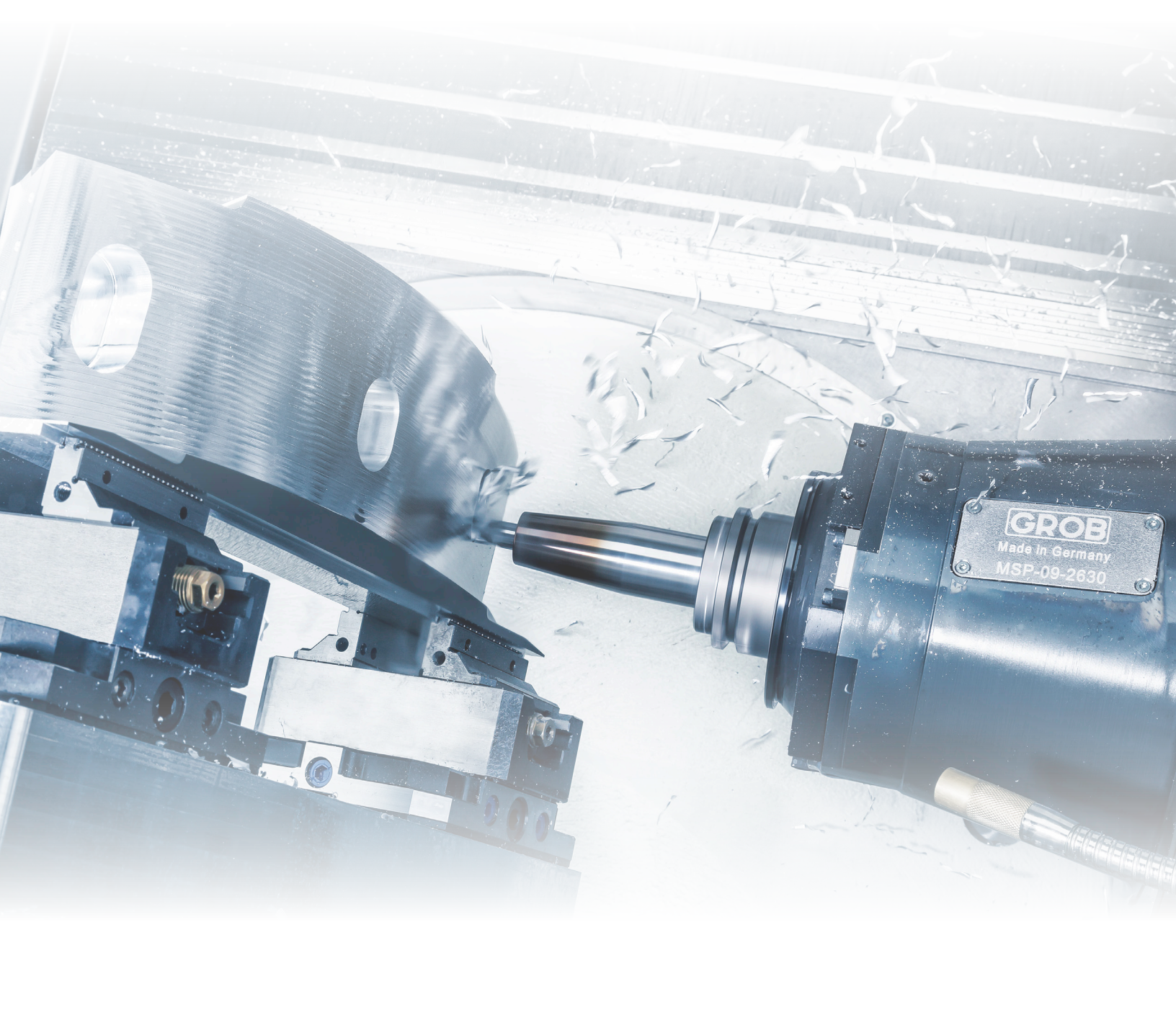


GROB



**IS YOUR SHOP READY
FOR 5-AXIS?**

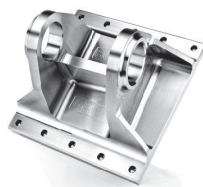
INTRODUCTION

Because of its clear advantages and proven successes, the increasing adoption of 5-axis machining is a trend that will continue. Adding the technology to a shop instantly eliminates competition that can't produce complex parts. Simply put, by delivering parts that fewer companies can produce, a shop with 5-axis capabilities will generate more revenue. What's more, production of simpler parts is dramatically expedited and any future transition in customer base or part complexity are more easily accommodated and planned.

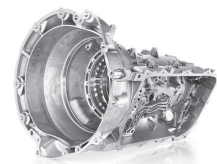
It's one-of-a-kind capabilities make 5-axis machining appropriate especially for companies already in, or thinking about adding production for aerospace, medical, oil and gas and automotive sectors. In fact, some common, high-demand workpieces are only possible with 5-axis machining. These include contoured parts like mold cavities, blisks (bladed-disk parts) and impellers.



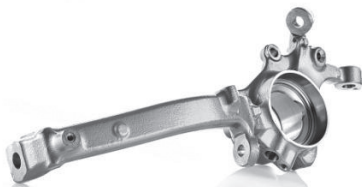
Console



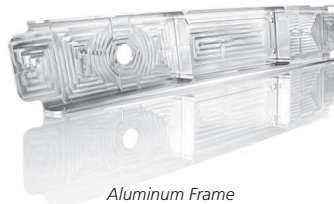
Bearing Bracket



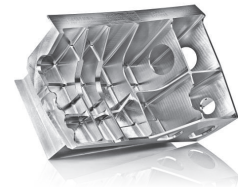
Gear Housing



Knuckle



Aluminum Frame



Structural Housing



Hinge Ground Spoiler



Turbine Blade



Radial Compressor

Examples of parts produced using 5-axis machinery

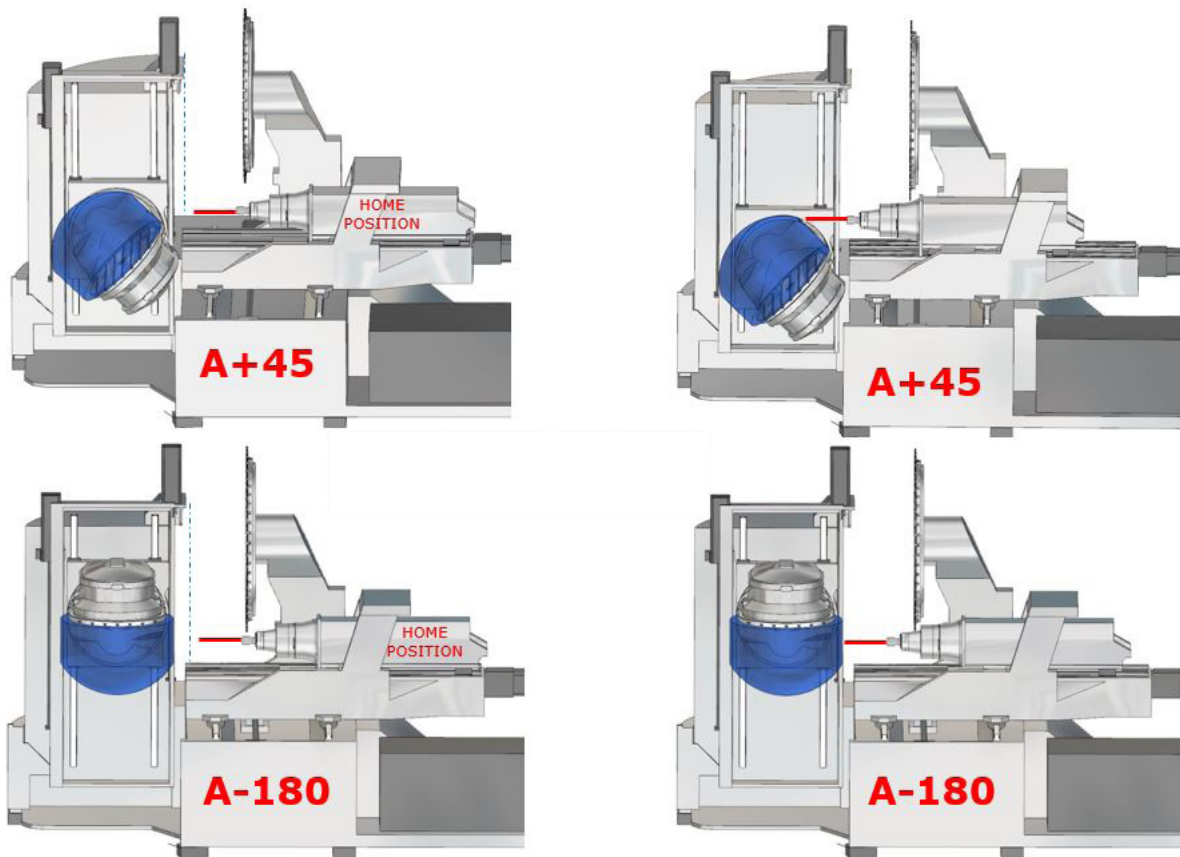
As with any capital purchase or infusion of technology, there are major strategic, financial and process considerations when planning to make a commitment to 5-axis machinery. In order to fully understand this process, one must first grasp the fundamentals of 5-axis machining and how it affects a company. Supported by application examples and case studies, this paper will examine these factors helping answer the question: Is your shop ready for 5-axis?

THE FUNDAMENTALS OF 5-AXIS MACHINING

Machining centers were traditionally limited to three linear axes commonly referred to as the X, Y and Z: one that moves the spindle in/out or up/down (depending on the machine center's orientation), one that moves the part perpendicular to the headstock and one that moves the part parallel to it. The two additional axes, referred to as A and B, that make up a 5-axis machine are typically spinning and tilting motions built into the table.

There are two basic kinds of 5-axis machining: 3+2, or 5-axis positioning, and 5-axis simultaneous machining, or contouring. A 3+2 configuration only moves the rotary axes outside of the cut. This allows access to features at different angles and on different faces of the part enabling most, if not all, of the work on a part to be done in a single setup. Five-axis simultaneous machining is when the rotary axes can feed the tool through complex cuts. This simultaneous movement enables cutting along contoured surfaces while holding demanding tolerances and producing fine finishes.

There are a few variations on how machine builders integrate five axes of motion. The most common alternative builds rotation and tilt directly into the table; that's why it's known as an A/B table. In this machine configuration, the spindle is oriented horizontally, enabling upside down or 90-degree machining for chip-removal and part-access options. HMC's also provide damping advantages thanks to ideal Z-axis (horizontal) stiffness through wide distances between roller guides. And, as represented in the graphics below, pairing a retractable spindle with the rotary table allows even more access and all but eliminates the chances of collision.



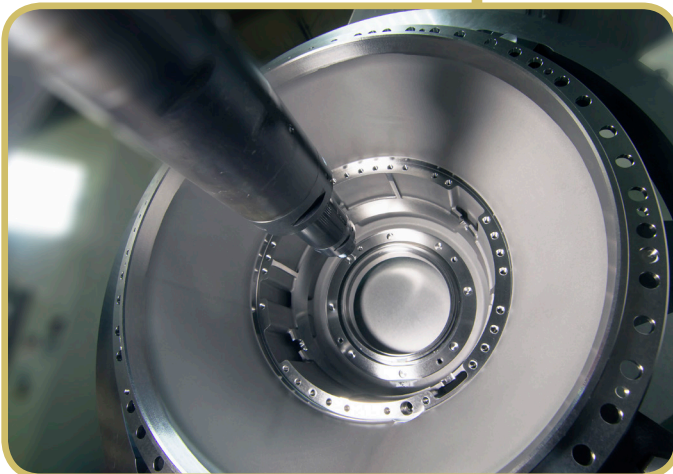
Rendering of 5-axis horizontal machining center with table rotation and retractable spindle

THE EFFECTS OF ADDING 5-AXIS MACHINING

The 5-axis platform is so powerful that the positive impact of adding it will be felt throughout a company. In addition to the speed and versatility it adds, those with 5-axis capabilities report several less obvious—but equally important—improvements to everything from shop floor organization to cash flow.

+ SIMPLIFIED SETUPS

With 5-axis machining, complex parts that once took multiple setups can often be reduced to one. Multiply the fixture and tooling preparations and changeovers that are eliminated with a single setup, and time and cost savings add up quickly. One setup opposed to four also represents three fewer opportunities for human error or misalignment when moving the part.



CASE STUDY:

STEIN SEAL KULPSVILLE, PENNSYLVANIA

ABOUT STEIN SEAL: Company founder, Philip Stein Sr. invented the circumferential seal

PART: Titanium bearing mount and seal support, 12" tall and 18" in diameter

CHALLENGES: Meet a customer's price/part requirement to earn a multi-year contract by finding efficiencies to make up for substantial non-machining time and fixturing/locating routines. The part also required hitting tolerances of $\pm 0.0005"$ and cutting complex features on the bottom of the part.

SOLUTION: Grob G550T Universal Machine with material handling

RESULTS

OPERATIONAL EFFICIENCIES: Converted to lights-out process that finishes entire part in one 12-hour overnight shift.

PRODUCTIVITY ENHANCEMENTS: 66% reduction in total process time

IMPROVED CHIP REMOVAL: With the part sideways, high-pressure coolant easily cleared chips

REDUCED TOOL LENGTH: Went from a 14" stick out to 6"

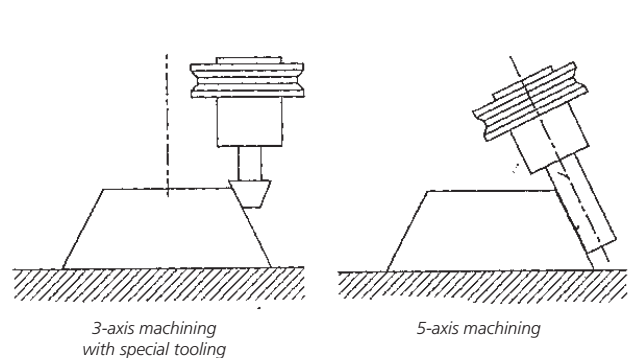
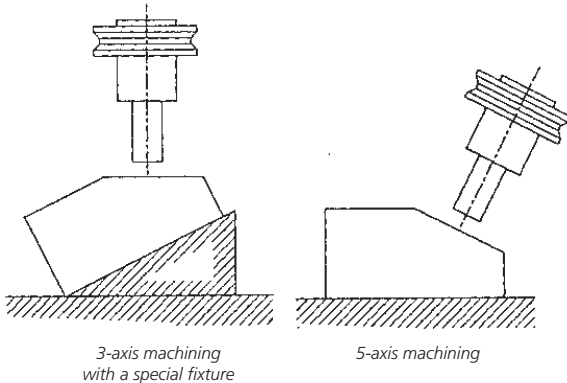
MORE PART MANEUVERABILITY: Retractable spindle made full workzone available to accommodate the part and its unique features.

MANUFACTURING MANAGER SAYS: "Because [the part] has tightly tolerance and challenging features at the bottom of its cavity, machining it on a vertical machine is inherently problematic. For one, we needed long tools to reach inside the cavity. For another, clearing chips was difficult." ... "[With 5-axis] we can hit the cost target proposed by our customer and meet all of the quality specification."

*The full case study can be read in the March 2016 issue of *Modern Machine Shop*

+ REDUCED TOOLING AND FIXTURE COSTS, INVENTORY

Having additional angles with which to approach the part has a direct positive impact on tooling expenses. It's much easier to adjust the part or spindle to the necessary cut than it is to change tools or fixtures. The spindle can get closer to a cut, meaning shops can reduce usage of specialized, more expensive tooling or accessories, like angle heads or long-reach drills, and the same goes for elaborate fixturing.



+ MORE SPEED, LESS CHATTER

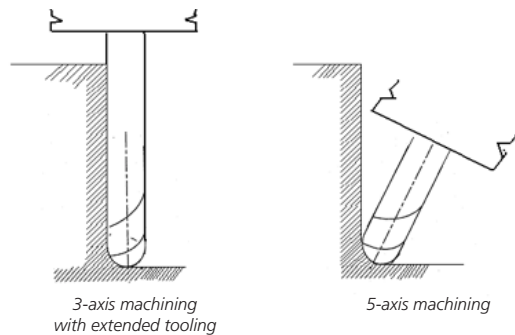
Using shorter, more rigid tools facilitated by a closer spindle-part relationship reduces chatter, even at higher spindle RPMs. This provides additional tooling savings because less vibration results in less wear—even in specialized cycles like trochoidal milling, helical milling or deep-hole drilling. Less chatter and higher RPMs also mean superior surface finishes can be achieved on just about any style of cut.

+ EASIER SMALL BATCHES

Shops with 5-axis capabilities are less reliant on waiting for forgings with long lead times, which is a common challenge in some aerospace applications. The ability to machine highly complex parts from solid also makes small runs and prototypes much quicker and easier. Jobs that once took months can be finalized in a few days with a 5-axis machine.

+ FINISHED QUALITY THE FIRST TIME

Moving the part or spindle is a superior option to trying to adapt tooling to a cut. This means shops can more frequently use cutters for the exact work they were intended and limit point contact. The ideal combination of tool type and length reduces chatter and increases speeds resulting in sharp edges and fine finishes that don't require additional work.



+ IMPACTFUL TRICKLE DOWN

Because processes are accelerated, some even eliminated, companies often take the opportunity to reconfigure the floor or sell off legacy machines. Accelerated processes and less money tied up in semi-finished products can also improve cash flow. In general, fewer moving variables—machines, tools, fixtures and setups—make for more reliable cycles and reduces quality control and inspection time.

EVALUATING PREPAREDNESS FOR 5-AXIS MACHINING

Investing in a 5-axis machine center only makes sense after careful consideration of the right strategy. As mentioned previously, the injection of such a powerful platform is likely to affect each division of the company directly or indirectly. The true test of a company's preparedness is a clear understanding of those effects and clearly defined goals.

+ BIG-PICTURE STRATEGY

Adding 5-axis technology simply because it's the hottest subtractive manufacturing technology is a mistake. There needs to be a clear reason for it. Two of the soundest reasons to add are to attract new customers with new products or decrease strain current products are imposing on equipment and staff. Needless to say, there is a lot more that goes into decisions of such gravity. A business case, cost benefit analysis, staff and facility considerations should all be a part of conclusions on strategy and the decision to add 5-axis machinery.

+ STAKEHOLDERS AND DECISION MAKERS

Only a person or team with intimate knowledge of the entire operation should develop the strategy and make decisions. If management is hands-off, there needs to be trusted people from the floor, accounting, management and customer-facing roles to provide thoughtful input. This is especially true if the 5-axis will support a new product. Decision makers need to be able to visualize how current equipment, processes and people engage that adoption.

+ THE RIGHT TEAM

There is a learning curve with 5-axis machining. It's why there's a tendency for companies to tap their most senior machinist to take the reins. It works for some, but others have met resistance from experienced operators about the new approach. Less experienced operators with an excitement about 5-axis, an open mind about new processes and a willingness to train can excel. The right mindset, in many cases, outweighs experience.

+ DETAILS OF THE WORKPIECE/S

Knowing the part/s the 5-axis will be used for is critical. Whether it's a future or current product, each feature of the part must be considered when transitioning to 5-axis machining, as must production volumes. These factors decide process—what machines can be removed and which capabilities and movements a new 5-axis center needs. Buying a 5-axis without understanding how to apply its efficiencies to the parts actually produced can prove a mistake.

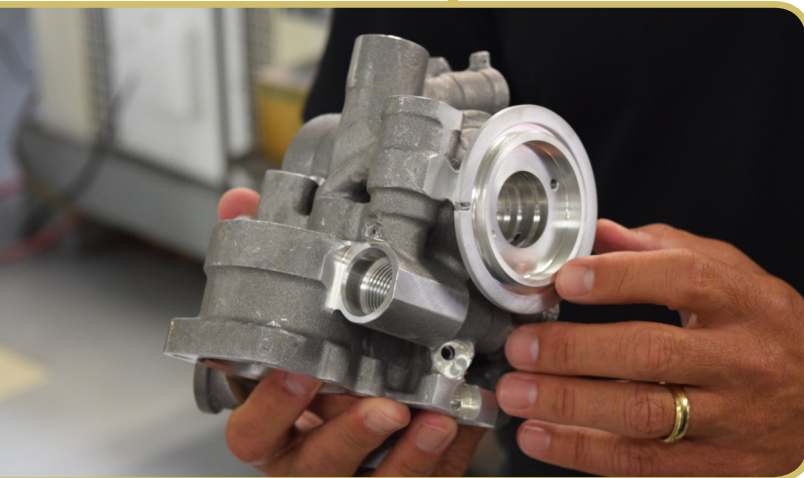


+ FACILITY AND ASSET MANAGEMENT

What will the shop floor look like after the addition of a 5-axis machining center? If the new center is being purchased for general-purpose work or to improve on a current process, there's a chance some other spindles on the floor may idle more often. There needs to be a plan for where those machines fit into new and old processes and the floor itself. It could be time to sell off those assets. Or, depending on the overall strategy, machinery may need to be added.

+ MATERIAL HANDLING

For the aggressive, well-organized shop, automated material handling unlocks a whole other set of options. Rotary and expandable (for multiple machines) linear pallet storage systems provide assembly-line style production. Custom solutions are suitable for machining complex components in small to very small lot sizes, for unmanned production environments and can supercharge existing cost-optimized processes.



CASE STUDY:

NORRIS PRECISION MANUFACTURING CLEARWATER, FLORIDA

PART: Fuel controller housing for auxiliary power unit used on most Boeing 737s and Airbus A320s

CHALLENGES: Increase capacity and reduce costs in a limited footprint without buying additional 4-axis machines and stacking a fifth axis.

SOLUTION: Two GROB G350 Modular Horizontal Machining Centers with horizontal capabilities, one standalone and one with material handling

RESULTS

SPACE SAVINGS: The two machines, including the pallet system, had a smaller footprint than one of the company's existing horizontal machining centers.

OPERATIONAL EFFICIENCIES: Reduced operations from eight to two. Tool magazine that accommodates 207 tools improved speed and repeatability

PRODUCTIVITY ENHANCEMENTS: Saved approximately an hour a part for a 30% increase in productivity

SHOP OWNER SAYS: "To get a trunnion, 5-axis machining center with horizontal capabilities, it's usually 500mm and 50 taper. It's a much bigger machine than we required" ... "We have the option for a 600mm work envelope if we need something bigger. But we try to stay within our core competency of size – not too big, not too small – just right."

*The full case study can be read in the October 2015 issue of *Aerospace Manufacturing and Design*

BY KEEPING PARTS FEEDING INTO THE MACHINE, ROI IS ALMOST EQUIVALENT TO A SECOND MACHINE.

+ STANDARD MACHINE WITH PALLET CHANGER

50%
MACHINE
UTILIZATION

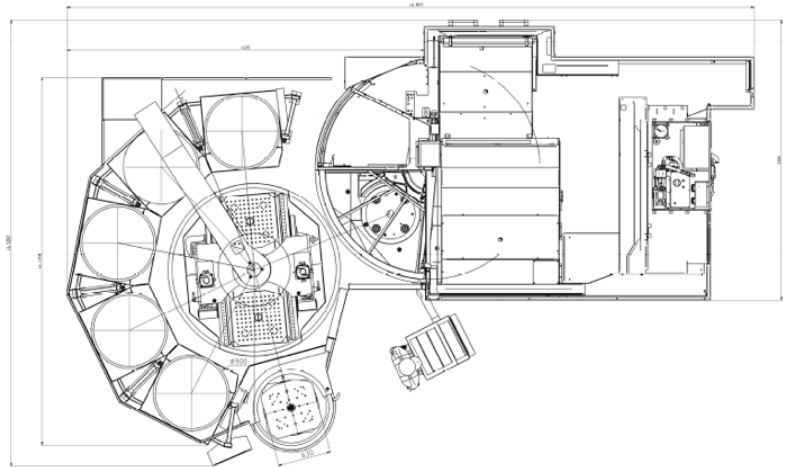


+ PALLET STORAGE SYSTEM

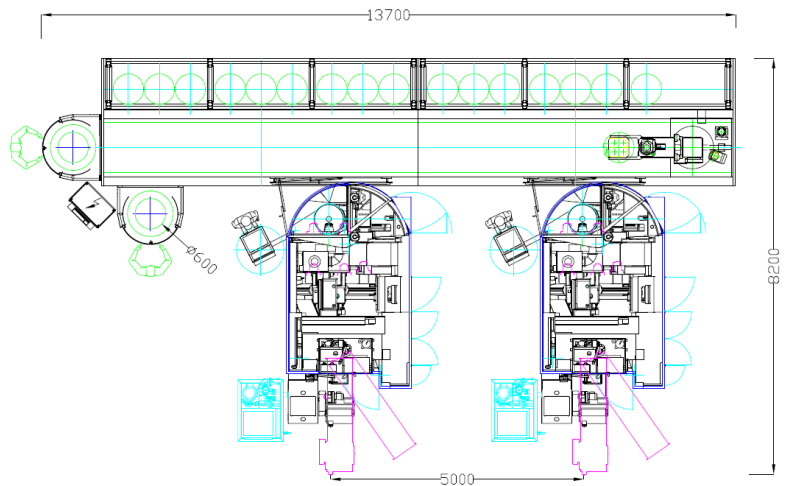
90%
SPINDLE
UTILIZATION



ADAPTABLE AUTOMATION SYSTEMS



Rotary pallet storage system: 13 pallets for storage, one setup station, no pallet changer



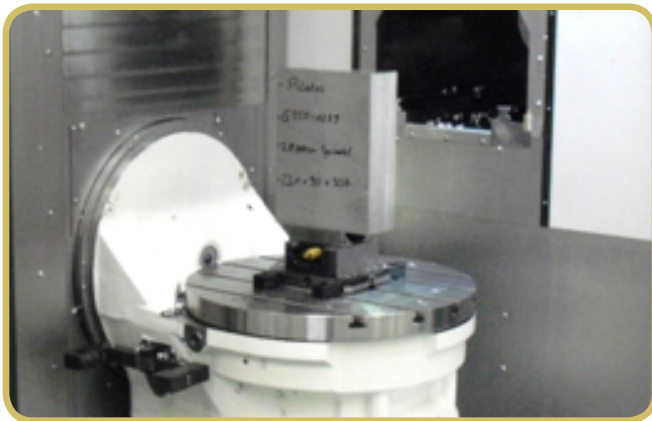
48-pallet storage system with 3 levels and two loading stations

+ MACHINE SELECTION

Most 5-axis work involves parts that require holding tight tolerances. This requires a machine with a rigid spindle and tool holder to eliminate vibrations. The machine must also maintain consistent acceleration and deceleration, while processing high volumes of data, to achieve smooth finishes. Keep in mind also, the machine's ability to compensate for temperature variations, and achieve desired accuracy in every area of the specific work envelope.

+ CONTROLS

Adding 5-axis machinery can consolidate part programs, making life a lot easier for programmers and operators. Complex toolpaths and voluminous series of short, linear moves require fast and powerful CAM processing and providers with tailored 5-axis products. Similarly, CNC controls need specific capabilities. Fundamental attributes like memory and speed need to be more advanced than in 3-axis machining. And, key features like tool center point management, automatic safe positioning, toolpath linearization and robust collision avoidance play a factor.



+ FINANCING

Those considering 5-axis machinery should only work with machine suppliers that have deep experience in financing such purchases. Shops need to understand things like trade-ins, how deferred payments ease start-up costs and how capital leases can be structured to provide depreciation benefits. Anticipated tooling and workholding should be established in order to bundle packages within the financing agreement.

CASE STUDY:

PART: Aircraft structural component

MATERIAL: Solid aluminum

SIZE: 8.1" x 8.7" x 3.5"

CYCLE TIME BEFORE 5-AXIS: 2 hours

CYCLE TIME AFTER 5-AXIS: 39 minutes

SAVINGS: 68 percent



CONCLUSION

Prepared companies identify the people that can completely and honestly assess the current situation and envision the shop with a 5-axis. The addition will have dramatic effects. In order to consider itself prepared, companies must understand these effects and plan for them.

It is a significant commitment on many levels, but as detailed in case studies and supported by continuing demand for the technology, the investment pays off. With the right plan, a knowledgeable 5-axis supplier and the right people, companies realize ROI and take market share because of faster throughput, more part versatility and higher overall quality. Additional efficiencies, tooling and fixture saving and inventory reductions improve cash flow. How quickly a company's 5-axis investment is paid back however, hinges almost entirely on preparation.

