Development of the FH630SX-i Horizontal Spindle Machining Center

Y. OKA H. TSUSAKA

To address the varying market needs concerning the machining of medium-sized workpieces made from steel and cast iron materials, we have developed the FH630SX-i horizontal spindle machining center based on the conventional FH630S and FH630SX horizontal spindle machining centers, and improved each function.

***Key Words**: horizontal spindle machining center, high speed, high stiffness, roller guide, thermal displacement compensation*

1. Introduction

Steel and cast iron medium-sized parts are mainly used for automobiles, airplanes, agricultural and construction equipment, energy-related devices, etc. Machining forms vary from high-variety, low-volume production to low-variety high-volume production and from high-speed cutting to heavy-duty cutting. Therefore, customer demand for machining equipment in these fields continues to diversify each year, and equipment rich in features is desired. Examples include equipment with features such as a wide machining range that allows flexible production, high-speed and high-efficiency machining, excellent cost performance, and high operability that does not require expert technique.

2. Purpose of Development

We have released the FH630S/FH630SX horizontal machining center (conventional machine) series as machining equipment for medium-sized parts.

To respond to customer demand and further increase of product competitiveness in the market, we have developed a FH630SX-i horizontal spindle machining center equipped with a wide machining range, high productivity, consistent accuracy, and high operability based on conventional machines.

Fig. 1 FH630SX-i Horizontal Spindle Machining Center

3. Features of FH630SX-i

The specifications of FH630SX-i (hereinafter referred to as “this machine”) are shown in **Table 1**. The overall layout of the machine is shown in **Fig. 2**.

Table 1 Main specification

				FH630SX-i
Stroke	X-axis		mm	1 050
	Y-axis		mm	900
	Z-axis		mm	1 050
	Distance from pallet top to spindle center		mm	100 – 1 000
	Distance from table center to spindle nose		mm	50 – 1 100
	Height from floor to pallet top		mm	1 250
Table and pallet	Pallet working surface size		mm	630 × 630
	Workpiece limitations	Max. workpiece swing	mm	ϕ1 170
		Max. workpiece height	mm	1 250
		Max. weight on pallet	kg	1 200 OP : 1 500
Feed rate	Rapid feed rate	X, Y, Z axes	m/min	60
		B-axis	mm^{-1}	30
	Cutting feed rate	X, Y, Z axes	m/min	30
	Rapid acceleration	X, Y, Z axes	m/s^2 (G)	6.86 (0.7)
Spindle	Spindle speed		mm^{-1}	6 000 OP : 6 000 OP : 15 000
	Spindle output (15 min/continuous)		kW	30/22 OP : 37/30 OP : 30/25
Tool	Max. tool length		mm	600
	Max. tool diameter		mm	ϕ250
	Max. tool mass		kg	27
	Tool change time	Chip to Chip	sec	3.6
		Tool to Tool	sec	2.5

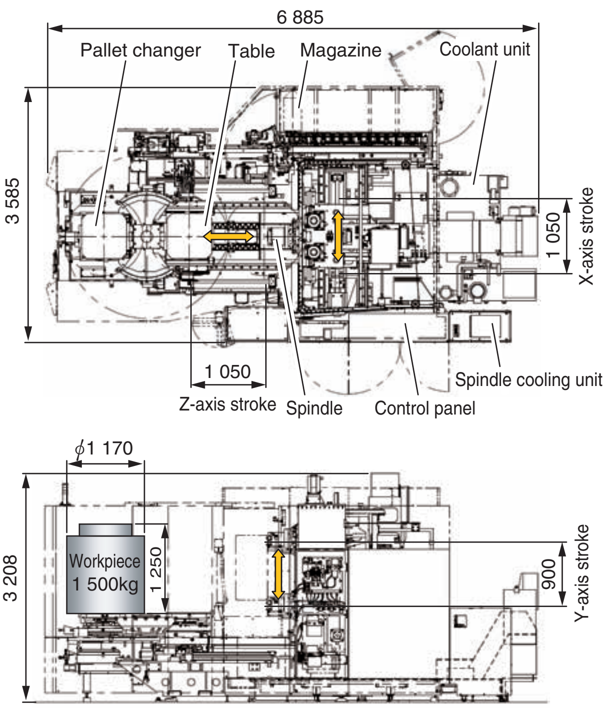

Fig. 2 Machine layout

3. 1 Wide Machining Range

Compared with conventional machines, this machine is approximately 1.8 times larger, with a maximum workpiece swing × height of ϕ1 170mm × 1 250mm, and 1.7 times heavier, with a maximum weight of 1 500 kg. It also has a 1.5 times wider machining range with the strokes of the X, Y, and Z axis being 1 050, 900, and 1 050mm. These features allow the loading of large workpieces of the highest level in the medium class, as well as the necessary and sufficient machine movements.

In addition, the shortest distance from the table center to the spindle nose has been reduced from 200mm on conventional machines to 50mm, allowing shorter tools to be used for the machining of workpieces. Furthermore, the Z-axis stroke has been lengthened from 850mm to 1 050mm, which reduces the limitations on workpiece shape, workpiece swing, etc. when a long tool is attached to the spindle. This expands the range of selection for tooling and fixtures.

3. 2 High Productivity

This machine has a highly rigid structure that can withstand high-efficiency cutting and high-speed feed, and achieves high productivity by shortening both cutting time and non-cutting time.

A roller guide is used for the feed portion of this machine to balance high speed and rigidity. Despite the increased mass of the moving object as a result of the increased machining range, rapid feed rate and rapid acceleration achieve the highest level of speed in this class, i.e. 60 m/min, 0.7G (X, Y, Z-axes).

A dual drive system consisting of two ball screws is used for the Y and Z axes, which receive large cutting resistance. Optimal rib arrangement through CAE ensures enough rigidity for major parts that support the ball screws, including the bed, column, table of the moving object, and spindle. In addition, the guide size and ball screw diameter have been enlarged to accommodate the increase in the mass of the moving object due to the expanded machining range, and the number of guide blocks have been increased to secure necessary and sufficient rigidity.

This machine construction enables the spindle to give full performance, achieving the highest milling capability in this class of 1 250 cm^3/min (workpiece material S48C).

3. 3 Consistent Accuracy

3. 3. 1 Low Thermal Distortion Design

Machine structure is thermally deformed by the temperature changes of the room in which the machine tool is installed. Bending and warping caused by temperature changes alter the relative position of the tool and the workpiece, causing reduced machining accuracy. Such bending and warping due to thermal distortion occur when the machine structure has uneven temperature distribution. Therefore, to prevent the reduction of machining accuracy caused by temperature changes, the machine structure needs to have even temperature distribution so that it will be insusceptible to bending and warping due to thermal distortion.

For this machine, non-routine thermal analysis through CAE was repeated to balance the arrangement of the rib structure of the bed and column to even the thermal capacity. This achieves a more even temperature distribution against temperature changes (**Fig. 3**) and reduces machining errors by 27% (**Fig. 4**), compared with conventional machines.

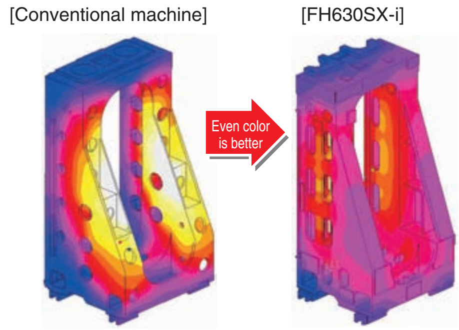

Fig. 3 Thermal distribution of column

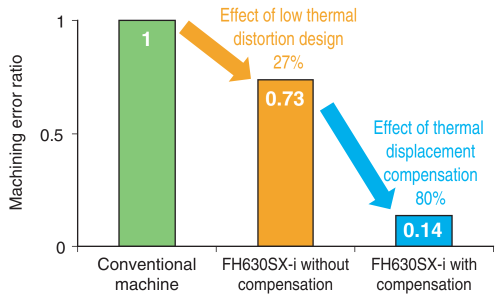

Fig. 4 Machining error due to room temperature change

3. 3. 2 Real time thermal displacement compensation function

This machine has a structure that is insusceptible to room temperature changes due to its low thermal distortion design, with a newly developed optional function that calculates and compensates thermal displacement of the machine in real time to further achieve consistent machining accuracy.

This function analyzes thermal distortion inside the CNC unit in a similar style to FEM and calculates the relative thermal displacement of tools and workpieces in the entire range, based on the temperature data measured by temperature sensors installed in each portion of the machine and 3D modeling data of the machine. Furthermore, the relative thermal displacement at each coordinate is converted into Cartesian coordinate components and spatially compensated as static geometric errors. FEM analysis normally requires a significant amount of calculation time, making it difficult to reflect the calculation results within commands in real time. In comparison, the JTEKT-developed high-speed calculation program enables instant analysis of complex thermal distortion and compensation (**Fig. 5**).

This thermal displacement compensation function can reduce 80% or more of the machining errors caused by room temperature changes (**Fig. 4**). Because of this, consistent machining accuracy is secured under substantial ambient temperature changes, and the machine can be warmed up in minimal time, contributing to production efficiency and energy conservation.

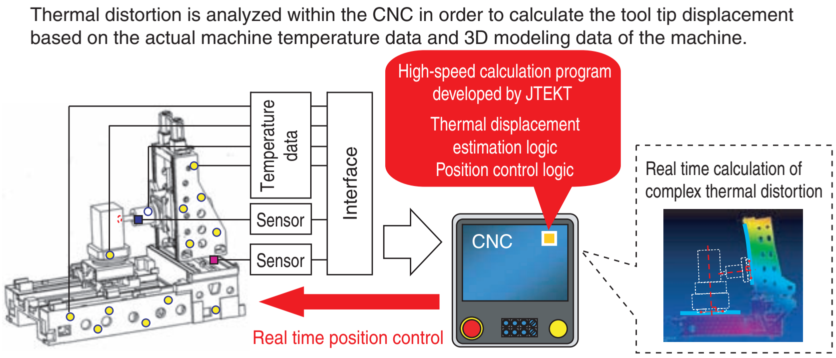

Fig. 5 Real time thermal displacement compensation system

3. 4 High operability

The opening portion of the pallet changer door of this machine includes the ceiling portion, in consideration of the loading/unloading of fixtures and workpieces by crane, etc., and prevention of coolant dripping from the cover ceiling onto the operator (**Fig. 6**).

The ceiling portion of the operator door for debugging operations also has a wider opening area compared with conventional machines, improving operability and the lighting on the operator's hands. The main operation panel is located on the left and can be swiveled so that the operator can check the cutting point and monitor in a natural position, similar to conventional machines. In addition, this machine has a people-friendly structure, including an angled keyboard that facilitates input tasks (**Fig. 7**).

Fig. 6 Pallet changer door

Fig. 7 Operator door

3. 5 Dialog programming functions

The dialog programming functions allow even non-experts to perform operations, from creating NC programs to machining products in a short period of time, merely by following the procedures shown on the screen. Equipped functions include the setup of workpiece coordinate systems, automatic setup of machining conditions according to workpiece material, setup of machining dimensions based on the machining guidance (**Fig. 8**), and automatic selection of optimal tools. In addition, expert know-how can be added to created programs using this function, allowing the transmission of machining technology. Furthermore, programs that shorten cycle time can be created by utilizing our company's know-how gained through production lines. These functions reduce the operation time from attaching workpieces to machining by approximately 25% (**Fig. 9**).

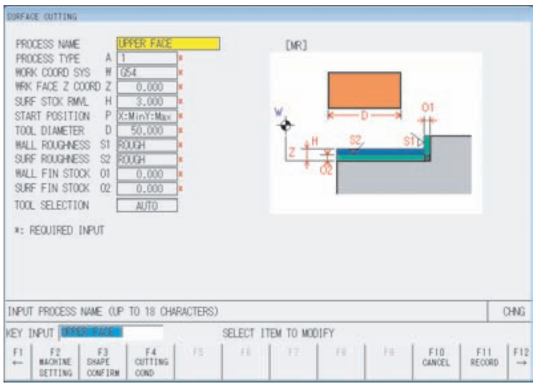

Fig. 8 Processing guidance

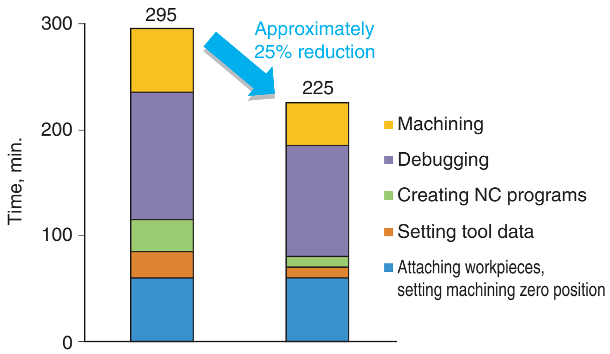

Fig. 9 Working time shortening effect

4. Conclusion

The newly developed FH630SX-i is a machining center that can respond to various customer needs, with improved machine specifications, machining accuracy, and operability compared with conventional machines. The improved machining accuracy and operability in particular utilize new technologies that did not previously exist, providing high added value to customers. We will endeavor to develop excellent, up-to-date equipment, while keeping an eye on industry trends and customer demands.

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Y. OKA* H. TSUSAKA**

* *Machine Tools Development Dept., Machine Tools & Mechatronics Operations Headquarters*
** *Mechatronics Control Engineering Dept., Machine Tools & Mechatronics Operations Headquarters*