The needs of the industrial machining marketplace are constantly evolving. Driven by changes in consumption patterns, greater flexibility in machining production lines is desired. A series of ultra compact machining centers for use in automotive production lines has been developed, which have been optimized for ease of line reconfiguration. The merits of this machine over previous machines in today’s industrial environment are shown, and the advantages of reconfiguration capability are discussed.

Introduction

The majority of machined automotive parts can fit into a 100mm cubic block. In general, these parts have common characteristics that influence the fabrication method, including high machining accuracy and repeatability requirements, a complex part shape, frequent design revisions, and large and changing lot sizes.

Customarily, the non-dedicated machining solution provided by machine tool manufacturers for these parts has involved a machine of width 1000 mm or greater. These machines have been designed to be capable of machining larger parts, with resulting large resource and energy consumption requirements. An example of this type of machine is the Mori Seiki FM303. Mori Seiki is currently using this machine in a 9-machine ABS production line. This machine has linear axis travels of 300mm x 400mm x 300mm (X, Y, Z), and is designed for a work size up to a 300mm cubic block. The width of this machine is 990mm. However, the dimensions of the ABS part machined is 100mm x 120mm x 70mm. Clearly, the machine is larger than necessary. It follows that energy and resource requirements are greater than necessary. A more compact machine is called for.

Although a smaller machine is desired, machining performance requirements, such as linear axis drive thrust and spindle torque, do not proportionally decrease. The same features must be machined, and reducing power would increase processing time, offsetting other benefits of a smaller machine. Previous compact machines (having machine travels 200mm or less) have featured reduced cutting performance, making them unsuitable for automotive parts production.

Part shape has become increasingly complex, driven by the need to fit expanding functionality into a decreasing package size. In a multi-machine production line, this complexity can best be handled by dividing production into a series of interchangeable machining units of differing configuration, such as a horizontal machining spindle-based machine, a vertical machining spindle-based machine, and a turning machine. Consider these as interchangeable machining modules of a complex production line. By making use of each configuration’s strong points where needed in the machining process, the overall line can be best optimized.

Design of a Reconfigurable Machine

As discussed in the previous section, the foreseeable benefits of a compact machine optimized for configuration flexibility in a high lot production line are many. Using that discussion as a design guide, we have developed a compact 680 mm wide machining center.

The machine has been developed for a maximum work size of...
140mm diameter x 100mm height. Linear axis travels are 150mm for the X- and Y-axes, and 220mm for the Z-axis on the horizontal machine and 200mm for the Z-axis on the vertical machine.

To provide maximum flexibility for line reconfiguration, three machines with the same 680mm x 2295mm footprint, a horizontal machining center, vertical machining center, and a vertical turning machine, have been developed. These machines all have a common work holding position, to enable common work transfer mechanisms between machines. Additionally, the space around the work was left open of machine structural elements, to allow work access flexibility.

![Figure 2. Differing machine configurations built on a common footprint. On the left is the horizontal, and on the right is the vertical machining center structure.](image)

Axial thrust force of 3500N and a spindle with a maximum torque of 11Nm were developed to provide adequate machining performance despite the small size. For aluminum, this allows drilling up to 14 mm holes, use of a 80mm diameter face mill, and tapping M14 holes. Since the target market for the machine is automotive parts production, functions common to high production machining centers, such as rapid automated tool changing, high speed / high acceleration rapid traverse, large coolant flow and high pressure coolant available through the cutting tool are also provided.

Merits of the Compact Machine

Machines have been built and assembled into an automotive part production line runoff at Mori Seiki. A total of ten machines, including 4 horizontal, 3 vertical and 3 turning machines are arranged linearly, with a swing arm-type serial work loading system transferring work from machine to machine. Included in the line are a parts washer and an inspection station. The total length of the assembled line is 10.6m.

Coolant supply and chip management are handled by a centralized system. The common chip trough runs on ground level below the work holding table across machines, moving chips and coolant to the central filtration unit. The narrow width of the machine reduces the overall length of the chip trough, minimizing post-machining chip handling problems.

The work size is 75mm diameter x 60 mm height and machining processes include drilling, milling, and turning. Process time has been reduced 50% from the previous parts line, including a work transfer time of 6 seconds. This quick time is possible because of reductions in non-machining time due to compact size. Rapid traverse acceleration rates were measured at 1.2 G for the X-axis, 2.7 G for the Y-axis, and 3.5 G for the Z-axis. Spindle acceleration and deceleration times are 40% shorter than previous machines.

The concept of a common work loading position on the machine has proved beneficial, as the work can be transported by single type of swing arm, whether the machine process is for milling or turning.

An additional merit anticipated when designing this small machine was improved thermal stability, due to less thermal mass and shorter drive component lengths. Testing proved this. The new machine exhibits uncompensated spindle growth stabilization at 14 microns.

![Figure 4. Thermal deformation at spindle face, 12000 min -l](image)

Conclusion

A new-type machining center series optimized for reconfigurability in an automotive parts production line has been developed and tested in actual part production line operation. The predicted merits of decreased overall line size, reduction of energy and resource usage, as well as the advantage of machining modules of differing configuration on the same footprint have been shown. Compact sizing of the machine has led to reduced part processing time due to a reduction in non-machining times.