The Merits of Multifunctional Machining

Flexibility and Productivity Make Solid Case for Machine Tool Integration

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The design of EMAG's VSC 400 DUO WF multifunctional machine is based on the pick-up principle of the EMAG single-spindle turning machine and features both gear turning and gear hobbing operations (courtesy of EMAG).

Increased business in the aerospace, power generation, shipbuilding, automotive and alternative energy industries has led many manufacturers to believe that 2011 might be as good a time as any to invest in new machine tools. This was certainly the case last fall at AMB 2010 in Germany, where 60 percent of attendees planned to make machine investments in the next six months and 30 percent in the next twelve. "According to the results of our survey, visitors' propensity to invest once again matched the same level as that seen at AMB 2008 when the economy was still booming," says Ulrich Kromer, managing director of Messe Stuttgart.

Machine tool investments were also a hot topic at IMTS in Chicago as "sold" signs popped up through the duration of the show. "Those searching for confirmation that manufacturing in the United States is not dying or dead found that it is robust and poised for growth. They clearly understand that investing in the latest technology is the key to being competitive," says Peter Eelman, IMTS vice president of exhibition and communications.

Higher productivity, faster setup times and single unattended operations are just a few of the capabilities gear manufacturers seek in the multifunctional machine tool market.

Though more expensive and robust than dedicated machine tools, many believe these machines represent the

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The multifunctional capabilities of the SAMP HG 1200 Invento was on display at IMTS 2010 in Chicago (courtesy of MAG).

Gleason's Agilus features a high-speed tool turret to locate fixed or driven tools for the complete range of turning, drilling and milling operations (courtesy of Gleason).

future of gear manufacturing altogether.

Brian Cluff, vice president at Star-SU, thinks they will be most relevant in the big gear industry. "The people we talk with in the large gear market are looking to combine operations into a single unit to minimize capital investment, maximize machine utilization and reduce space and energy costs for manufacturing very large gearing," Cluff says. "In the medium size gear market users are arranging machines to be automatically loaded (pallet loaders, gantry loaders) to reduce changeover and idle times.

"Spline and some gear cutting are already done using Tsugami screw machines, Mazak Integrex, Bonfiglio lathes and other turning centers," Cluff adds. "This has been going on for some time, but in the 500 mm and above, combo machines for turning, milling and hobbing are not yet a large influence in the technology of gear manufacturing. Combination machines one meter and above will have the greatest impact in large gear manufacturing in the next few years."

The Art of Integration

Combination machines. Integrating a number of different manufacturing technologies into a single machine tool is a growing trend at EMAG LLC. "Multifunctional machine tools make an important contribution to the consolidation of process streams in both soft and hard machining, as they combine turning, milling, gear cutting and grinding operations," says Peter Loetzner, CEO of EMAG.

Apart from eliminating transport and wait-times, they also shorten incidental set-up and non-productive times. When optimally equipped, they can be used as full-fledged turning machines or full-fledged gear hobbing machines. "The machines can be tailored to suit the application, offering the optimal solution for a large variety of manufacturing requirements," Loetzner says.

In the case of multifunctional technology, the most important developments in gear hobbing have been in the areas of high-speed, dry and hard machining. "The driving force behind such innovations is usually the desire for cost reduction or product quality improvement without attendant cost escalation. These new areas of application for gear hobbing operations have depended—to a large degree—on developments and innovations in machine design, tooling materials and tool coating technologies," Loeztner says.

The design of EMAG's VSC 400 DUO WF multifunctional machine is based on the pick-up principle of the EMAG single-spindle turning machine. Both turning and gear hobbing operations are of equal status. The VSC 400 allows for the second operation in the same set-up.

By utilizing the VSC 400, Agco Fendt, a manufacturer and distributor of farm equipment, has brought an overall cost savings of 18.5 percent compared to the previous manufacturing process that used individual machines. The cost of machining an internal clutch plate carrier on the VSC 400 is only 71.5 percent of what it was when the component was made on a number of different machines.

Loetzner believes that the benefits and limitations of process integration are workpiece- and company-specific. "This calls for close scrutiny of all advantages and disadvantages with individual processes on one hand and multifunctional processes or machines on the other."

Machine tool integration in both large and small gears is definitely becoming more feasible in today's manufacturing environment, according to Johannes Brogni, technical director at Gleason Pfauter Maschinenfabrik in Studen, Switzerland. In early 2010, Gleason unveiled the Agilus 180TH, a combination of a lathe and a hobbing machine that accommodates shaft-type parts and is capable of producing disc-type parts as well.

"The biggest advantage of this type of machine is that you can load a forged blank that has been cut to length and centered, and you get a finished part ready for heat treatment," Brogni says. "This concept reduces the throughput time tremendously, provid-

ing the gear producer with a significant cost reduction, especially when he is producing smaller lot sizes of 50 to 500 pieces."

With a long track record in gear processes, Gleason developed the Agilus for the single setup of all shaft- and disc-type cylindrical gears up to 180 mm in diameter with shaft lengths up to 500 mm. It features a high-speed tool turret to locate fixed or driven tools for the complete range of turning, drilling and milling operations.

"One customer running an Agilus machine recently reported that the throughput time of his parts has been reduced from five days to one day, and that he was able to reduce the manufacturing time by 45–50 percent, depending on the parts," Brogni says. "This reduction came primarily from the fact that the operator was able to optimize the process sequence very easily, without the need to consult others."

Additionally, the company has developed the ability to combine the Agilus cell with other manufacturing cells. "This means that we can place other machines like long hole drilling machines, dedicated turning machines, etc., enabling the manufacture of a part from the blank stage until the part is complete and ready to be hardened," Brogni says.

One key to making this technology work is the software. Brogni says the software is one of the major components to the success of the machine—it's also a key challenge. "Two approaches were considered at Gleason; using turning software as the base and adding hobbing software or using Gleason-Pfauter hobbing software as the base and adding turning features. Either approach can work but we chose the latter so that the gear-related technology data and corrections can be handled easily and the hob management is integrated into the software. This has the advantage that the turning programs, which are becoming very simple, can be created on external ISO program generators."

Brogni believes the benefits of multifunctional machines will drive a significant change in manufacturing thinking in the future. "It is possible to integrate processes that could not have been done before, like rough-cut hobbing, chamfering and deburring the part, and then finish hobbing so that the deburred flank is still large enough. When we are looking to machining centers for rotary symmetrical parts we can see that lathes today are capable of performing many more processes beyond turning, like drilling, milling, rolling, etc. I think it is logical that this will also be the case with gears."

With the acquisition of SAMP's gear hobbing line, MAG IAS is able to provide solutions for all processes from the soft blank to the finished gear. This puts the company in the unique position to offer a wide array of multifunctional equipment.

The SAMP HG 1200 Invento, for example, addresses the requirements of large gears with diameters up to 1,200 mm and module 35.0 (40.0) in the energy, transport and construction sectors. It features a twin-table concept, enabling the operator to execute the complete setup and centering process

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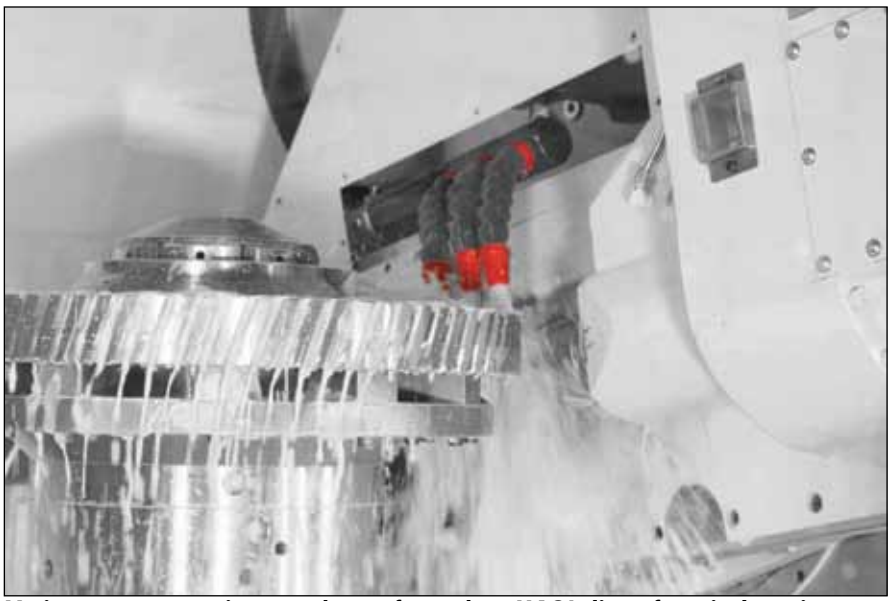
in masked time while the manufacturing process proceeds on the second work table. Reduction of setup time is not only possible for mass production but also for the manufacturing of small lots.

MAG's own range of vertical turning centers (VTCs) can process the gear in one setup, both the turning and gear cutting. The part setup time and workpiece handling are reduced, which is particularly important for large gears.

"The advantages include faster processing speed and higher throughput. In addition, part accuracy benefits from the one setup process since you don't have the errors inherent in multiple setups. There's also a lower initial investment since one machine can do both turning and cutting. This also saves valuable manufacturing floor space," says Helene Nimmer, global product leader at MAG IAS. "We see multifunctional machine demand growing, especially in the industries that produce large gears. We've applied the 1,000 mm machines and are expanding the technology to larger machines and gears."



Various gear operations can be performed on MAG's line of vertical turning centers (courtesy of MAG).

Through simultaneous five-axis machining, Mazak's Integrex e-670H II can produce complex shaft workpieces containing tapered holes, blisks and spiral bevel gears in a single setup (courtesy of Mazak).

The company has an extremely wide range of products including vertical and horizontal lathes, machining centers, boring mills, agile powertrain machines, profilers, composite processing, software, automation and component production, according to Nimmer. "Relative to gear production, we have turret and ram head vertical turning centers that start at 250 mm and extend to eight meter tables. For the VTC series, one tooling advantage we offer is the ability to use standard modular tools such as KM 80 and Capto."

Multitasking machines. Cutting gears on non-gear machinery is a trend that continues to grow as software programs and machine tool upgrades give users the versatility, functionality and customization to do jobs both in and outside the gear industry.

"Multitasking machine tools can compress the manufacturing cycle by performing a variety of operations without manual intervention," says Mike Finn, development engineer at the Mazak Corporation. "Combining operations such as turning, milling and, now, some forms of gear cutting on a single platform not only minimizes setup time, but also reduces floor space. Plus, the customer gets the service and support benefits that come with a standardized machine tool, as opposed to the challenge of maintaining a special-purpose machine tool, which can become very expensive, especially if not fully utilized."

Mazak, for instance, has a broad range of machine tool experience beyond gears. "We have been creating processes on multitasking machine tools for our customers, and in our own factories, for many years. Adding gear cutting capabilities onto existing multitasking machine platforms and working with customers and suppliers to refine this are in a growing trend," Finn says.

One of the keys to Mazak's success in this market is repeat business. "Our customers who have maintained their competitiveness with multitasking are collaborating with us and our supplier partners to add additional capabilities. They want the benefits of standardized Mazak multitasking machine tools,

but with ultra-tasking capabilities. They're pushing us to add capabilities such as gear cutting, so that they can do that one additional operation while keeping the part on the machine, rather than moving it off to specialized equipment. Exceptional accuracy and ultra-fine synchronization of rotary and linear axes allow quality levels in the AGMA class 8 to class 10 range in certain applications, without adding to the overall cycle time of the workpiece. Combining subsequent process into one, along with additional metal cutting time, increases utilization of the machine tool, thus reducing overall cost per hour to provide additional profits."

The Integrex j-series offers four-axis simultaneous machining with five-axis tip positioning. It features large Y-axis strokes and offers a milling spindle that can be indexed in five degree (one degree optional) increments over a total range from -30 degrees to 190 degrees, allowing outer diameter machining and facing with the same tool. The Integrex e-series is suitable for the production of large parts and performs various gear cutting processes.

"The Mazak e-650H II is available with a unique tool holder that can be automatically loaded onto the milling spindle offering deep-hole drilling operations," Finn says. "It offers 191 Nm of maximum torque and a maximum spindle speed of 400 rpm. It can perform hole-drilling to a maximum depth of 800 mm."

In cooperation with Voith, a major transmission manufacturer in Germany, Heller Machine Tools has developed a process that significantly enhances the productivity of pre-milling and gear milling operations performed on a single five-axis machining center. Both companies have applied for a patent on the jointly developed process.

The process is aimed at manufacturers of vehicles, machines or machine components that can use the machining center for lower volume production of larger gears as well as other machining tasks, according to Tracy Ellis, sales manager, machines at Heller Machine Tools.

Gear milling has recently been an interest of some machine tool builders as it is more efficient to use the existing capability of a five-axis machining center for new applications beyond those typical for machining centers. According to Ellis, gear milling provides an opportunity to use the full potential of its five-axis machining centers from its new F series machines to its heavy-duty MCH-C series.

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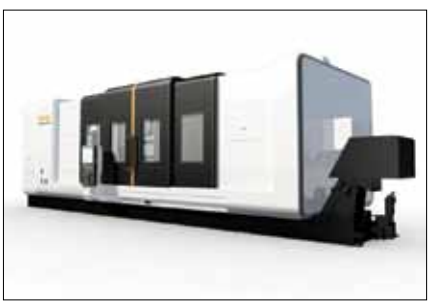

Mazak categorizes its multitasking machines into five levels, allowing customers to navigate the product lines and select the best machine for specific applications (courtesy of Mazak).

For the machining of gears, a module two or smaller fits the capabilities at Index and Traub (courtesy of Index).

Ellis pointed out that traditional gear-making machine manufacturers continue to concentrate on special-purpose machines and tools dedicated to gear machining, but that manufacturers of machining centers can provide complete machining for a wide range of applications as well as solutions for gear modeling using special software. The software permits the user to generate an ideal gear geometry from which the gear-making process can be developed.

A global turning machine manufacturer, Index products include CNC lathes from single-spindle to multi-spindle machines as well as fixed and sliding headstock machines.Tyler Economan, proposal engineering manager at Index Corporation, says, "When a part can be machined in a single-step process, the accuracy is much greater. The result is fewer scrap parts because less handling is required. In addition multifunctional machines can offer lower cost per piece."

The machines at Index are designed to have extreme thermal and dynamic stability, and the engineers are attentive to today's technology demands. "Machining all of the features is much simpler than using fixtures or complicated workholding as in a traditional gear making machine. Another benefit is that this process allows for optimal run-out between the bearing diameter and the gear profile," Economan says.

The Index MultiLine multispindle CNC machines combine the benefits of traditional high production multi spindle automatics with the benefits of modern CNC technology. The MS40 is a new machine that offers multiple operations on small workpieces from bar up to 40 mm or chucking up to 120 mm. "It features six fully independent liquid-cooled, hollow shaft CNC spindle drives each capable of 7,000 rpm."

Without fixed tool assignments, any tool can be used in any position in most scenarios, according to Economan. "The machines have an innovative guide way design that provides high stiffness and dampening, this is very important when machining high precision parts."

Index also includes a simulating and optimizing software system called *Virtual Machine*. This software is a simulation tool for Index machines that features Siemens 840D controls. Users can operate various functions from their offices just like they would at the machine itself.

"With technology continually evolving in the gear industry, Index and Traub are continually designing and offering new machines," Economan says. "Gear machining as an integrated process can be advantageous when the relationships of certain features on the part to the gear form are critical. When it comes to machining gears, a module two or smaller is a good fit for our capabilities."

Brian Nowicki, sales agent for North American Machine, the Depo importer, sees machining centers as a key advantage for the large gears found in the oil/gas, mining and wind energy industries. "While cycle times are not as quick as conventional methods on smaller gears, the benefits come as you get into the larger sizes," Nowicki says. "In the traditional gear cutting world, each of the gear families requires a different type of machine. With this new technology, one machine is equally effective for all gear types within its given diameter range."

Nowicki says a Depo machine was able to perform a project involving double helical gears in 45 hours instead of 150 from a dedicated machine. "The accuracy of the machine, the functionality of the software and the support and knowledge of the engineers are the keys to our success."

Depo's five-and seven-axis vertical and horizontal machining centers include thermal compensation, broken tool detection and workpiece inspection. Depo's unique software package—*Gear Engineer*, *DepoCam* and *Inspect*—are all integrated with its machine tool line and high-end tooling solutions, to produce the gears.

Additionally, the system can do lifting and mounting holes as well as gearboxes. "It's often overlooked that we're selling a machining center that can do much more than dedicated gear cutting machines," Nowicki adds.

He warns that customers should do some research before making a decision on machine tool purchases of this nature. "Everything is about integration today. It's about providing the customer with a complete turnkey process. If you don't have the software or the expertise to back up your equipment, you're going to play catch-up. Depo's ability to simplify the manufacturing process is one of our greatest strengths."

He adds that there are three important factors to take into consideration when shopping for multifunctional machines, "The quality of the gear, the quality of the machine itself and the rotary table. Accuracy plays a major role in what you can or cannot do. If you don't have the sales and support staff that understands gear geometry, you're not going to be happy with the product. The industry is trying to piece together the technology and get the most out of their machines and tools, but you must have experience and knowledge to do it right."

The All for One Philosophy

Multifunctional technology has certainly created a buzz on the trade show circuit recently as more companies come together to share knowledge in their respective areas of expertise. Companies are aggressively expanding product lines to capture new markets—chalk up gear manufacturing as one area of interest.

The impact of MAG's acquisition of SAMP's hobbing machinery line, for example, clearly points to a future where more companies may bring a variety of expertise to a specific industry. Combining MAG's complete range of multifunctional turning products with SAMP's gear cutting products opens an entirely new customer base.

"The marriage of the two technologies and the opportunity for our product leaders to work together will produce new technology for markets that

demand that their machines do more," Nimmer at MAG says. "Since partnerships are the quickest way to bring new technology to the market, we may still see additional joint ventures."

The Mazak Corporation is also currently working with other companies on future business in the gear industry. "We're working with another company to develop optimized models of the spiral bevel gear. Like many in the industry, we're working on a long-term partnership that can only increase the productivity of our machine tools," Finn says. "When we put all of our heads together, it's interesting to see the kind of impact you can have on the engineering side. This seems to be a popular trend at the moment in gear manufacturing."

"With more products to offer and additional knowledge from these mergers, these companies will have more opportunities for new customers and a great customer base," Economan at Index says. "With the current economic climate, it may also be true that some financially weaker companies will consider merging."

More important than what companies are saying about mergers and acquisitions are what they're not saying. Many of the companies interviewed for this article chose not to comment at all on the subject, though a select few hinted at new developments happening in 2011 and 2012.

Future Considerations

While sales agents and engineers are quick to point out why their company's machine tools are the best, customers must look at their current machine capacity and determine what upgrades they can afford and what logistically makes sense.

"Bottom line, traditional gear makers use dedicated machine tools because individually they are the best at whatever it is they do," Nowicki says. "In high production scenarios, the machining centers are not nearly as competitive with cycle times. The dedicated equipment can machine the gears faster, but when you're dealing with critical parts, there are machining centers that can do things that have never been done before."

Any debate on the advantages/disadvantages between multifunctional equipment and dedicated machine tools is not easily answered, according to Brogni at Gleason. "It is dependent upon a wide range of different factors, and can even be different from one manufacturing plant to another that is producing the same part."

In talking with many machine tool users, it's going to take education, awareness and a little faith in new technology for some to incorporate multifunctional machines into existing manufacturing environments.

"We have seen some customers that are not yet ready for this idea. They have existing equipment or organizational issues that prevent them from taking this approach at the moment. It has to do with the education of the machine operators," Brogni says. "Some are skeptical that such a concept will improve their productivity while others understand the benefits when

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they see the machine in operation and enthusiastically begin to create ideas for what additional processes might be integrated."

Adds Nowicki at Depo, "Multi-functional is the direction this industry is going. It's been a frequent topic of conversation at trade shows and AGMA meetings. Big gears are coming into play in a variety of industries and the market is hot right now. Maybe you're not considering this technology, but there's a very good chance your competition is."

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