HEIDENHAIN INFO
Machine Tool
Volume 1 • 2009

# Fast, Accurate Contour Milling With High Surface Definition

Manufacturing processes in mold and die making, as well as in aerospace technology, can be optimized through modern milling technologies like High Speed Cutting (HSC). The machine motions so essential to this purpose—very fast and yet true to the contour—require very precise control of the acceleration and braking processes along a programmed contour.

Beyond this, users have to be able to implement their requirements for workpiece quality by making simple changes in parameters. The path control of the CNC has a decisive influence on the optimization of machining times under given requirements for accuracy and surface quality.

**HSC in mold and die making—requirements on machine tool controls**

High feed rates in HSC machining require higher path accelerations on curved workpiece contours. If the acceleration rates of the feed drives increase, greater acceleration forces are introduced into the structure of the machine tool. This consequently increases the risk of exciting troublesome machine oscillations that can result in loss of surface quality. The CNC therefore requires a strategy of motion control that minimizes machining time and yet achieves optimum surface quality under compliance with accuracy specifications. In order to keep the production times for molds and dies in an acceptable range, neighboring paths are frequently milled with directions reversed between passes. Here the CNC must generate reproducible tool paths when approaching contour elements from opposed directions. Otherwise, one must expect a loss in surface quality.

Machine tool users require the CNC to enable them to take into account job requirements for workpiece accuracy. The accuracy requirements must be met with the very first part without time-consuming tests. Moreover, the requirements must be defined in the NC program to ensure a permanent assignment to the work order.

The need to optimize machining times, surface definition and workpiece accuracy leads to the following basic requirements on the CNC:

- Effective monitoring of contour tolerances
- Exact reproduction of adjacent paths after direction reversal
- Avoidance of vibration from highly dynamic movements

**Effective control of contour tolerances**

NC programs for free-form surfaces are usually created with a CAM system

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## Contents...



## Did You Know...

…that HEIDENHAIN linear scales were the chosen components serving as the basis for four lathe linear upgrades at TRW in St. Catharines, Ontario, Canada? According to **TRW** (www.trw.com), these lathe upgrades were required in order for them to prove process capability on the required machining of rear toe-link tie rod ends for Ford Expeditions and Lincoln Navigators.

The tie rod ends on these rear toe-links feature a ball stud which needs to be round requiring high accuracies and repeatability. "We needed to maintain accuracies of ±0.001 inch and this was really pushing the limits of what a standard lathe is capable of holding," explained Stuart Lockhart, Manufacturing Engineering Supervisor at TRW Automotive Linkage and Suspension Systems Division. "And because all four of our 30-horsepower CNC turning center lathes here only had rotary encoders on motors connected to ballscrews for positioning, we also had backlash and thermal expansion issues that were proving unacceptable to us as well."

That is when **Elliott Matsuura Canada** (www.elliotmachinery.com) came in, recommended and handled the machine upgrades. "I have 28 years experience in my job and knew that upgrades to HEIDENHAIN linear scales would fix TRW right up by serving as a reliable direct measurement source as they compensate well for many machine imperfections," said Jim Earl, Senior CNC Service Engineer at Elliott.

The upgrade process to the lathes at Elliott took only a few days. The before-and-after capability studies showed machining improvement to the point where they now exceeded TRW's minimum requirements. TRW's four lathes now include HEIDENHAIN's **LC 400 series absolute scales**. These scales are characterized by their sealed slimline design and provide true absolute position value without any previous traverse required.

*Stuart Lockhart at TRW with upgraded lathe*

*For more information, go to www.heidenhain.us/mt1* ■

# Fast, Accurate Contour Milling

*continued from cover*

and consist of simple line segments. HEIDENHAIN controls automatically smooth the block transitions while the tool moves continuously on the workpiece surface. This automatic smoothing is controlled by an internal function that monitors the contour deviations. With this function (Cycle 32), the user can define in the NC program the permissible contour deviation. The default value is defined by the machine tool builder in a machine parameter of the control (typically 0.01 to 0.02 mm). If parameters are so chosen, the HEIDENHAIN control iTNC 530 can ensure that given contour tolerances are complied with even during great changes in path velocity. If a larger tolerance can be defined, the production times can be shortened significantly. In an example of a milling operation, the machining time is reduced by about 12% by increasing the contour tolerance from 0.01 mm to 0.02 mm.

On free-form surfaces, the deviation from the CAD model can, in the worst case, consist of the sum of the defined contour tolerance and the chordal deviation defined in the CAM system. The result on the workpiece depends in the end on the total characteristics of the machine and the values adjusted for the jerk and acceleration of the feed axes.

*Figure 1*

*Figure 1a*

*Figure 1b*

**High reproducibility of adjacent paths in alternating directions**

On the test workpiece shown in Figure 1, neighboring paths were milled efficiently with reciprocating movements (multipass milling with direction reversal). The individual passes consist of only few straight-line blocks with very different lengths. The chordal deviation set in the CAM system is 3 µm.

The workpiece photos in Figure 1 show the difference achievable with optimized path control when free-form surfaces were machined in reciprocating passes (programmed feed rate 10 m/min, finishing allowance 0.1 mm). The surface quality of the workpiece shown in Figure 1a is unacceptable. The machining results attainable using an iTNC 530, shown in Figure 1b, illustrate the high reproducibility of adjacent paths. Contour deviation between forward and backward paths stays negligible, resulting in very high workpiece surface definition.

**Effective avoidance of vibrations during highly dynamic motion**

The feed velocities required for HSC milling technology place machine controls before a great challenge. Short machining times can be achieved only at higher mean contouring feed rates. However, wherever the milling path includes small radii, the velocity has to be drastically reduced in order to keep path deviations within the permissible tolerance band. The accelerating and braking motions can cause frame vibrations that impair workpiece surface definition.

*Figure 2*

Jerk and acceleration are smoothed in the motion control offered by HEIDENHAIN. This can suppress machine vibrations very effectively. If necessary, the control automatically reduces the programmed feed rate to reduce the excitation of vibration to a minimum. Effective prevention of excessive machine vibration enables a part program to run at very high velocity and thereby significantly reduces machining times. The workpiece surface shown in Figure 2 clearly illustrates the benefits of motion control by HEIDENHAIN controls. Movement along the illustrated circle segments requires a change of axis acceleration at every point, which usually causes machine vibration (Figure 2a). By smoothing the jerk, the iTNC 530 makes it possible to realize high surface definition without disturbing effects from vibration (Figure 2b).

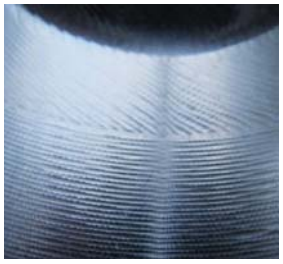

*Figure 2a*

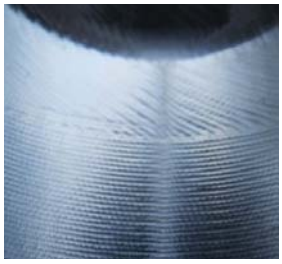

*Figure 2b*

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# Building a Better Machine

## Two Retrofitters Work Together

*Steve Colasanti, Systems Integrator at Dual Electric & Refrigeration Services, and Frank Cirino, President of Lomar Machine Repair Inc.*

When it becomes imperative in a machining business to find ways to improve production, there are always options. But which way to go? Are there personnel or machine repair issues that need to be addressed? Is obtaining the latest advances in new equipment in order? If so, how much will that cost?

These questions are commonly asked and answered by those in the industrial machining business everyday. And while each situation has its own set of incidentals, there are some common truths that must be acknowledged, or so explains both Steve Colasanti, Systems Integrator at Dual Electric & Refrigeration Services, and Frank Cirino, President of Lomar Machine Repair Inc., both in Tecumseh, Ontario, just outside of Windsor, Canada.

"The cost of upgrading a machine tool to almost new is typically a fraction of the cost of buying new," says Colasanti, "and if you have a solid machine base to work with, modern advances in digital CNC and servo technology can yield a machine tool with a large decrease in cycle time while providing accuracy similar to that of new machinery."

Both Colasanti and Cirino should know as they have been doing just that, often as a tag team, for almost ten years. "We at Lomar specialize in mechanical service work for the tool and mold industry, and the Dual guys are experts at the electrical end of things," explains Cirino. "Coincidentally, we both typically support and use high quality components from HEIDENHAIN Corporation in our machine retrofits. They just hold up in implementation and drive up the quality of the end result to a whole new level."

And their experience proves it. Together, they have participated in the successful implementation of over 50 CNC machine retrofits plus numerous DRO and scale integrations. Both have been working with HEIDENHAIN equipment for their entire careers, but Colasanti pointed out that in his early years working for a local machine tool builder, he had the opportunity to integrate various other CNC systems before working with his first TNC 425 control. "The quality of the HEIDENHAIN product as well as the highest level of support provided by Canadian and US offices have given us no reason to look elsewhere" states Colasanti. "We have many success stories that we can share and many happy customers," said Colasanti, citing Concours Mold Inc. in Ontario as just one.

**CNC Retrofit**

"My first experience with Concours Mold goes back to 1998," said Colasanti, citing the retrofit of a large Parpas BF 160 vertical milling machine with a HEIDENHAIN TNC 426 analog system. "After that, we've been called in to complete five other major CNC retrofits, the last one being a full digital

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# The Flexible New MANUALplus 620 Contouring Control for CNC and Cycle Lathes

HEIDENHAIN's MANUALplus NCs have been proving themselves in daily use on action-oriented lathes for many years now, but with the introduction of the new MANUALplus 620, HEIDENHAIN marks another step toward simple and efficient programming. With this control and its increased functions, now both cycle and CNC lathes can effectively be handled.

*With the MANUALplus 620 both cycle and CNC lathes can effectively be handled*

At the heart of the MANUALplus 620 is a new NC kernel. With it, the cycle programming feature of this control enables the machinist to quickly and efficiently program and machine workpieces without having to write NC programs.

A key addition to this control is the new programming mode "Smart.Turn". This mode allows users another friendly interface, allowing inputs of working blocks simply and quickly. Smart.Turn is intended to supplement programming on cycle-based lathes, though also allows work with standard CNC lathes – a double bonus.

All in all, the MANUALplus 620 provides three programming modes for the user: Cycle programming, Smart.Turn programming and DIN PLUS programming. In all programming modes, contours can be described with ICP interactive graphics (Interactive Contour Programming).

The MANUALplus 620 is designed for lathes with spindle, one slide (X and Z axis), one C axis or one positionable spindle and a driven tool. It is suited for use on horizontal and vertical lathes (vertical boring and turning mills). The MANUALplus supports simple tool holders (e.g. Multifix) and tool turrets. On horizontal lathes, the tool carrier can be located in front of or behind the workpiece. The MANUALplus also supports systems with two tool carriers on one slide.

This new control also includes the implementation of a tool database (up to 250 tools) and a technology database. As a whole, the MANUALplus 620 is designed as an integrated digital servo-drive control, though the spindles and/or axes can also be controlled by analog speed command interfaces as well.

*For more information, go to www.heidenhain.us/mt1* ■

# Offering One of the Most Accurate 3-D Touch Probes in the Market Today

With the introduction of the TS 740 infrared touch probe, HEIDENHAIN offers machine tool users the opportunity to perform measuring tasks that require an especially high probing accuracy and repeatability. Boasting a probing accuracy of $\leq \pm 1$ µm and a repeatability factor of $2\sigma \leq 0.25$ µm, the TS 740 workpiece touch probe is one of the most accurate 3D touch probes for machine tools in the market today.

To do this, the HEIDENHAIN TS 740 touch probe features a new sensor whose principle of function is completely different from that of the optical sensor of their standard touch probes. The new technology involves the use of three sensor elements. When probing a workpiece, the stylus is deflected so that a force acts on these elements. This results in the generation of charges that are detected by the electronics and converted into trigger signals. This system allows for more accurate results.


*The TS 740 infrared toch probe*

Also in spite of its low probing forces, the TS 740 is designed in such a way that it is well suited for use in modern machine tools with a fast tool changer. Rapid acceleration or deceleration does not cause uncontrolled trigger signals, as is common with those with low probing forces that are typically sensitive to mechanical disturbances.

*For more information, go to www.heidenhain.us/mt1* ■

## Two Retrofitters Work Together *continued from page 3*

retrofit of that first Parpas after a highly successful digital retrofit of an identical BF160 machine acquired a year earlier. Our first digital retrofit for Concours was on a 12-year-old OKK machining center with a Mitsubishi Digital system. "Originally, we were competing with a PC-based system on the quote. We came in at a similar price, but the word around town on the PC-based systems was shaky."

Colasanti explains "Providing a high quality digital retrofit begins in the quoting stages. We need to investigate the mechanics of the machine to determine the feasibility for a digital upgrade. Proper inertia matching calculations for each axis drive system is essential to peak high speed operation. The next step is to understand the electrical system and how to properly integrate to it. Our goal is to provide a system with the highest performance with the least amount of downtime.

"One of the nice things about using the HEIDENHAIN iTNC 530 is the diagnostic capabilities including a feature that allows us to monitor the scale feedback amplitude and frequency right on the monitor," said Colasanti. "This is a real bonus as it is uncommon to be able to do so with other systems. You know, the HEIDENHAIN product is already well known to be bulletproof and easily used; all these extras are a bonus."

"Also, it is especially important to note that I'm finding that customers are more eager to specify the HEIDENHAIN as they find out that the available service support from this provider is second to none," explained Colasanti who says that HEIDENHAIN is the only CNC manufacturer that freely makes available its knowledgeable technicians regularly within minutes of a call. "There is not one other company that I know of that can match that. This is key when it matters most."

"It's also important to talk about payback in retrofits. I always tell people that when you're busy, the payback is fast; when you're slow, the payback is not fast but it is evident in shorter production times for your tooling for your customers," said Colasanti. "Also, often a machine retrofit allows the customer to stop farming out jobs. That alone results in huge cost

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# Dear Abbe...

**Q: "How do you improve the IP rating on a scale?"**

**A:** A few issues back we discussed the definition of IP rating and what the various values mean. To ensure and even increase the IP rating, specifically for sealed linear scales, there are a number of measures you can take.

1. Always install the scales with the sealing lips facing down.
2. Install a guard above the scale to direct contaminants away from the scale.
3. Never use an air hose to clean the area below the scale sealing lips.
4. To increase the IP rating, add an air purge system.

Most HEIDENHAIN scales now use the single field scanning principle, which by virtue of the technology is very robust against contamination but not completely immune. An air purge system introduces clean, dry air into the scale thus pressurizing it and preventing the ingress of contaminants. Sealed scales from HEIDENHAIN feature inlets on either end of the scale and on the scanning unit for this purpose.

The DA 300 air purge system from HEIDENHAIN features particulate filtration system down to 0.1µm and an activated carbon filter for oil vapor up to 0.003 mg/m³. It also has adjustable air pressure with new visual gage and can supply up to 10 measuring systems.

The DA 300 system raises the ratings for LS/LC scales from IP 53 to IP 64.

Remember, contaminated scales are not accurate and if the air you are putting into the scale is not clean and dry, you are introducing contamination; no air purge is better than a bad air purge!

Sincerely,
Abbe

*If you have a question for Abbe, please send it to us at www.heidenhain.us/mt1* ■

## Two Retrofitters Work Together

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savings. Colasanti cited one example where a job had to be farmed out by Concours at about $100 an hour, where it ran around the clock resulting in a cost of about $17,000 a week. "After a digital HEIDENHAIN TNC retrofit of that Concours machine, the jobs could be done much faster and that money stayed in house. That retrofit, which took two weeks, held about a ten-week payback."

Performance increases do vary by machine. In the case of the twin BF160's described earlier, the first machine with the original TNC 426 analog control took 180 hours to cut a large tool while the second identical machine with a PC-based High Speed CNC on it took over 300 hours, according to Colasanti. It was at this point that Concours decided to remove the PC-based control and all of the problems that that came with it. "Our end result was a performance increase of over 265% which would bring the cutting time down to 110 hours for that same tool."

*For more information, go to www.heidenhain.us/mt1* ■

## Fast, Accurate Contour Milling

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**Summary**
HSC milling technology has a decisive influence on manufacturing processes in mold and die making as well as in aerospace technology. The required feed velocities place machine controls before a great challenge. In the conflict of interests between machining time, contour accuracy and surface definition, the HEIDENHAIN iTNC 530 control ensures that machining complies with selected preferences. This means that the tool paths are planned so that machine vibrations are prevented, accuracy requirements are fulfilled, and machining time is minimized. Moreover, the iTNC 530 achieves high reproducibility of neighboring milling paths to enable users to meet very stringent requirements on surface quality and reduce machining time for reciprocating multipass milling. The iTNC 530 has set new standards in the harmonization of the control, the drives and the machine frame.

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*For more information, go to www.heidenhain.us/mt1* ■

## HEIDENHAIN's 2009 North American Exhibitions

See what's new and exciting in the precision measurement/motion control industry by visiting HEIDENHAIN on the road this year! ■

**Lab Automation**
January 25-27
Palm Springs Convention Center
Palm Springs, California

**ATX (Automation Technology Expo)**
Feb.10 -12
Anaheim Convention Center
Anaheim, California

**Motor, Drive & Automation Systems Conference**
March 3-4
Hilton Hotel at Walt Disney World
Orlando, Florida

**TECMA**
March 10-13
Expo Bancomer Santa Fe
Mexico City, Mexico

**WESTEC**
March 30 – April 2
Los Angeles Convention Center
Los Angeles, California

**EASTEC**
May 19-21
Eastern State Exposition
Springfield, Massachusetts

**SEMICON**
July 14-16
Moscone Center
San Francisco, California

**Design & Manufacturing Midwest**
September 22-24
Donald E. Stephens Convention Center
Rosemont, Illinois

**Technical Tidbit:**

# Effect of Eccentricity

When installing an exposed angle encoder, one of the biggest factors affecting accuracy is mounting eccentricity to the center of rotation.

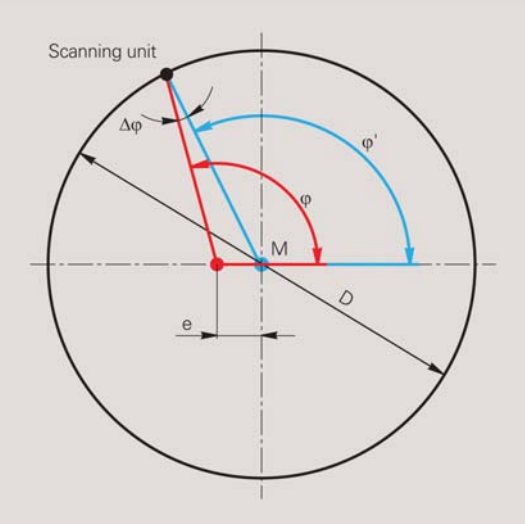
### Error due to eccentricity of the graduation to the bearing

Under normal circumstances, the graduation will have a certain amount of eccentricity to the bearing after the disk/hub assembly (ERP), circumferential-scale drum (ERA 4000) or scale tape (ERA 78x C and ERA 88x C) is mounted. In addition, dimensional and form deviations of the mating shaft caused by the positioning of the centering collar can result in added eccentricity. The following relationship exists between the eccentricity e, the mean graduation diameter D and the measuring error $\Delta\varphi$.

$$\Delta\varphi = \pm 412\ e\ /\ D$$

$\Delta\varphi$ = Measuring error in " (angular seconds)
$e$ = Eccentricity of the radial grating to the bearing in µm
$D$ = Mean graduation diameter (ERP) or drum outside diameter (ERA 4000) and scale-tape carrier diameter (ERA 78x C/ERA 88x C) in mm
M = Center of graduation
$\varphi$ = "True" angle
$\varphi$ = Scanned angle

*Eccentricity of the graduation to the bearing*

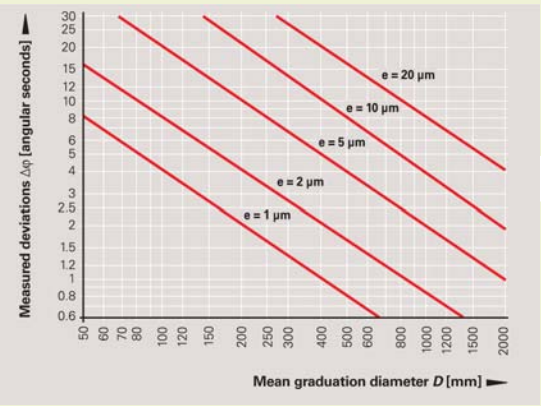



If we take the example of an ERA 42XX with an OD of 127.64 mm and a line count of 20,000, the specified accuracy of the graduation is 3.7". If we installed this device with 2µ (0.002 mm) of eccentricity, the following additional error would be added.

$$\Delta\varphi = \pm 412 \cdot e / D$$
$$= \pm 412 \cdot 2/127.64$$
$$= \pm 6.45"$$

The chart to the right can be used as a quick reference to calculate the effect of eccentricity at various ODs with various deviations. ■

*Resultant measured deviations $\Delta\varphi$ for various eccentricity values e as a function of mean graduation diameter D*



# "Linear vs. Rotary" Came to Life at IMTS

*By Chris Weber*
*National Sales and Product Manager, Machine Tool*

At this year's International Manufacturing Technology Show (IMTS) in Chicago in September, the debate of whether to use linear or rotary encoders as precision measurement feedback components on CNC machine tools took center stage at the HEIDENHAIN booth and throughout the show.

As was done at last year's EMO show in Germany, HEIDENHAIN continued the campaign to educate the users of machine tools about the specific benefits of linear scales over rotary encoders on ballscrews for CNC machine tool position control. Over the years, it has become clear that the benefits of linear scales for these applications extend far beyond just improved accuracy and repeatability of parts to the addition of machine up-time and costs savings for the machine user.

On display at the HEIDENHAIN booth were dynamic demonstration units where attendees could actually see the benefits in action. Also on display were machined parts highlighting the difference in finish between machines using linear scales vs. ballscrew/encoder systems.

HEIDENHAIN partnered with important machine builders who have long since realized not only the benefit of linear scales in these instances, but also the extraordinary benefits of the HEIDENHAIN scales themselves. Whether the requirements are for incremental or absolute positioning, HEIDENHAIN has a broad range of products to fulfill the demanding tasks of today's complex machines.

HEIDENHAIN is currently looking for a few more customers who have experienced both types of positioning to share their experiences, preferably machine owners who have upgraded their newer machines to linear feedback and can now perform more jobs, more accurate jobs, achieve more work, less down time, and in general have seen an overall increase in the accuracy and ability of their equipment.

In these challenging economic times, it makes even more sense to upgrade your existing equipment and with HEIDENHAIN's vast network of accuracy professionals, virtually any machine, anywhere can be retrofitted with state of the art positioning technology.

I also welcome the opportunity to personally discuss your experience, put you in touch with your local accuracy pro or provide information on the benefits of linear scales.

Give me a call at (847) 884-3717 or drop me an e-mail to cweber@heidenhain.com.

*For more information, go to www.heidenhain.us/mt1* ■

HEIDENHAIN
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