and the time consuming EDM process is greatly reduced. With the surface finishes possible by hard milling, I have also seen the need for labor intensive hand polishing of molds greatly reduced and in some instances eliminated.

As the demands of hard milling grow, the manufacturers of machine tools, end mills, and software are constantly advancing their technology. With this advancement in technology, it is important for shop owners, programmers, and operators to continue to advance as well. Unfortunately it can be difficult and expensive to test and develop the process in a shop environment while keeping up with production demands. For that reason, shop owners around the country rely on hard milling specialists like Dale Mickelson to test and develop the process. For the past three years I was one who appreciated the data Dale would provide. Today it is a privilege to me to now work with Dale and to continue to develop the hard milling process.

Gerry Byykkonen
Application Engineer
Gosiger Michigan

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NTMA

PRECISION

The National Tooling & Machining Association is the largest trade organization in the Unites States representing manufacturing companies all across America. The NTMA is made up of over 1700 small to medium size manufacturers, covering all industries and utilizing nearly every type of process imaginable. Most people are completely oblivious to the economic impact that manufacturing has on this country and its dynamics that shape our lifestyles. Work is moving offshore to emerging countries, customers are looking for cost reductions and stretching their payments, and skilled labor is becoming more difficult to find. These issues and others continue to drive the cost of doing business higher.

The NTMA has the honor of working with some very talented and knowledgeable individuals, organizations, and institutions. A shining star among these partners is Dale Mickelson. With Dale's extensive background in testing tooling and programs designed for use in high speed machining and hard milling, his expertise has become increasingly in demand by our members. Dale's knowledge of all the machining variables, in combination with his database of real world test results, enables his clients to develop the high speed machining and hard milling processes required to be competitive in today's business climate. By helping his clients decrease cycle time and tooling costs, and increase machine tool utilization, he has helped our members realize tremendous improvements in their operations.

It is through partnerships with innovative and leading edge authorities in the manufacturing and precision machining industries, that the NTMA assists its members produce goods at a faster rate, at a higher quality, and at a reduced cost. Our partnership with Dale Mickelson has provided a much-needed competitive edge to the United States manufacturing industrial base and is one that we are proud to have.

Kevin King
Manufacturing Technology Director
National Tooling & Machining Association

INDEX

Index Terms	Links		

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