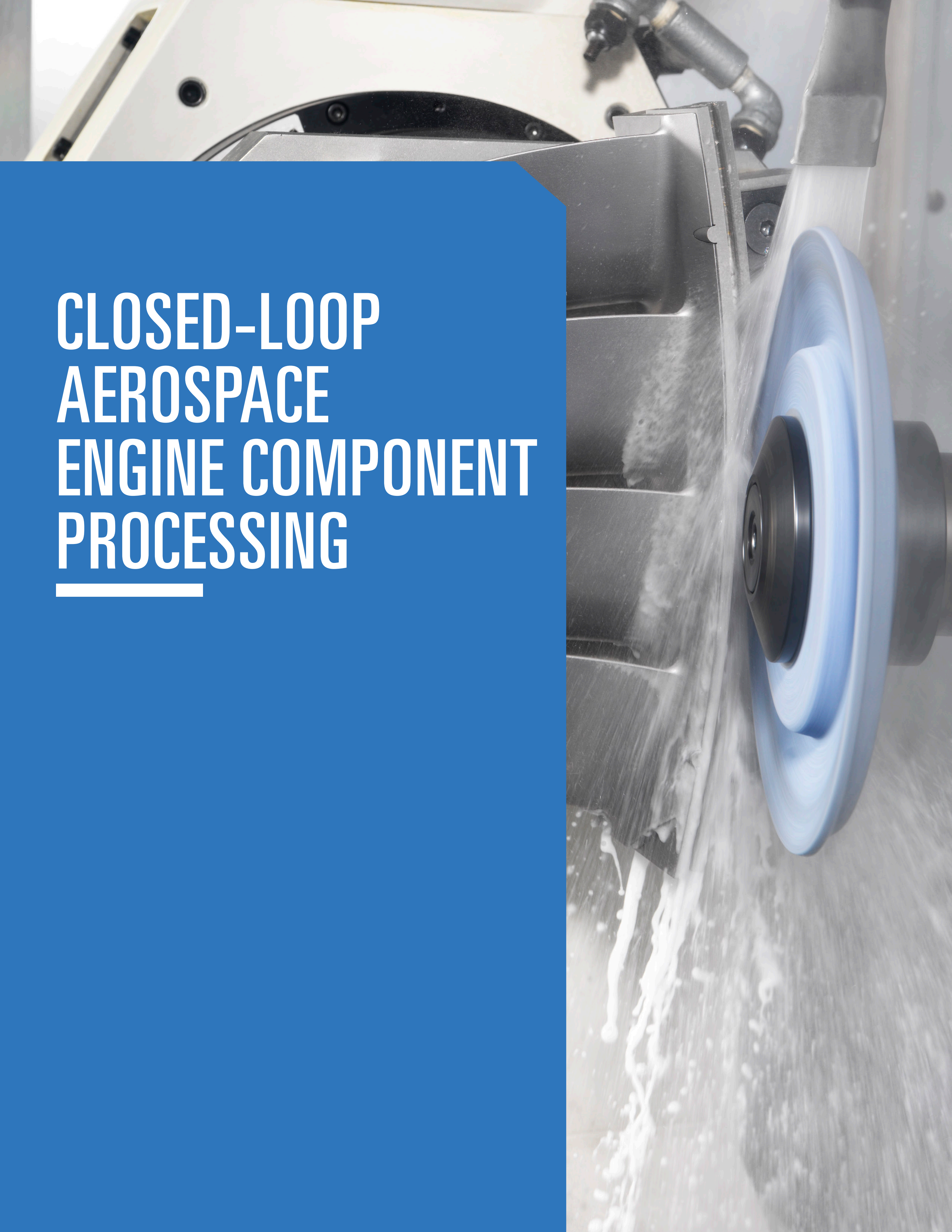
CLOSED-LOOP AEROSPACE ENGINE COMPONENT PROCESSING



AUTHOR BIO

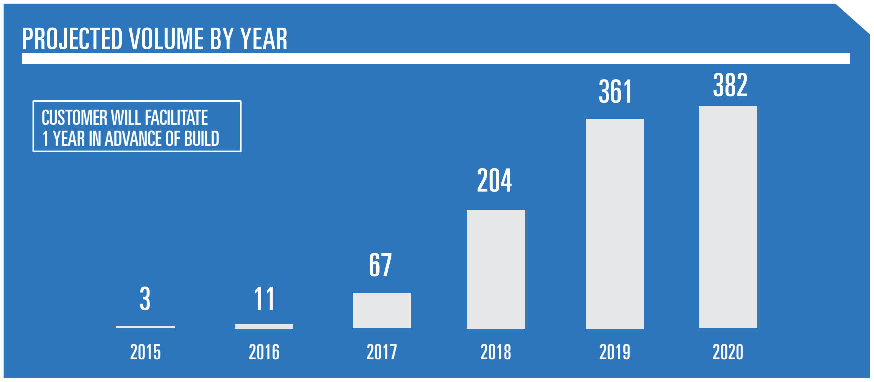
BILLY GROBE

MANAGER – AERO ENGINE TECHNOLOGY, MAKINO

Billy Grobe currently leads the aero engine technology group at Makino (Mason, Ohio). He has three decades of experience in aerospace, die/mold, EDM and process applications.

DEFINING CLOSED-LOOP MANUFACTURING FOR TODAY'S AERO INDUSTRY

As the commercial jet market continues to grow with orders and deliveries at record levels, production rates are soaring to historic highs to meet demand and reduce the backlog of jet engine orders. By 2019 the projected need for aerospace parts is expected to skyrocket even more. To meet these projections, manufacturers are putting equipment in place and proving out processes in advance, all while engaging in full production on the orders already coming through.



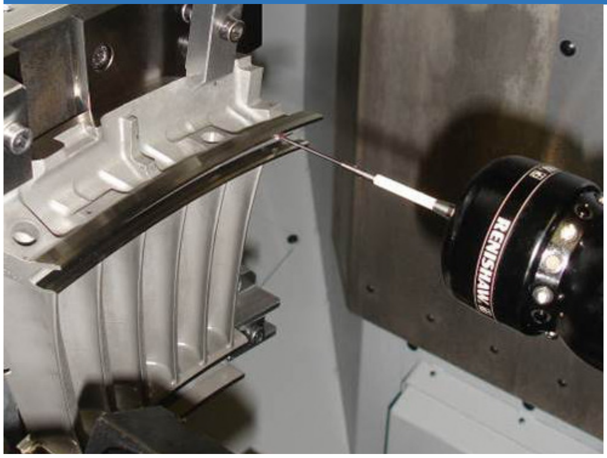
To produce these large quantities of high-quality parts with virtually no scrap, manufacturers need a mechanism that helps them be efficient in producing more products without a lot of operator intervention.

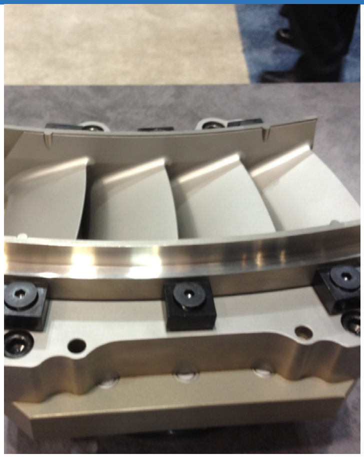
In a closed-loop manufacturing process, the quality and accuracy of the parts being made are improved by providing correlation between the measuring device and the manufacturing device. The machines communicate and react to each other, correcting any errors and making improvements without human intervention while keeping the process on track.

At an elemental level, closed-loop manufacturing involves dropping raw parts into the machine and then collecting data from probing to get a best fit before machining the part, processing it, checking it and sending it back out before loading another part. The feedback that occurs throughout the process provides the closed loop.

IN THIS PAPER, WE DISCUSS THESE FOUR AREAS:

- How to select the right partner and right equipment
- The importance of cell layout and automation
- Testing and process checks
- How the closed-loop process works





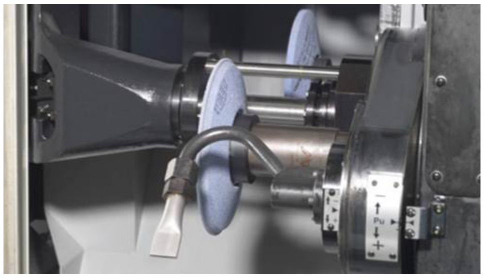
SELECTING THE RIGHT PARTNER AND RIGHT EQUIPMENT

To implement a closed-loop manufacturing system, it's important to find the right partner. Look for a team with planning and experience in this area and strong supplier relationships. This partner should be able to execute a turnkey package, handling the automation, software, mechanical and electrical engineering, and providing local support. The right partner should be familiar with the machine, probing, part machining, using a coordinate-measure machine (CMM) and performing quality control, and be willing to help set up the application and debug the process before the machine even comes in. The partner should also be available for post-sale technology transfer.

There are several equipment/machining features to consider when preparing for closed-loop manufacturing:

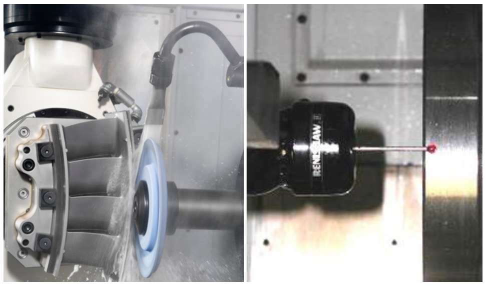
ROTARY AXES

Look for a machine with the ability to perform five-sided machining so that the part can be machined complete in one setup.



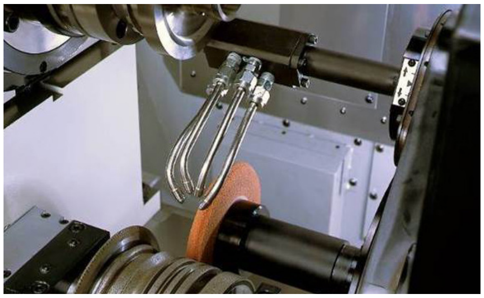
ATC AND TOOL STORAGE

The machining platform should have the ability to quickly and easily change the grinding wheel and traditional cutting tools to provide variety in the cut.



MULTIFUNCTION CAPABILITY

Look for machines that are able to handle a variety of parts and 5-axis machining. Ones that can perform many types of cutting, such as milling, drilling and grinding, along with probing, in-cycle work measurement and through-spindle coolant to provide thermal stability, are preferable.

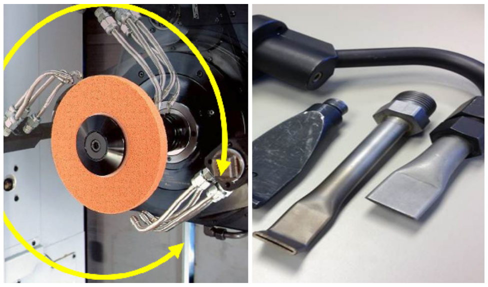


ROTARY WHEEL DRESSER / TWIN-ROLL DRESSER

The wheel dresser helps to maximize the grinding wheel life through the process of conditioning the surface of a trued wheel to expose the grain for efficient grinding action. Where the wheel is dressed and how it is approached should be carefully considered. Depending on where the rotary dresser is mounted, it can provide angular correction. Some machines have a dual, or twin-roll, dresser. These can be designed to not only keep contaminants out of the work zone but also be set up quickly to change out the dressing roll. This design increases the likelihood of the first part, good part after each part changeover.

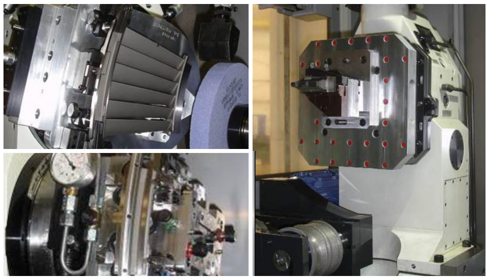
RELIABLE MACHINE DESIGN

To produce quality parts, the machining platform should include core-cooled ballscrews and a spindle with rigid construction and excellent stability, along with a large central trough to collect waste.



COOLANT NOZZLE

Look for a machine that can be equipped with a variety of coolant nozzles. Coolant should be delivered at high pressure while delivering a high volume of coolant directly into critical locations along the grinding wheel. Look for a dual nozzle or one with the ability to reach around the part. For example, a 360-degree NC-controlled coolant nozzle can be especially helpful for multidirectional grinding, providing flexibility with the ability to cut in all directions. Other features to consider include machines with no external hoses or cables, with wheel-diameter tracking and the ability to reverse directions, positioning the nozzle at the best location on the grinding wheel.



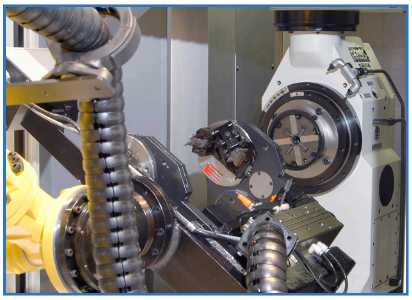
PALLET CHUCKS

A power chuck usually comes standard on most machines, but some manufacturers also offer the option for additional chucks that accommodate greater weight or a bigger pallet.

CELL LAYOUT AND AUTOMATION

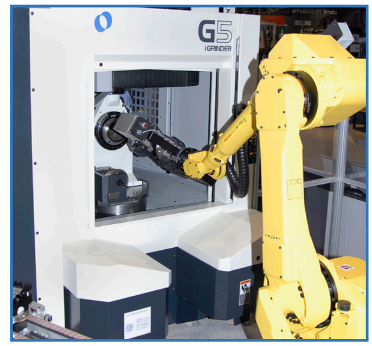
It should be decided whether to implement a closed-loop process into an automated or non-automated cell. Automated machining systems have been key to global competitiveness for many manufacturers and are configured to meet a variety of needs across nearly all industries. While the automated systems may have a slightly higher initial cost, they can improve output. In fact, some companies use automation to increase machining efficiency and capacity to gain extra revenue potential, to save direct labor costs and setup times, or to improve quality by eliminating scrap.

For example, incorporating a robot into the cell can help increase throughput. It enables the convenient loading of parts without stopping the machining



sequence, reduces risk of incorrect load, provides rapid loading of fixtures into the machine, helps with sequential machining, and yields higher productivity and increased efficiency. It lets the operator keep the work-setting station loaded while a part is in the machine, providing increased output at a slightly higher initial cost.

In a closed-loop machining environment, it is important to choose a provider that has proven experience in automation. Moreover, when it comes to machine selection, with floor space at a premium in most shops, the automation cell should be designed in a way that optimizes the use of square footage. It can be helpful to choose machines that require little area while still allowing access to the cell. Machines with stacked components can maximize floor space; yet leave room for maintenance personnel to walk between machines for servicing.

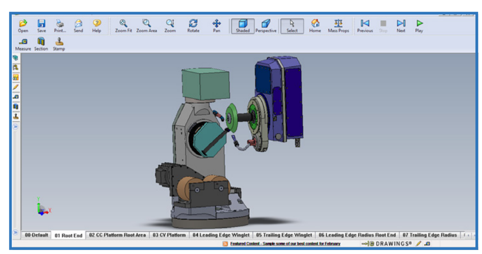


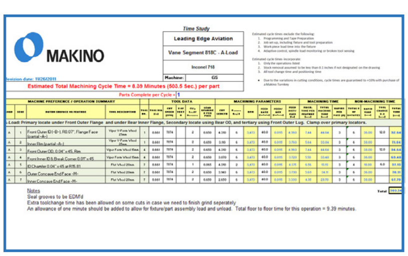
The flow of material through the cell should also be decided—such as where the raw material is introduced into the cell, and the location for the finished product. Specifications for the production volumes should be known, as should requirements for additional capacity.

TESTING AND PROCESS CHECKS

In a closed-loop environment, having the right equipment is key; but in order to ensure quality parts, it's all about having access to a supplier with the engineering expertise required to create the closed-loop processes. In addition to the pre- and post-sale support, this resource should conduct process checks during design to manage the quality of the part and to make sure everything is achievable so that the manufacturer has the best machine package and tooling package. From conducting programming for coolant trajectories to engaging an in-house fixture designer, it's important to work with a provider that has the resources to predict what is going to happen and then provide exactly what was supposed to be built.

It is important to perform fixture testing prior to running production on the system. Finite element analysis (FEA) studies compare test loads and ensure that a stable fixture is built in to achieve reliable results. In essence, it compares what finite element analysis indicated it would be versus what was actually measured. It is helpful to work with a provider that models everything in 3-D, proving it out in SolidWorks or another similar program before building it.





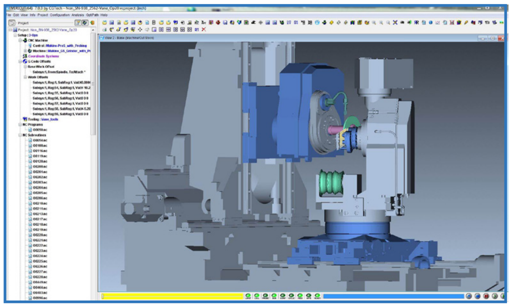
Conducting a time study as part of the product package can also help to ensure a robust process from the start. This study provides an estimate of the cycle time that should be achieved and where processes can be improved. It essentially helps you better understand your process—such as the tools needed, the machining parameters and the cut and non-cut time. Inspecting design CAM, programming, simulation, feedback and wheel tracking all helps to predict cycle time.

The cut strategy makes use of the time study and plans the cuts in more detail to ensure a robust process from the start. It examines the individual sequences of all the cuts needed, determining how to best approach the part so that the machine can get to all the features. It details the individual attributes that contribute to cycle time, and it determines the types and shapes of wheels needed as well as wheel usage.

PROCESS/CUT LIST

Description of orientation being held:
Part is encapsulated and held in a fixture with Root End facing out. The part axis is nominally parallel with the machine C-axis centerline.

Tool#	Sequence #	Feature	Tool Desc	Wheel Shape	Wheel Width	Tool Max OD	Form Depth	Tool Min OD
T59		Measure Part Location Datums	OMP400			2		
T28	1	Rough Leading Edge End Face	60 grit Viper Wheel		10	220	4.68	149.36
T28	2	Finish Leading Edge End Face						
T25	3	Rough Trailing Edge End Face	60 grit Viper Wheel		10	220	0	140
T25	4	Rough CV Platform						
T25	5	Rough CC Platform						
T25	6	Finish Trailing Edge End Face						
T25	7	Finish CV Platform						
T25	8	Finish CC Platform						
T22	9	Rough CV Form	60 grit Viper Wheel		25	220	7.703	155.406
T22	10	Rough CC Form						
T22	11	Semi-Finish CV Form						
T22	12	Semi-Finish CC Form						
T22	13	Finish CV Form						
T22	14	Finish CC Form						
T19	15	Rough Leading Edge Form	60 grit Viper Wheel		25	220	8.529	157.058
T19	16	Semi-Finish Leading Edge Form						
T19	17	Finish Leading Edge Form						
T16	18	Rough Trailing Edge Form	60 grit Viper Wheel		30	220	7.772	155.544
T16	19	Semi-Finish Trailing Edge Form						
T16	20	Finish Trailing Edge Form						

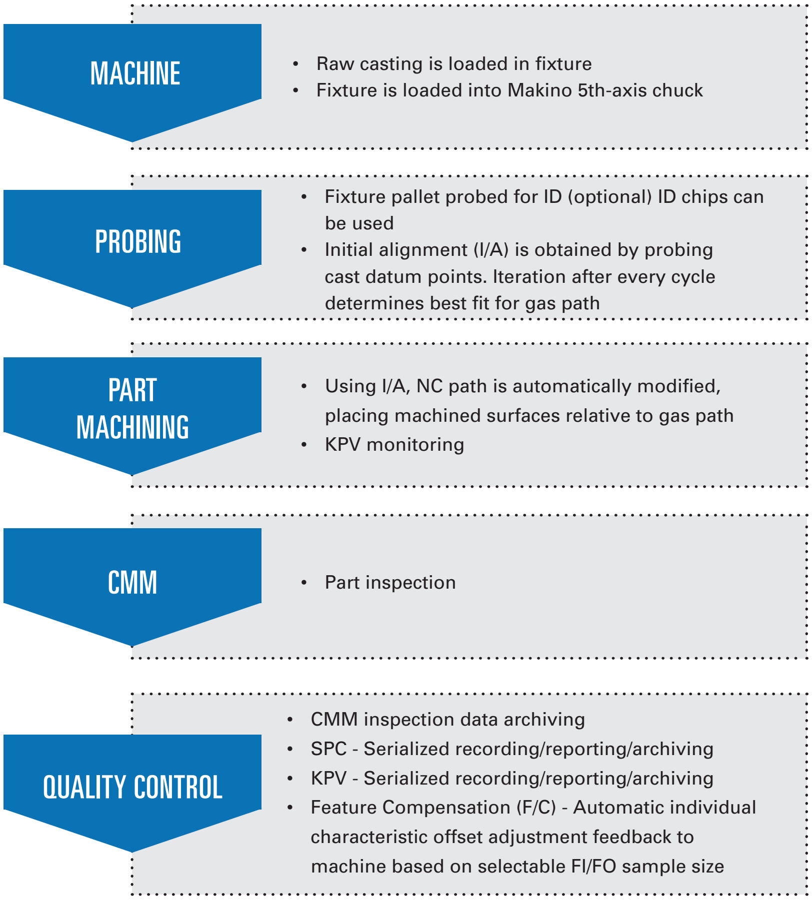


These studies may show that the part needs to be approached from a different angle or side. And the Vericut simulation proves out the part path and ensures that all features have a robust process. It also makes sure the nozzle path is clear.

THE CLOSED-LOOP PROCESS

In the closed-loop process, the casting is loaded into the fixture and the fixture is loaded into the machine. The next piece of the process—probing—is optional, but manufacturers should correlate between the machine and probe, machine to machine, or the CMM on which the part is ultimately measured. Initial alignment is obtained by probing cast datum points. Probing can be completed in the machine or outside the machine in a CMM or other measurement device. That data can be stored or passed to the machine program to compensate the cut path.

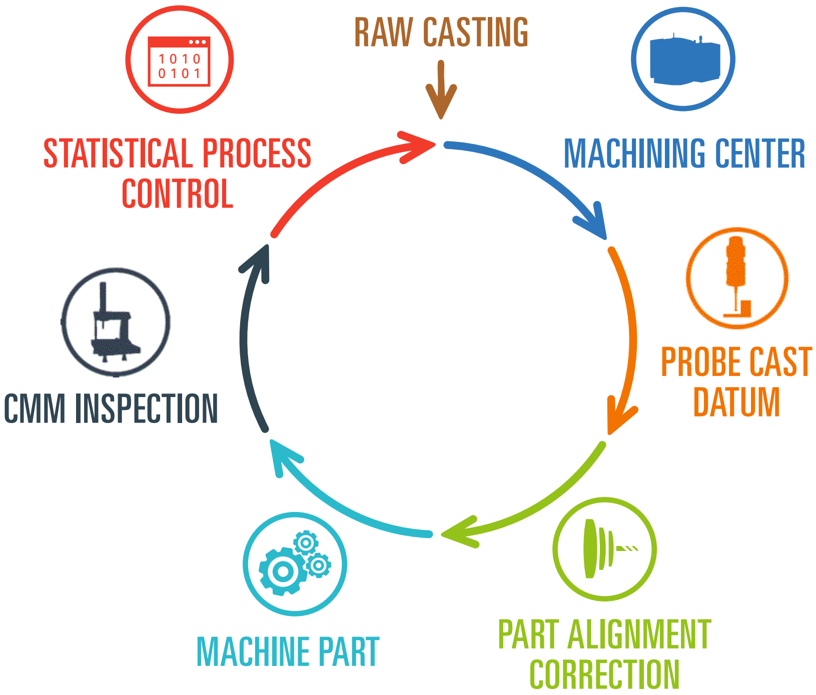
The next step of the process is the part machining. Using initial offset, the NC code is modified, automatically making the path match the initial alignment that was adjusted. During part machining, key process variable (KPV) monitoring is also conducted. Some of these KPVs include coolant pressure, volume and temperature. This is the #1 item to monitor as a drop in pressure could lead to scrapped parts. Other KPVs to monitor include spindle rpm, dresser rpm and tooling. For tooling there are checks



on how often the part has been in the spindle and how accurate it is. The KPV data is usually kept for each part so that the manufacturer can go back later and look at how a part was produced.

After machining, any data from part inspection is fed back to the machine to determine whether adjustments are needed. Corrections can then be made for slight part misalignments.

In order to have a capable production process, typically the part is tracked along with offsets for the fixtures, the part and the tool.



In a highly automated cell, some closed-loop providers have software with a graphics panel that helps the operator monitor the machines, show CMM results, review robot speed control, cell sequencing, KPV reporting, feature correction and coolant monitoring. This information is valuable in that it can quickly show at a glance that the closed-loop process is performing properly.

CONCLUSIONS

Ultimately, using closed-loop manufacturing technology not only reduces machining time but also increases accuracy and quality. In today's global environment, manufacturers must gain every competitive advantage they can.

While the closed-loop process can be complicated, it doesn't have to be if the right supplier is selected. When implementing a closed-loop manufacturing process, companies should look for these six criteria:

- A single-source provider with a complete engineering staff and the commitment to the planning and execution of the process.
- A machining platform that includes milling, grinding and EDM, along with 5-axis capability.
- A turnkey process with the reliability and stability to reproduce the same kind of parts day in and day out with minimal adjustments.
- A supplier that automatically conducts testing, 3-D modeling and time studies prior to setting up the machine and running parts.
- A provider that has capabilities for automation.
- The ability to monitor key machining processes to help maintain the closed-loop process.

By having the proper resources in place to execute this type of solution, manufacturers can ensure a smooth and accurate process.

RESOURCES

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