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Mazak Hybrid Multitasking

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Learning Objectives

- Gain an understanding of hybrid multitasking machinery and the benefits of this technology
- Learn about where this technology has the best use
- Learn about the complex nature if this technology
- Learn about evaluating current processes as candidates for Hybrid Multitasking

Description

As workpieces become more complex with the need to bring them to market at a faster rate, hybrid multitasking machines help manufacturers deliver quality products in less time. This session will briefly touch on the history of multitasking, and how it paved the way to hybrid multitasking. We will also discuss the hybrid machine platforms and the technology each offers, along with examples.

Speaker(s)

Mike Finn has been with Mazak Corporation as an engineer since 2000 and specializes in process development on gear cutting, 5-axis machining and additive manufacturing. He holds a Master of Science in Industrial Engineering from the University of Cincinnati College of Engineering. He also holds a Bachelor of Science in Mechanical Engineering Technology from the University of Cincinnati College of Applied Science.

Joe Wilker is Mazak Corporation’s Advanced Multi-Tasking Group Manager for North America. In this role, he oversees a wide range of Mazak product lines including but not limited to all additive Multi-Tasking products. Joe has over 30 years of industry experience in various technical and sales support roles and has been an instrumental part of the Multi-Tasking evolution, from Mazak’s earliest INTEGREX machines to today’s HYBRID Multi-Tasking platforms. He has a Bachelor of Science degree in mechanical engineering and serves as a DONE IN ONE subject matter expert for machine platforms designed to produce complex workpiece geometries.

Introduction

This Industry Talk will provide insight into Hybrid Multitasking machine tools and Hybrid Multitasking Processing. The examples covered in this handout will serve as a reference to any manufacturing company wanting to explore the possibilities of using this technology in their current operations.
The deep technical aspects of each of these technologies are beyond the scope of the session. We will cover a quick review of Multitasking, define Hybrid Multitasking, list and define the Hybrid Multitasking Processes, and discuss Hybrid Machine Tool Configuration.

What is Multitasking?

Multitasking is a well-established technology with over 30 years of servicing a wide range of industry applications. It is a consolidation of multiple part processing such as turning, threading, milling, drilling and tapping operations within a single machine platform.

What are the benefits of Multitasking in a machining environment? Multitasking will reduce part handling resulting in less human error, reduced fixturing and redundant tooling. For example, in a non-multitasking scenario, if a turning center is used to turn features on a workpiece and two milling machines are used to machine different sections of the workpiece, there would be three sets of fixtures and redundant tooling on the milling machines. A multitasking machine with one fixture will machine the part complete with less tooling and less operator intervention.

Another benefit is an increase part accuracy by machining multiple features in the same work holding. Whenever a part is re-fixtured, opportunity for error exists.

Figure 1

In the previous AutoDesk University Industry Talk, Mazak covered levels 1-4 of Multitasking as shown above in figure 1. This session covers Level 5 – Hybrid Multitasking.

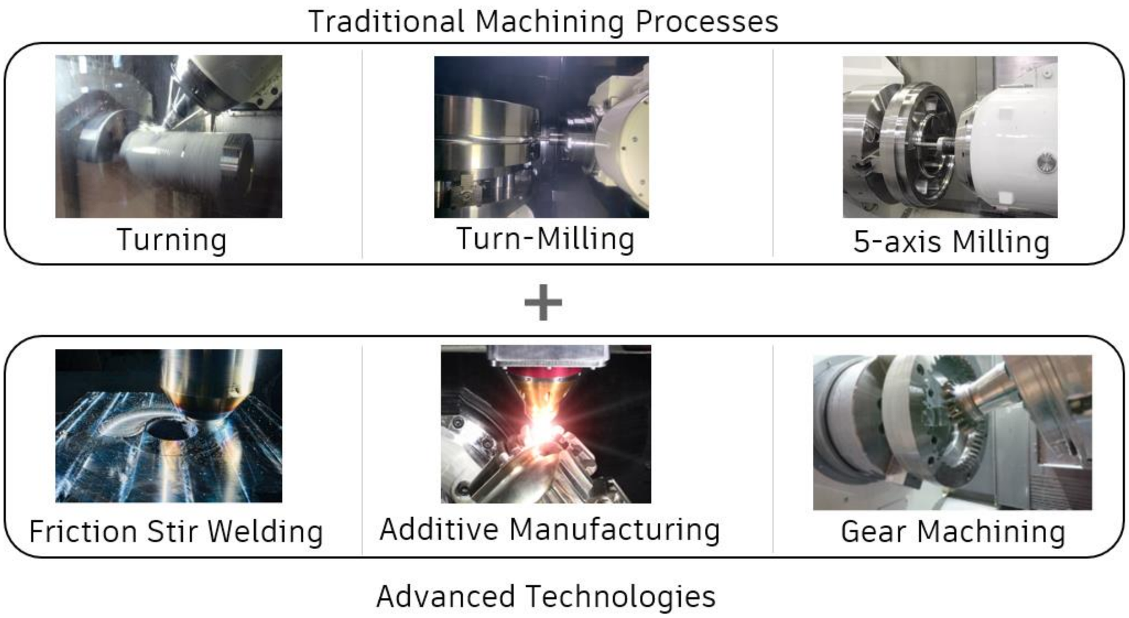

Figure 2

Hybrid Multi-Tasking combines subtracting machining processes with Advanced Technologies to perform new tasks like additive processes and joining materials as well as Done in One Smooth Gear Cutting Solutions as shown in figure 2.

Friction Stir Welding

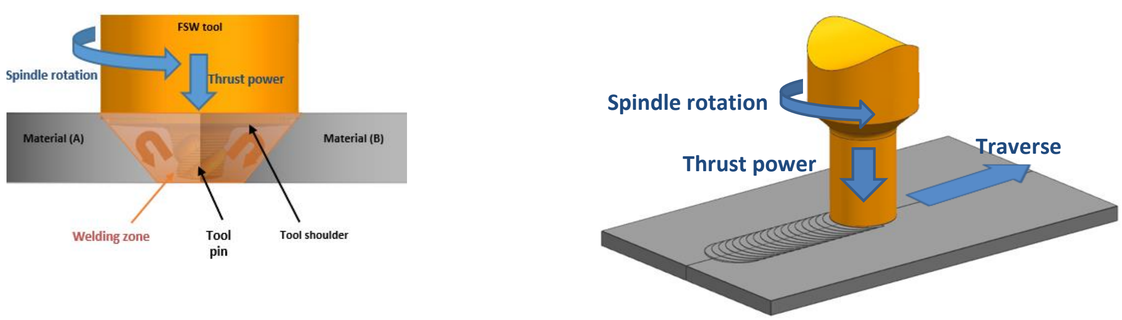

Figure 3a & 3b

Friction Stir Welding or (FSW) is a solid-state joining process, also commonly known as a forging process, that uses a non-consumable tool to join two plates without melting the workpiece material (figures 3a & 3b).

Heat is generated by friction between the rotating tool and the workpiece material, which leads to a softened region around the FSW tool. While the tool is traversed along the joint line, it mechanically intermixes the two pieces of material, and forges the hot and softened metals by mechanical thrust.

The FSW process creates a refined grain structure throughout the welded joint, making the material stronger while retaining its original thermal and chemical properties.

FSW Benefits include:

- A seamless weld appearance after final machining.
- High strength welds having the same joint strength as the base materials.
- Joining dissimilar alloys such as copper, steel, nickel and aluminum.
- Green joining alternative that produces no fumes, no flames, no flash, and no waste.
- No additive/filler materials required.
- Low setup cost and easy to train operators with self-guided software.
- The FSW tools can operate in all positions and orientations.
- Utilizing a standard CNC machine tool without expensive machine modifications.

Friction Stir Welding Parts

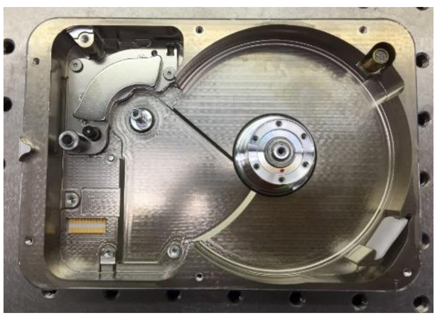

Figure 4

Figure 5

Typical Friction Stir Welding parts include: computer components, such as a hard drive housing (figure 4), battery cooling jackets (figure 5), automotive components, aerospce components and oil and gas related components.

Components of a Friction Stir Welding Hybrid Machine

Figure 6

The machine tool is the foundation and capable of all standard machining center processes such as milling, drill and tapping. Some machine models are equipped with a center-partition for machining components on the left side and Friction Stir Welding components on right side of the machining envelope for maximum throughput.

Figure 7

Figure 8

The Intelligent Tool Holder (figure 7) and perishable tools (figure 8) enable the Friction Stir Welding process. Like any cutting tool, the FSW tool is tool changeable for seamless operation.
The patented tool holder is balanced for joining parts up to 10,000 rpm which translates to faster production rates.
The PCD type tooling provides extremely high tool life at high speeds.

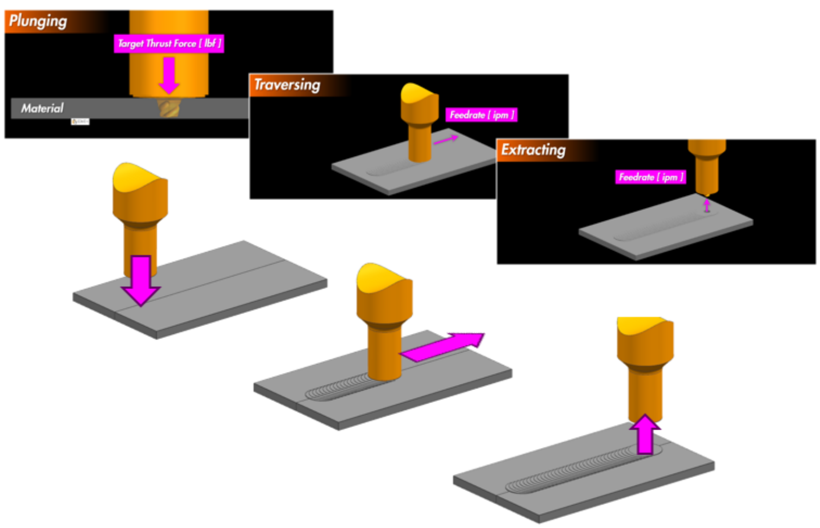

Figure 9

Mazak's HMI (Human Machine Interface) help screens (figure 9) walk the operator thought simple programming for plunge, traverse and extract processes of the FSW tool.

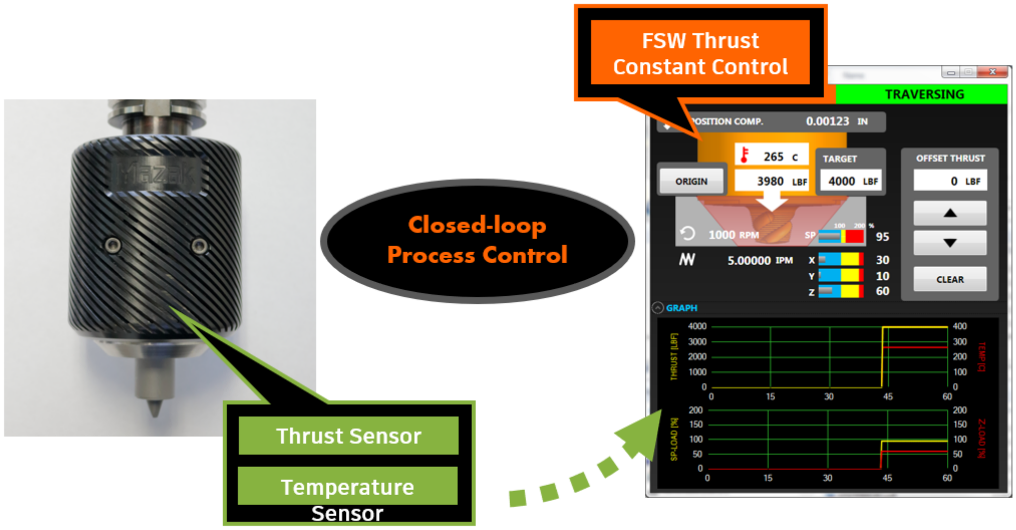

Figure 10

With Bluetooth Technology, Mazaks Smooth CNC control allows for a closed loop processing and monitoring of the FSW tool (figure 10), while constantly controlling the target thrust and temperature of the application at hand. The closed loop software records and charts the weld data for traceability for future needs.

Friction Stir Welding Process Flow

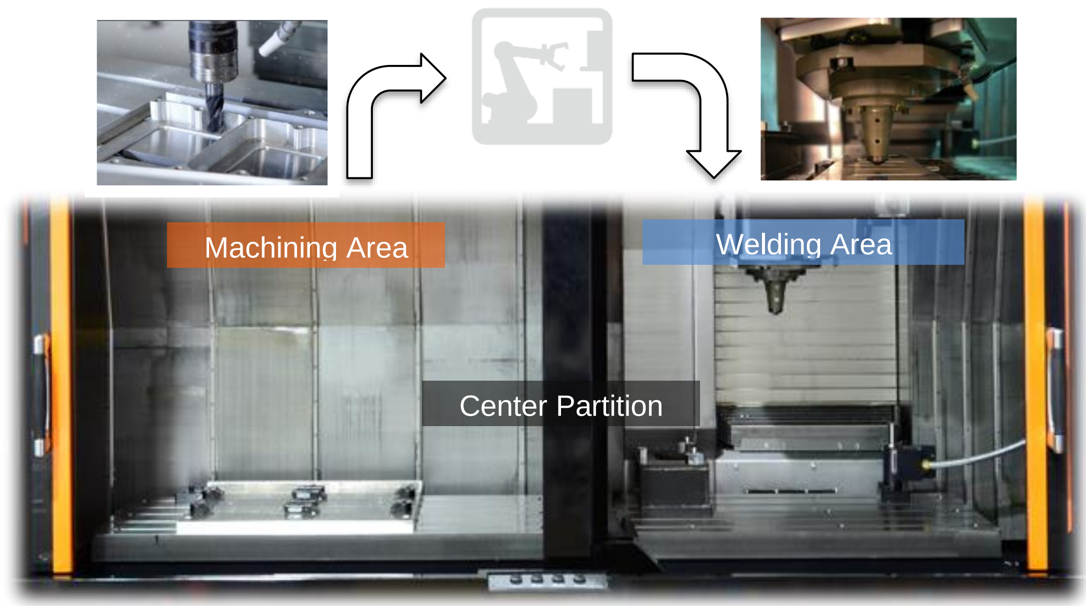

Figure 11

Figure 11 shows a typical FSW process on a machine tool with a center partition. On the left side left side of the partition is the machining area where the workpieces are machined using conventional milling, drilling and tapping processes.

On the right side of the partition is the Friction Stir Welding Area where the machined components are assembled onto the fixture followed by the Friction Stir Welding Process. All machining tools and the Friction Stir Welding tool is automatically changed for seamless operation. The workpiece can be transferred from the machining area to the FSW area and vice versa manually or by automation (robot).

These Friction Stir Welding Machines are targeted toward the semiconductor industry for chamber component processing, however, there are many other applications.

It is also well suited for flat plate joining, coolant channels, heat exchangers, vacuum chambers, cylindrical components and even parts of irregular thickness.

Additive Manufacturing

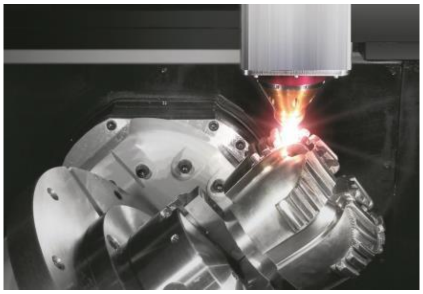

Figure 12

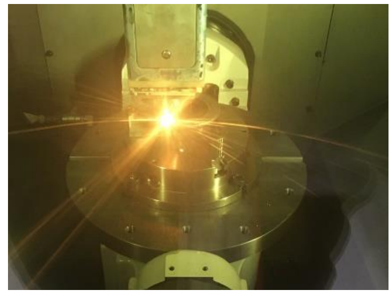

Figure 13

The Mazak Hybrid Multi-Tasking machine tool combines machining center capabilities with Additive Manufacturing (AM) technology.
There are two AM processes used on the Hybrid Machine Tools: Laser Metal Deposition (figure 12) and Hot Wire Deposition (figure 13).
Both processes build geometry layer by layer using either powder or wire material. The build geometry is strategically arranged to minimize material usage, optimize component strength and reduce machining time.

Typical Additive Manufacturing Parts

Figure 14

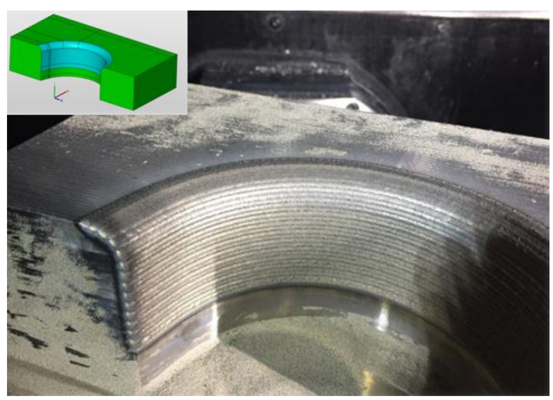

Figure 15

Component Repair of high value components are great candidates for Additive Manufacturing on a Hybrid machine tool as shown above, blade repair (figure 14) and die repair (figure 15).

Parts can be repaired and put back into service at less cost than producing a new component. Rather than machining a new component from raw stock, which requires 100% machining, repairing and machining only the damaged sections reduces machine time, tooling and labor.

Figure 16

Cladding of Dissimilar Materials is possible with Laser Metal Deposition.
Adding a more wear resistant material to a less costly material can lead to less overall material cost and machining cost. An example is a drill head shown in figure 16. The drill head body can be made from a less costly and free machining material and a hard-durable coating can be bonded to the cutting edges by Laser Metal Deposition. Additional examples include manifolds, sealing surfaces in valve bodies, wear pads in rotating/sliding components, and cutting blades in roll dies.

This is an industry first making parts with multiple materials in a single setup.

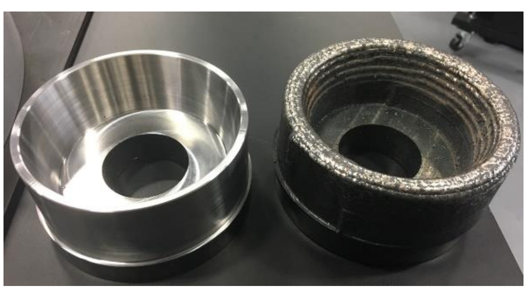

Figure 17

Figure 18

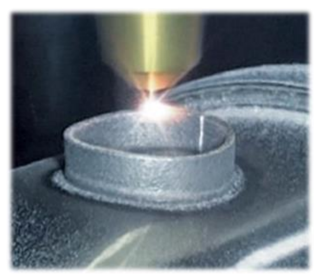

Figure 19

Rapid prototyping is another possibility with Additive Manufacturing.
Rather than machining from solid blanks resulting in long cycletimes and high tooling cost or waiting on expensive castings, component features can be built using AM and then machined complete. This technique can shorten the delivery time to test component design performance. Figures 17 -19 demonstrate building features onto substrates. These features can be easily modified, via 3D modeling, rebuilt and machined.

What Skill Sets and Tools are Required for Additive Manufacturing?

Figure 20

CAD/CAM systems must possess both Additive capability and Subtractive (machining) capability. It is important the software has built-in AM patterns (figure 20) with control over the bead parameters as well as the post processor outputting the correct G and M codes for the AM process.

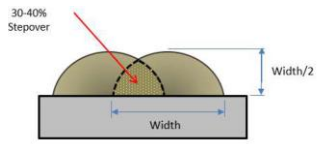

Figure 21

The engineer may have to create a “build model” with enlarged cross-sections to ensure enough material is deposited in the appropriate areas and design bead track patterns with proper stepover (figure 21) to ensure no voids.

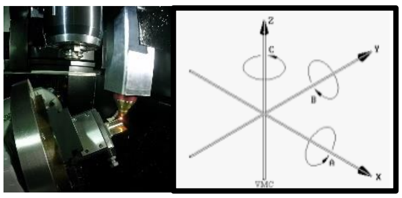

Figure 22

The understanding of 5-axis is important as the additive head may need to be tilted with respect to the drive surfaces to deposit material in the desired locations. The additive head is much larger than the cutting tools; therefore, additional rotary motion (side tilt/lead or lag) may be required for clearance purposes.

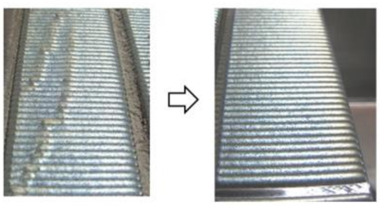

Figure 23

The engineer must have a good understanding of the process parameters which control bead quality and how these parameters relate to one another.

The Additive Manufacturing Process on Hybrid Machine Tools

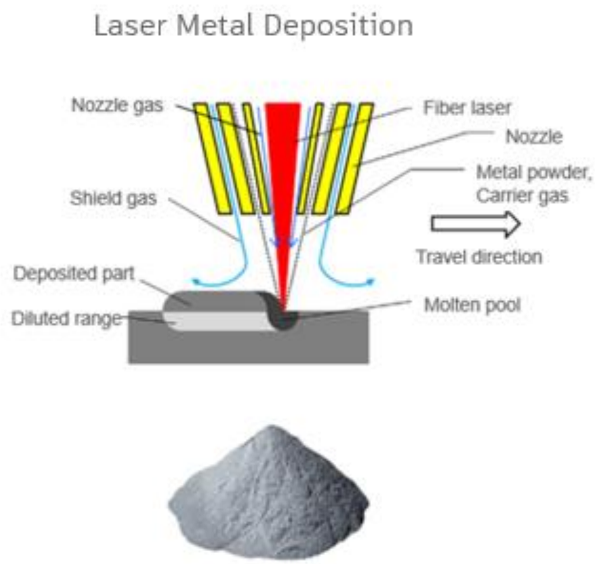

Figure 24

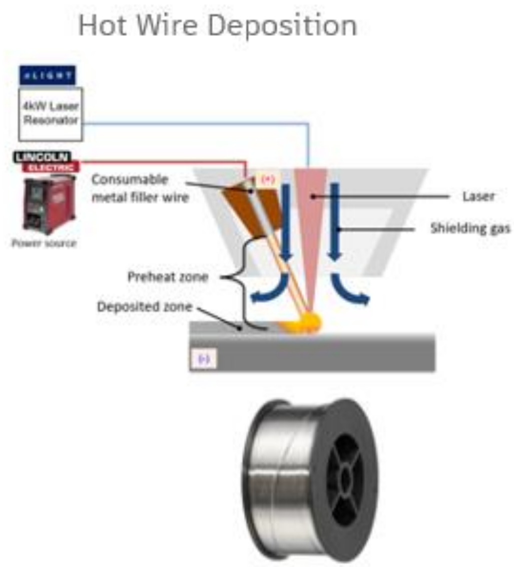

Figure 25

Two Additive Manufacturing processes are available on the Hybrid machine tool.
Figure 24 shows Laser Metal Deposition using metal powder material.
Figure 25 shows Hot Wire Deposition using wire material.

Laser Metal Deposition

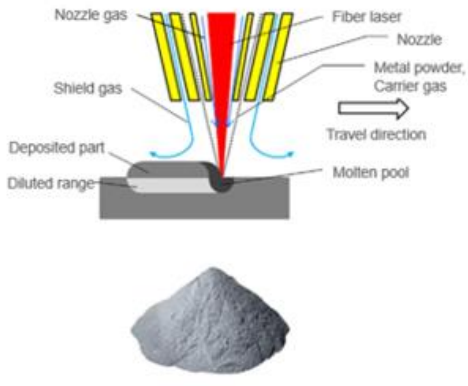

Figure 26

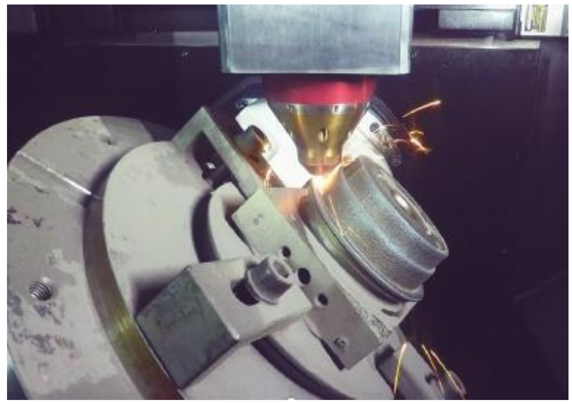

Figure 27

In Laser Metal Deposition process (figure 26), the metal powder is delivered by the carrier gas and discharged from the nozzle and melted by the fiber laser in the melt pool. The fiber laser travels along the part surface creating bead tracks. The nozzle gas prevents contamination of the optical components and the shielding gas prevents the deposited material from oxidation.

The 5-axis positioning and contouring capability (figure 27) allows the nozzle to precisely add material to the desired location as shown.

The Hybrid Laser Metal Deposition machine can interleave additive and machining processes to produce geometry otherwise impossible to manufacture.
The benefits of LMD are:

- Dissimilar materials within one part
- Low heat input and low distortion
- Thin bead tracks for fine geometry
- Up to 75% material utilization

Components of an LMD Hybrid Machine Tool

Figure 28

The machine tool (figure 28) is the foundation and must be capable of all standard machining center processes such as 5-axis milling, drill and tapping. The cutting tools are tool-changeable and are safely stored in the tool magazine during AM process.

Figure 29

The fiber optic laser (figure 29) is the energy source which melts the powder material onto the substrate. The laser power is controlled by the CNC program.

Figure 30

The chiller unit maintains a safe operating temperature within the AM system

Figure 31

The powder feeder (figure 31) regulates the powder material during the AM process. The powder delivery rate is controlled by the CNC program.

Figure 32

The carrier, nozzle and shielding gases are supplied by external tanks (figure 32). The flow rates of each are controlled by the CNC program.

Figure 33

The Dust (figure 33) collector extracts fumes from the machining envelope.

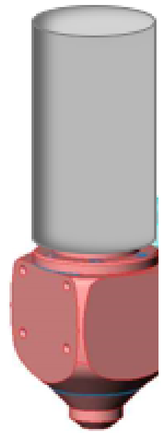

Figure 34

The additive head (figure 34) delivers the laser emission, shielding gases and powder to the deposition zone and is controlled by the CNC program.

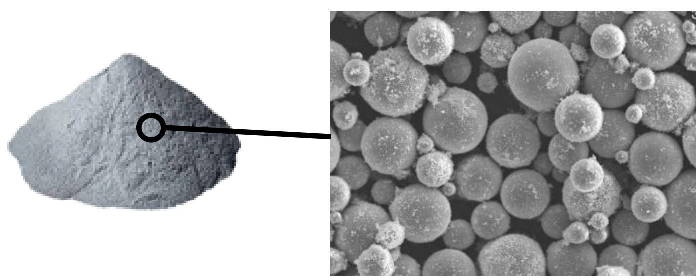

Figure 35

Powder material (figure 35) a consumable product, typical spherical size range is 45µm to 106µm.

Laser Metal Deposition Process Flow

Figure 36

Figure 37

Above depicts a typical repair operation using Laser Metal Deposition.
Figure 36 shows the deposited material on the damaged features. The deposited material is “Overbuilt” to a proper thickness to ensure 100% cleanup for repair machining.

Figure 37 shows the completed machining operation. Upon completion of the additive process, the additive head is stored away, and a milling cutter is tool-changed into the spindle to machine the repaired feature to print dimension.

Hot Wire Deposition

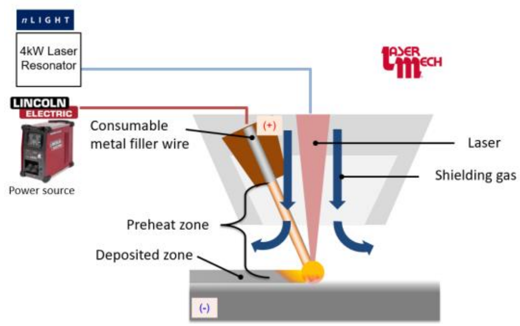

Figure 38

In this process, the fiber laser, emitted from the additive head, creates a melt pool where pre-heated wire is delivered to the deposition zone.

Like powder deposition, the additive Hot Wire head travels along the part surface creating geometry layer-by-layer where the shielding gas prevents the deposited material from oxidation

The parameters which control bead quality are laser power, gas flow rate**,** pre-heat wire power, wire delivery rate, bead step over and additive feedrate.

There are several benefits of Hot Wire Deposition. It is a cost effective method to build 3D geometry.

Some of these benefits are:

- Up to 98% of the wire material is utilization in the build process
- By Joining Dissimilar materials within one part, often improves overall part quality and operation lifespan
- High deposition rates of 3-6 lbs/hour offers FAST time to market:…… hours vs weeks
- A wide variety of materials available including ferrous and some non-ferrous

Components of a Hot Wire Deposition Hybrid Machine

Figure 39

The machine tool (figure 39) is the foundation and must capable of all standard machining center processes such as 5-axis milling, drill and tapping. The cutting tools are tool-changeable and are safely stored in the tool magazine during AM process.

Figure 40

The fiber optic laser (figure 40) is the energy source which melts the wire material onto the substrate. The laser power is controlled by the CNC program,

Figure 41

The chiller units (figure 41) maintains a safe operating temperature within the AM system.

Figure 42

The power source (figure 42) pre-heats the wire close to melting point prior to the deposition zone.

Figure 43

Wire feeder device (figure 43) controls the rate of wire material discharge.

Figure 44

The shielding gas (figure 44) is supplied to protect the deposition zone from oxidation.

Figure 45

The dust collector (figure 45) extracts fumes from the machining envelope.

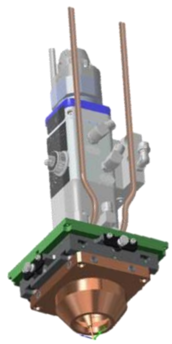

Figure 46

The omni-directional additive head (figure 46) delivers the laser emission, shielding gases and wire to the deposition zone and is controlled by the CNC program.

Figure 47

Wire material (figure 47) is a consumable product.

Hot Wire Deposition Process Flow

Courtesy of: OAK RIDGE National Laboratory

Additive Operation

Figure 48

Machining Operation (Subtractive)

Figure 49

Above depicts a complete build operation using Hot Wire Deposition.
Figure 48 shows the HWD process building the hexagon shape onto the substrate.
The deposited material is “Overbuilt” to a proper thickness to ensure 100% cleanup for finish
machining.

Figure 49 shows the finish machining of the hexagon geometry. The machine table can tilt the part to allow machining on the inside as well as outside.

Gear Machining

The Mazak Hybrid Multi-Tasking machine tool combines machining center and turning center capabilities with Gear Manufacturing.

Gear machining on a Hybrid Multi-tasking machine is made possible using three different process. Each process uses a different method and tool to create the gear tooth form.

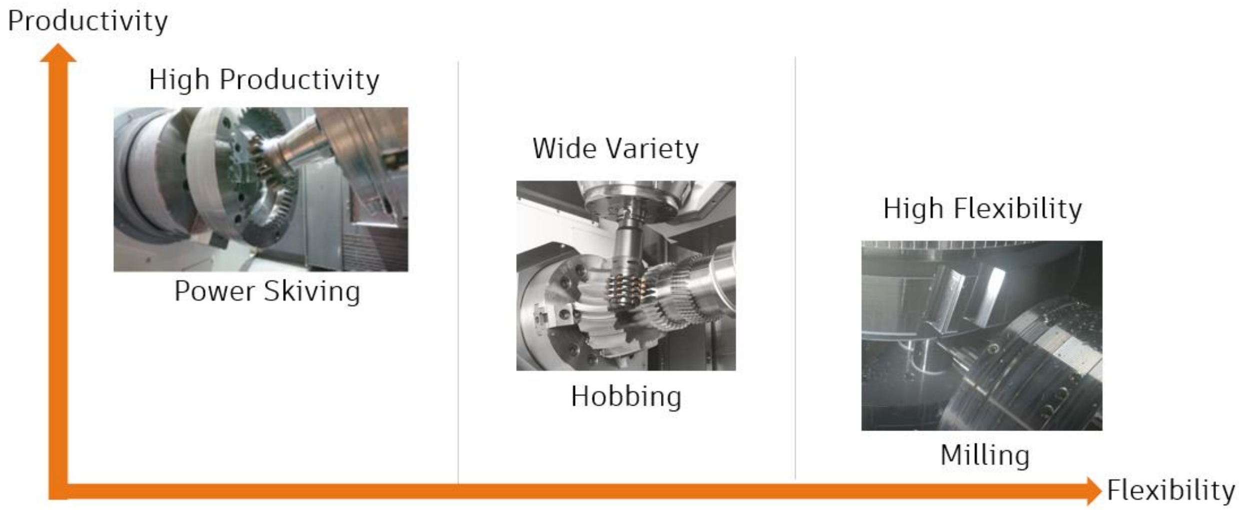

Figure 50

Figure 50 is a graphical representation productivity verses flexibility of the three gear machining processes on a Hybrid machine tool.

<u>Power skiving</u> offers high productivity on OD and ID gears and splines
<u>Hobbing</u> offers medium productivity on OD Gears and Splines
<u>Gear milling</u> offers high flexibility on OD gears

There are several benefits to gear machining on a Hybrid Machine Tool such as:

- Cost-effective solution for producing a wide variety of gear types
- Complete part processing from raw stock to complete part on one machine
- Flexibility to process a wider range of parts with one machine
- Simple gear toolpath programming via HMI
- Gear chamfering and edge prep in the same setup
- Machine datum features and gear teeth in the same setup to achieve minimal runout
- Simple work holding
- Geometric freedom of gear types
- Gear inspection

Common Gear Machining Parts

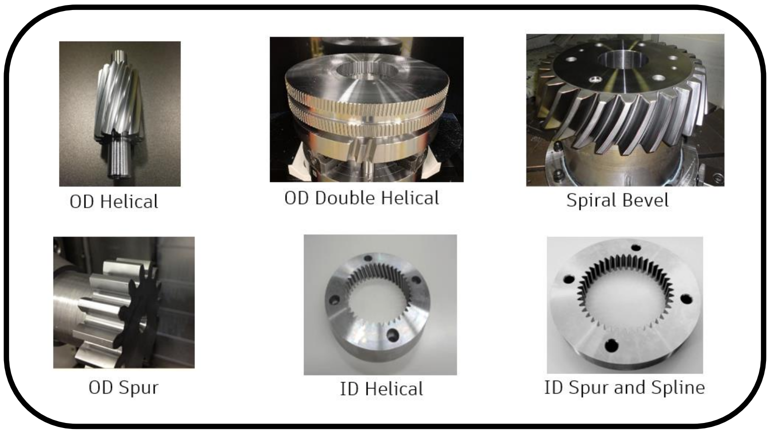

Figure 51

Figure 51 shows several gears machined on a Hybrid machine tool.
All the gear teeth machining programs were created on the machine control using the Mazak Smooth Gear software except for the spiral bevel gear.
Bevel gears (both straight and spiral) require a tooth model and a CAD/CAM system to produce the toolpath.

Spindle Synchronization

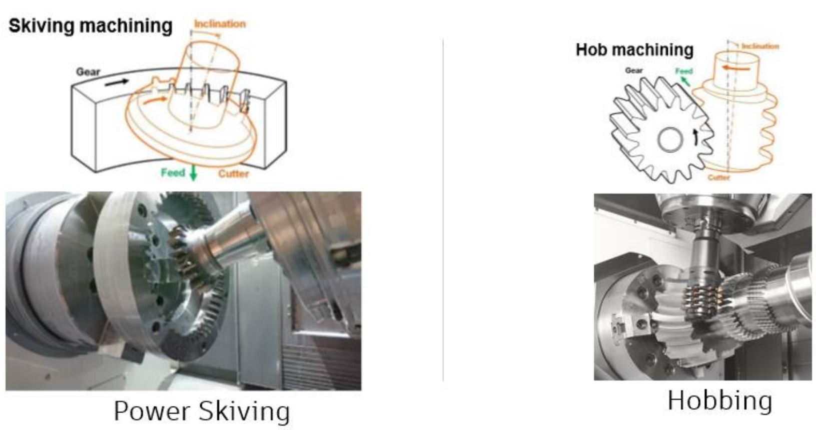

Figure 52

Both power skiving and hobbing processes (figure 52) require accurate tool spindle and part spindle synchronization at high rpms to deliver proper cutting velocity and to ensure gear tooth quality. Mazak's Hybrid gear cutting machines have high resolution rotary scale feedback to ensure synchronization.

Components of a Gear Cutting Hybrid Machine

Figure 53

The machine tool (figure 53) is the foundation and must be capable of all standard machining center processes such as 5-axis milling, drill and tapping and turning center process such as turning, grooving and threading. All cutting tools including the gear cutting tools are tool changeable.

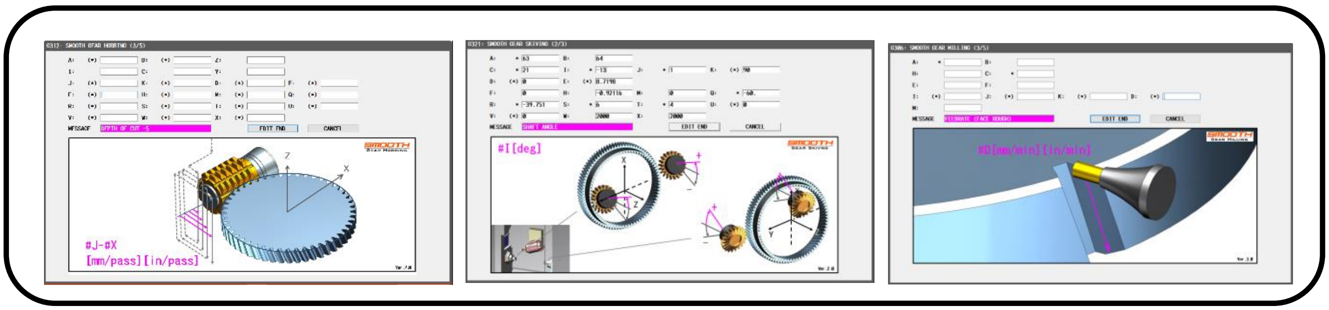

Figure 54

Figure 53 shows the on-board gear programming software (HMI) which enables the user to create gear machining programs on the machine control.
The user simply enters data into the HMI such as: tooling information, gear geometry and cutting strategy. The software creates the reliable cutter path to rough and finish the gear teeth complete. No additional external software needed.

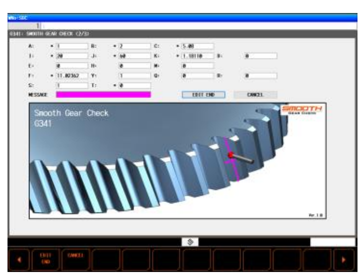

Figure 55

The gear inspection software interface (figure 55) works in the same manner as the gear machining interface. The user enters the gear data along with the scanning parameters into the HMI and the software creates the program to scan the lead and profile.

Gear Machining Process Flow

Figure 56

Figure 57

Above is a typical process flow for gear machining on a Hybrid Multitasking machine tool.

Figure 56 shows the pre-machining (turning) prior to the gear machining processes.
Figure 57 shows the gear machining process.
A benefit of combining turning and gear machining on same machine tool and the same setup is maintaining the relationship between the gear teeth and datum features such as bearing diameters and back faces.

Power Skiving an ID Spur Gear

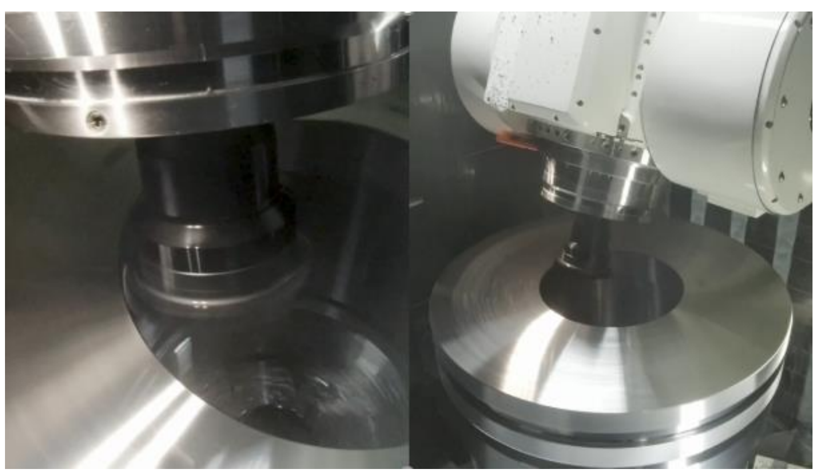

Figure 58

Figure 58 is an example of a power skiving process on an ID spur gear on the Mazak i-630AG. The cutter and workpiece mesh together like a pinion gear and a ring gear. The cutting velocity is directly related to the tool rotation speed and the angle of the cutting tool. With multiple cutting passes increasing in depth, all the gear teeth are generated.

Gear Milling an OD Helical Gear

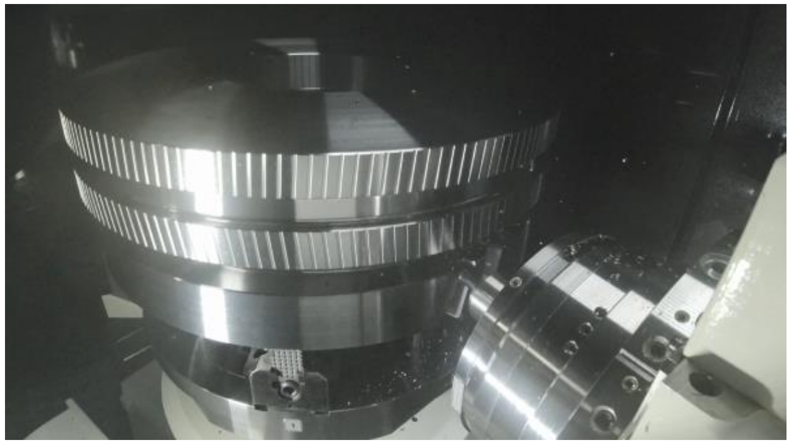

Figure 59

Figure 59 is an example of gear milling process. This process is a surface milling technique; however, no gear tooth model needed as the Mazak Smooth Gear software calculates the toolpath based on the user defined gear geometry.

This process uses standard milling cutters such as end mills and ball mills to cut the gear tooth complete.

Unlike hobbing and power skiving, gear milling cuts each tooth individually.

ID Gear Inspection using a Scanning Probe

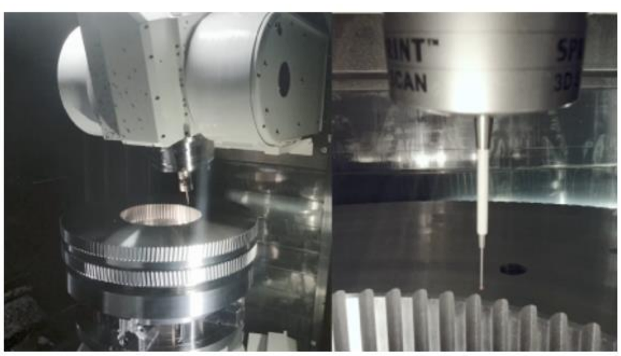

Figure 60

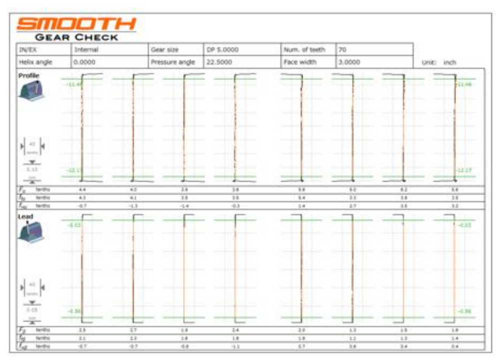

Figure 61

Figure 60 shows the Renishaw scanning probe measuring the lead and profile on an ID gear. The scanning path is produced by the Smooth Gear Check software on the machine control. The scanning motion is like the motion on a gear CMM. Upon completion of the inspection process, the profile and lead chart (figure 61) is displayed on the machine control and can be exported for traceability.

Conclusion

Mazak's Hybrid Multitasking models are being used across a wide variety of industries offering "Done in One" productivity from additive to subtractive. In particular, we see huge opportunities in repair and long lead time replacement component applications. Hybrid machines also offer Manufacturers more solutions to be more competitive in today's world markets. Combining processes compress the manufacturing cycle resulting in fewer work holdings, reduced part handling and ultimately delivering goods to your customer faster than previous methods.