YOUR TECHNICAL GUIDE TO GRINDING A HIGH PERFORMANCE ENDMILL
THOMSON MATHEW, ANCA’S SOFTWARE PRODUCT MANAGER HAS A HUGE WEALTH OF KNOWLEDGE AND EXPERTISE, HAVING WORKED IN THE CUTTING TOOL INDUSTRY FOR ALMOST 25 YEARS.

The architect of many of ANCA’s market renowned software products – Thomson has written a technical guide on creating the perfect Endmill running through a five part instructional series covering:

1. Geometry design and parameter verification
2. Machine and accessories setup
3. Production process setup
4. Measurement and quality control
5. Machine and production monitoring in 24/7 unmanned production
There are many factors which will impact the overall performance of an Endmill. Four major ones that get cited are the grade or quality of carbide material, the cutting tool geometry design, the precision manufacturing process or quality control and the type of coating.

The hardness of an Endmill’s material, usually carbide, will depend on the grade of carbide in the matrix. Smaller grains mean more substance versus binder, and therefore a harder tool. Exotic coatings will improve lifespan and cutting performance. Quality control means a workshop can get a consistent result each time from a set of Endmills.

But geometry has an outsized role, one that highlights the blend of art and engineering – and for a long time, trial and error – involved in creating the ideal Endmill. This begins with design. Some of the important factors in Endmill design include the combination of both variable helix and index flute geometry design, core geometry design, the OD clearance angles eccentric versus facet reliefs design, endface design with wiper flats and pad grinding or end dubbing etc.

As I have written elsewhere, the progress of the industry has seen Endmills grow increasingly “weird” as toolmakers have sought high material removal rates while avoiding “chatter”.

Regenerative chatter happens when the harmonics between a tool and workpiece are at different frequencies. The two self-excited objects will hit against each other, which is a negative for surface finish and dimensional accuracy, as well as the lifespan of the tool and machinery. It is a drain on productivity and profits.

High helix tools (over 35 degrees) have long been popular for their strength and fast feed and swarf removal rates. While they have these advantages over low helix Endmills for hard materials, they are also more prone of the two to chatter. Some of the trial and error to combat this has been around variable helixes and pitches and trying to better balance tools. This has led to “weird” Endmills, with higher geometrical levels of complexity.

In high helix tools the cutting forces are directed more vertically and less horizontally, which reduces tool deflection and results in quick and efficient chip evacuation.

More positive axial rake lowers cutting forces which helps to increase feedrates. The core of the tool is thicker due to the shape of the helix and the tool is stronger. High helix Endmills are typically used in tougher harder materials because they wear better, although they can also be used in softer materials like aluminium. One disadvantage of high helix Endmills is the tendency to chatter more, and they really bite into the material.

On the contrary, low helix tools are less likely to chatter and typically perform better in soft materials. Their disadvantage is the lower feedrates and hence lower material removal rates. Our understanding of how to mitigate chatter has come a long way and involves no guesswork nowadays. The geometry and design are purely based on material to be cut whether it is soft or hard.

Variable helix end mills with variable index are considered state of the art these days. The idea is to vary the helix along the flute length or from flute-to-flute. The aim of the variable helix is to fight chatter. Since chatter is a resonance effect, anything we can do to break up the resonance of the flutes beating against the workpiece will reduce chatter. The tool balancing capabilities in the RN34 release of ANCA’s ToolRoom software is the perfect solution to combat chatter.
ANCA is a partner to toolmakers all over the world – with almost 50 years in cutting and grinding tool and related innovations – and has responded to the war on chatter in various ways.

ToolRoom is one of many customer-led innovations to take the guesswork and complexity out of making increasingly complex Endmills. It is also designed to work seamlessly with ANCA’s CIM3D simulation software for process verification pre-grinding.

ANCA’s ToolRoom software suite provides industry-renowned tool design flexibility from the simplest to the most challenging cutting tool designs. Tool wizards, integrated 2D and 3D graphics, and clear help images for all parameters in ANCA’s main tool design software, iGrind, are capable of generating a wide range of production-ready tools directly on the machine, ensuring minimal design time and maximum machine utilisation.

ToolRoom utilises sophisticated mathematical libraries developed in-house over decades to solve generating grinding paths to cater for the high accuracy requirements. The unsurpassed application diversity delivered by ToolRoom ensures your ANCA grinder is able to be utilised for all your current and future CNC grinding needs for all cutting tools catered to all industry types.

CIM3D allows a user to virtually create and test a part, as well as the grinding process. Before anything is ground out, it can be verified for possible collisions, toolpaths, cycle times, material removal rates and more.

The latest release of ToolRoom, RN34, has further expanded tool types to cover all industries, including die mold, power generation, aerospace, automobile, wood working, medical etc. Included in RN34 is automated tool balancing for variable helix/index tools to eliminate chatter and for better surface finish along with improved tool life.

Tool balancing is an automated way to minimise the influence of eccentric weight distribution when using high-speed spindles, and can eliminate noise and vibration. It balances tools by incorporating flute length extension and shank notches into tool design.
ToolRoom RN34 also has new designer edge ballnose with several new and improved geometries, including chisel edge, especially for the diemold, power generation and aerospace industries. Another tool type is the barrel shape ballnose and lens shaped double corner radius tools also known as circular segment cutters especially for titanium and Inconel alloys.

The geometry of these Endmills is the large radii in the cutting area of the respective tool which offers entirely new possibilities when machining. The larger-radius edge permits larger stepover increments which enables machining with a larger cross over pitch or tool path distance during pre-finishing and finishing operations. The large tangential form radius simulates a Ballnose or Corner Radius Endmill with a large cutting diameter which is how these cutting tools save cycle time relative to a Ballnose tool. Not only does productivity improve, but the resulting surface finish is also better.

Another new weapon in ANCA’s flexibility and customisation arsenal is scripting. On a simple level, it can be used to automate most tool design tasks that can be achieved using the keyboard and mouse. But at a higher level, it can be used to create sophisticated solutions such as fully featured custom tool wizards with graphical user interfaces. Scripting can provide tremendous productivity benefits and is an evolving technology. Capabilities are expanding rapidly with every ToolRoom release.

Designer edge ballnose with chisel edge for aggressive cutting - high helix improves fracture resistance and optimised irregular curve reduces vibration.

**PART TWO**

**MACHINE AND ACCESSORIES SETUP**

If tool design is a recipe, then accessories and machine setup are mise en place.

The French phrase is one of the first things a chef-in-training learns, and translates to “everything in its place.” While there are obvious differences between running a kitchen and a factory for manufacturing Endmills, there are also some notable similarities.

The key one is the benefit of doing everything as efficiently as possible by being prepared. When you are doing anything more than once, every wasted effort adds up, whether it’s a trip to fetch a utensil or ingredient that should be at hand, or changing a wheelpack that should’ve been refreshed before a production run began.
ANCA’s CPX Linear is one productivity-booster for busy workshops. The four-axis blank preparation grinder with a 43 KW, 250 mm wheel (roughing) spindle and 9.7 KW, 150 mm wheel (finishing) spindle can prepare blanks up to 380 mm long and with shank up to 32 mm. It is capable of a surface finish better than 0.2 Ra. For environments with few staff, CPX can be paired with an ANCA AR300 low-cost SCARA robot, capable of up to 221 blanks in three pallets, with one empty and two full.

MX7 Linear, the next generation production machine

All ANCA TCG machines including MX7 and FX7 models come with a Wheel Probe. This measures and qualifies a wheel pack within a machine, saving an operator from having to manually qualify or use expensive external qualification methods. The accuracy of the wheelpack qualification directly reflects the quality of the tools ground and it’s important to get the first tool right every time. Qualifying a wheel pack inside the machine increases productivity since the values are directly written to the wheel editor during the process.

Wheel performance can be further optimised by iBalance software, which guides a user to the optimal grinding position and RPM for vibration monitoring and balancing the wheel pack inside the machine. Correctly balanced wheel packs result in superior surface finish and reduced wheel wear due to the elimination of wheel vibration. This leads to increased wheel life and better quality tools.

Wheel balancing inside machine with correct RPM

ANCA’s Premierplus collet adaptor is another patented innovation. It has a very high clamping force and is easy to set up. The increased clamping force increases the consistency of tool geometry across a batch of tools. It assists with maintaining very high precision and consistency, with tool runout under five microns. This can be further improved by using PCA Premierplus collet adaptor with the support of the micro adjustable popup steady.

Partnering of CNC machines with robotics is a growing trend in recent years, first in loading, then in wheelpack changing and other applications.

Wheel qualification probe provides automatic measurement and qualification of wheel packs inside machine

Premierplus collet adaptor — Consistent and repeatable tool runout of ≤ 5 microns

The RoboMate Fanuc loader is a versatile and flexible automation solution that is equally efficient on FX7 and MX7 tool and cutter grinders. Pallets and tooling such as handling grippers are interchangeable, so you can use them on any RoboMate equipped ANCA machine.

The use of a patented “compliant gripper head” standard on all Fanuc robots for loading tools from pallet to collet helps to control and maintain tool runout. This new product design incorporates the ability to have a small amount of “give” within the gripper head. This allows the head to pivot slightly when loading tools or collets to tight tolerance collet adaptors, if a slight misalignment is present.

CPX Linear blank preparation grinder

For production environments – particularly with few or no staff – a six-wheel changer station, also filled with coolant manifolds, is an important part of high-throughput models such as the FX7 or the MX7 Linear. These machines include new technology linear motors that enable them to achieve higher levels of surface finish, accuracy and performance. To minimise the time spent on automated changeovers, wheel stations are kept close to the spindle, meaning the task takes only 10 to 12 seconds at most.
In part three, we outline how to have everything in place to start manufacturing large batch quantities of Endmills. This section also covers accessories, but particularly to aid unattended production: perhaps for a short run, a shift, a day, or even a weekend.

To start with, let’s take a look at how we can manage wheelpacks for a large unattended batch of Endmills. When a wheelpack is mounted and used in production, it will become unusable after it has either ground a certain number of tools or been dressed down to a specified size. An option is available on the wheel changer machines like FX7 and MX7 to set a redundant wheelpack. This will be used after a certain number of tools have been ground and the wheel is no longer suitable for the job due to wheel wear.

Through the Mount Wheel Pack Wizard, identical fresh wheelpacks wheels can be set up to automatically replace old ones at set intervals. A warning message can be set when the number of tools ground is nearly up, for example five left to go in a set limit of 100 Endmills.

When continually grinding, wheels become glazed or loaded. The sticking process exposes the wheel grit and removes chips (swarf) embedded in the wheel so the wheel cuts better. Before a wheel needs to be changed, it can be cleaned up with a dressing stick. This is a long-standing technique to achieve better feed rates, a better grinding ratio, less tool burn, and higher productivity. Sticking uses an aluminium oxide stick applied to glazed wheels.

ANCA has automated dressing through an AutoStick assembly of one or four sticks, which is pneumatically deployed and removes the task and the danger of this from the operator. This is managed through the dressing software and can be calibrated based on factors including frequency, wheel speed, and compensation for wheel wear.

Lights out operation and large batches, especially fluting from solid blanks, mean large amounts of material removed, which can take its toll on wheels and in turn accuracy of the core profile. The Ruby Probe innovation is one way to compensate for core diameter variation. It performs in-process measurement of the core diameter at specified positions, compensating to match specified tolerances. Once again this can be set at required intervals based on diameter of the Endmill and amount of material removed.

Mounting with tool count expiry and threshold warning

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While workshops generally do their best to keep a suitable ambient temperature, and machine builders do theirs to keep their machines as thermally stable as possible, machining and machines create heat. Another long-standing innovation at ANCA – like the thermally stable and vibration dampening polycrete – is the ability to deal with varying temperatures is Coolant Temperature Variation (CTV).

CTV is on every ANCA machine. It accounts for offsets due to changes from thermal expansion and other factors. It digitises the position of a known qualification ring or block between the headstock and collet adapter and allows measurements of changes in distance between the tool and spindle. These are measured and compensated after a set number of tools, with the interval between compensations becoming shorter as the machine and its coolant warm up and their temperatures become more stable. This also minimises cycle times and maintains stability of batch production.

Finally, an important process accessory for productive and accurate Endmill manufacture, especially when the machine is unattended, is a robotic loader. ANCA’s RoboMate solution uses a Fanuc 200iD, and takes a tool from the pallet to the collet, accommodating a range of diameters up to 32 mm, and lengths up to 350 mm. It uses RoboMate pallets, with a loading cell accommodating two or four pallets, and is operated by the user-friendly RoboMate software.

At the start of this article, we looked at some of the things contributing to making a good Endmill a high performance Endmill.

You will remember the mention of precision manufacturing process or quality control. If you can make one perfect Endmill for a given application, then good. What really matters is that Endmill number 100 is also perfect.

Quality control has moved a long way since handheld gauges and micrometers.

One of ANCA’s proud contributions to this progress is the LaserPlus system, which is mounted inside machines and uses a non-contact laser beam. LaserPlus uses a laser to accurately measure and compensate features on a cutting tool. This product is extremely beneficial for measuring tools to maintain tight tolerances in large volume production.
An air blast unit fitted alongside the LaserPlus makes sure the tool is optimally cleaned from coolant and swarf for accurate sub-micron measurements.

Using the laser, the operator is able to perform accurate in-process measuring without removing tools from the machine. Measuring and compensating tools inside the machine will enable customers to reduce scrap, maintain tolerances and increase productivity.

LaserPlus is used to measure or compare a tool’s geometry and compensate for discrepancies, and maintain ±0.002 mm tolerances on diameter and form measurements. It also removes the need to manually handle parts, which saves time and effort, and keeps delicate, smaller tools safer.

While LaserPlus is a very popular and effective way to measure tool OD and profiles including ballnose and corner radius in-process, the Zoller Genius 3 measurement machine can automatically measure a diverse range of tool features.

Zoller is typically used for more detailed tool measurement during tool setup or intermittently during batch runs to ensure features remain in tolerance.

Zoller measurement machines are widely adopted in the market as an effective solution for measuring complex geometry of cutting tools. ANCA and Zoller have worked together to design a fixed Zoller measurement process, and a fixed ANCA grinding parameter adjustment to which it is directly linked. Data can be transferred using a USB stick or direct network communication if both Zoller and ANCA machines are on the same network.

Another major development is the Total Tool runout measurement and compensation operation in iGrind. Runout refers to the differences or variations in the diameter of a cutting tool at certain points along the outside edge while the tool is rotating. When an Endmill is in rotation it is important that each tooth hits at the exact same spot along the workpiece for longer tool life and efficient cutting.

Every tool in the batch can be measured and compensated for runout to make sure the entire batch is within tolerances.

It is another piece of assurance that Endmill number 100 will be as good as Endmill number one.

The LaserPlus is mounted inside the machine

Barrel shape form and ball radius +/-0.002mm

Barrel shape ballnose tool accuracy with LaserPlus

It measures the top and bottom of a part, and the outer diameter can be integrated with statistical process control software. Features such as the ability to produce measurement reports for ground tools including ballnose and corner radius types have been added since the beginning of LaserPlus.

Many users have incorporated LaserPlus as part of lights out operations, as well as in reducing the amount of scrap parts produced.

Complete tool runout compensation for volume manufacturing

Parameter measurement and compensation from Zoller
PART FIVE
MACHINE AND PRODUCTION MONITORING IN 24/7 UNMANNED PRODUCTION

Through this series we have discussed different facets for creating a great Endmill, starting with design, then machine setup and accessories, setup for processes, and quality control.

What remains to be discussed is removing an operator from the picture altogether and letting a grinding machine do its work, and this is enabled by virtual machine monitoring technology.

Manufacturers are constantly developing new ways to increase the efficiency of their machine shops, to reduce machine downtime and manage grinding schedules to maximise output.

ANCA’s Management Suite is a game changer for the CNC grinding industry. The software enables customers to monitor the operational performance of their machines no matter where they are in the world and provide live production data to make informed operational improvements. Management Suite provides machine analytics which give companies the ability to produce highly accurate reports on machine usage, enabling them to identify waste and increase overall equipment efficiency.

Management Suite consists of three products: Tool Management, Wheel Management and RedaX. Tool Management allows you to easily revert to older versions through revision control of your grinding programs. Program changes can also be visually identified using the file difference tool.

Wheel Management is a central inventory for wheels and wheelpacks. It provides a platform to easily share wheelpacks and qualification data between machines. A handy search function allows operators to easily find what they are looking for.

RedaX is a remote data analytics real-time monitoring solution for machines. Its open platform communication unified architecture runs on machines to monitor and broadcast machine data. Users are then able to consolidate the findings on a web page displayed in a real-time web browser.

Another key feature is the differentiation between simulator-qualified wheels, which prevents the usage of them on machines to avoid collisions and damages to machine and wheelpacks.
RedaX overview page

RedaX makes the invisible visible for each connected machine. It provides real-time information on factors such as spindle load, temperatures, tool and batch cycle times, and Cp and Cpk values for batches. Reports can compare differences over time, allowing you to measure and therefore manage performance of machines. Information on parts produced can be integrated with a company’s ERP system, telling it when a part or batch is ready to be dispatched.

RedaX also provides SMS and email alerts for unplanned stoppages.

One scenario where this is invaluable is completely unmanned operation. A workshop team might be off for the weekend, but one or more members could keep tabs on production remotely. They would know if there’s a stoppage (and why) and would head to the factory and fix the problem, minimising the machine’s downtime.

This worker would previously have had to be on-site all weekend to catch the problem, with obvious costs to the company.

RedaX dashboard displays real-time details about machine status and activity

The other two elements of Management Suite are the server-based Wheel Management and Tool Management. These allow a team to work to a single source of truth for wheel inventory and qualification, or for grinding files. These are not specifically related to 24/7 unmanned operation but provide the benefit of sharing consistent information across users.

Unmanned production for the perfect Endmill is possible. All the elements mentioned in the first four articles need to be in place, but once they are, then you can really push things to their limit.

ANCA also provides and supports ancillary products for Endmill production, which includes laser marking on tools. It can be done using a standalone product such as the AutoMarkX, or incorporated into the MX machine platform inside the RoboMate loader with the RoboMate LaserEtch. The suitable solution depends on the customers’ requirements and production volumes.

Looking to the future

By now you should have all the information you need to grind a superior endmill. However that doesn’t mean it is the end of the story – as technology continues to advance so does the opportunity to improve on your grinding processes and end product.

ANCA Integrated Manufacturing System, AIMS, is emerging in to the market and promises to be the future for optimised cutting tool production, delivering a holistic solution for end to end tool manufacturing challenges.

Using streamlined manufacturing, with connected tool production processes, it can be integrated into IT systems to fully automate a tool grinding production. The concept of AIMS is to maximise productivity, improve quality and free people from doing simple manual tasks, so they can be re-deployed to others where they can really add value.

In summary AIMS enables connected machines, connected processes or smart automation that connects sequential tool production processes. Cutting tool manufacturers can achieve lights out operations with continuous, unattended production to dramatically reduce non-productive machine time.

I, for one, see the future is bright. We continue to grow and learn as an industry and technology enables better processes and accuracy, meaning we can make a more superior product for the market.