Friction Stir Welding: The Key to Single-Setup Component Machining

With the birth of modern Multi-Tasking, Mazak helped launch a new era of manufacturing...

INTRODUCTION

When Mazak first added a milling spindle to the SLANT TURN 40 ATC Mill Center in the early 1980s, the idea of "Multi-Tasking" was still new. The model of industrialization pioneered in the late 1800s and early 1900s centered on mass production, such as that used in Henry Ford's famed automotive assembly line. With the birth of modern Multi-Tasking, Mazak helped launch a new era of manufacturing, one that would eventually result in the high-mix/low-volume approaches that have become prevalent in the 21st century.

Indeed, the pace of change was impressive; by the time it introduced the INTEGREX series in the late 90s, Mazak could offer machines with turning, milling, drilling, tapping and boring capabilities, second turning spindles, multiple tool turrets, Y-axis capability, and tilt/rotary milling spindles and worktables – combinations that allowed manufacturers to take raw materials and turn them into finished parts in a single setup, a concept Mazak dubbed "DONE IN ONE®."

Mazak's current lineup of Multi-Tasking machines can handle most, if not all, of a part's machining and processing operations in a single setup. But this conventional form of Multi-Tasking has a key limitation: All of its operations are subtractive in nature. And because the part-processing needs of manufacturers are driving machine tool technology beyond today's levels, Mazak has sought to change everything once again with its HYBRID Multi-Tasking concept.

Mazak

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HYBRID MULTI-TASKING

In terms of Mazak's Five Levels of Multi-Tasking, HYBRID Multi-Tasking represents Level 5: bringing together subtractive processes with additive and joining capabilities in highly productive combinations never before possible. In addition to broadening the subtractive capabilities of these machines by offering new ways to perform gear skiving, hobbing, honing, grinding and broaching, the HYBRID lineup includes innovative additive manufacturing and joining solutions such as HOT WIRE Deposition, laser and multi-laser metal deposition and friction stir welding (FSW).

In many respects, the benefits of HYBRID Multi-Tasking are similar to those manufacturers discovered with the first SLANT TURN 40 ATCs. Multi-Tasking significantly reduces lead times, especially when factoring in research and development time, and streamlines the development of processes. The cost savings from eliminating changeovers and setup time alone quickly add up. With their easy integration into automation solutions such as Mazak's PALLETECH system, Multi-Tasking machines allow manufacturers to reduce operating costs and capital equipment expenditures sharply.

Additive manufacturing and joining represent where the HYBRID revolution begins to take Multi-Tasking to the next level. In previous decades, these processes were slow, expensive and imprecise; in most cases, a part produced with an additive process or joined to another via welding would need an additional finishing process. But with HYBRID, there are no second separate processes, no additional setups – just the same DONE IN ONE approach that has made Multi-Tasking an integral part of the manufacturing environment.

FRICTION STIR WELDING

First introduced by The Welding Institute in 1991, friction stir welding generates heat with friction using a rotating pin pressed against a workpiece. Particularly useful with metals with low melting points, including aluminum, FSW creates joints that require little post-processing, use no filler material, resist corrosion and produce a wide range of join types, including hollow ones. Furthermore, FSW can even join dissimilar metals, which represents a major step forward in welding technology.

The FSW welded area can be divided into four regions, including the unaffected material. The heat-affected zone with no plastic deformation is kept to a minimum thanks to the lack of traditional arc torches or other welding equipment. A thermo-mechanically affected zone with plastic deformation and altered microstructure can be found on the exterior of the weld, as well as a recrystallized area within the thermo-mechanically affected zone in which the FSW process changes the grain structure of the metal.

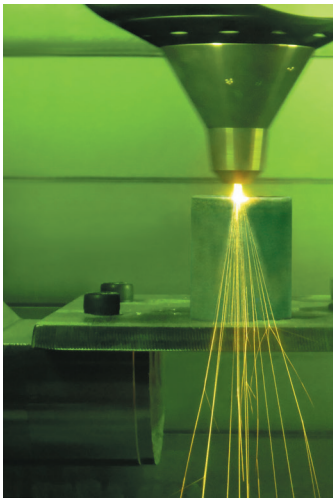
Both low-temperature and high-temperature forms of the FSW technique exist, with the former operating below 932°F and the latter between roughly 932°F and just under 1,292°F. Aluminum and aluminum alloys – important in the aerospace, marine, transportation and electronics industries – fall under the low-temperature heading, including difficult-to-weld materials from the 7000 series of aluminum alloys. Low-temperature FSW represents 95 percent of customer applications.

Despite these advantages, the cost of dedicated FSW machinery made it prohibitively expensive for most manufacturers. These machines could only handle a small number of applications and were not produced in quantities sufficient for more than research and development, much less high-volume production. Now, the advantages of FSW – improved part accuracy and a significant expansion of use cases as compared to traditional welding – are now available in a traditional CNC Multi-Tasking platform.

Mazak's first FSW-focused HYBRID Multi-Tasking machines include the VTC-300C FSW and VTC-800/30 SR FSW, vertical machining centers with full traveling-column designs and fixed tables ideal for long and heavy workpieces. Designed in conjunction with Mazak MegaStir, the nonconsumable FSW tool itself, integrated within the machine using a unique tool holder, includes thrust and temperature sensors to allow the CNC to continually adjust the Z-axis position for closed-loop process control and optimal welds.

REAL-WORLD APPLICATION: MANUFACTURING FOR SEMICONDUCTOR FABRICATORS

Semiconductor fabrication suppliers typically construct equipment for their customers from aluminum billet, a lightweight, non-reactive and corrosion-resistant material that machines easily and cost effectively. It can also be finished to create high-quality surfaces, which is important when attempting to prevent contaminants within a manufacturing system. Of course, because these components require precision machining, they cannot be cast or otherwise produced as one piece – they must be welded together to create airtight spaces, such as for vacuum chambers and gas lines.



Unfortunately, traditional welding introduces a number of challenges, even with metal inert gas (MIG) welding, often considered the standard solution for the industry. Creating a perfectly smooth weld requires experienced welders operating single-purpose equipment, and any error in production can scrap an entire piece of equipment. The smallest impurity trapped in the join could find its way onto silicon wafers, resulting in a scrapped part.

Welding also takes time, especially the highly precise welds required for producing semiconductor fabrication equipment. Because these manufacturers must maintain a high production volume to keep up with demand, that time comes at a high premium, particularly when considered in the context of the upstream and downstream product requirements. These costs go up higher once the risk of scrapping workpieces or the idle time surrounding every welding operation has been factored into the overall production costs.

Due to these factors, for the semiconductor industry, the advantages of using FSW to produce semiconductor fabrication equipment are obvious: FSW merely moves material from one side to the other, breaking down grain structure and allowing the grains to regrow while the tool shoulder constrains the direction in which they form. That controlled, refined grain regrowth consolidates the welded joint, making the material stronger and less porous while retaining its original thermal and chemical properties – all while reducing production costs and helping users realize more optimized processes.

More manufacturers than ever before can enjoy the process optimization benefits made possible by Multi-Tasking DONE IN ONE efficiency.

SUMMARY

Today, with the introduction of this technology to Mazak's HYBRID Multi-Tasking ecosystem, FSW has become the cost-effective, optimal choice for precision welding and novel joining techniques alike. In addition to the advantages for the end user, manufacturers can also perform machining and solid-state joining applications in a single setup. By loading raw material and unloading finished parts – complete with perfect welds for the first time ever – more manufacturers than ever before can enjoy the process optimization benefits made possible by Multi-Tasking DONE IN ONE efficiency.

About Mazak

Mazak Corporation is a leader in the design and manufacture of productive machine tool solutions. Committed to being a partner to customers with innovative technology, its world-class facility in Florence, Kentucky, produces over 100 models of turning centers, Multi-Tasking machines and vertical machining centers, including 5-axis models. Continuously investing in manufacturing technology allows the Mazak iSMART™ Factory in Kentucky to be the most advanced and efficient in the industry, providing high-quality and reliable products. Mazak maintains eight Technology Centers across North America to provide local hands-on applications, service and sales support to customers.