Horizontal Spindle Machining Center FH1250SX

K. IMANISHI

Based on technology cultivated through the conventional FH-SX series, which features high cutting performance and productivity, the Horizontal Spindle Machining Center FH1250SX has been developed as a machine tool that leads its class in processing range and high-speed, high- stiffness performance.

***Key Words**: horizontal spindle machining center, heavy machinery, high speed, high stiffness, roller guide*

1. Introduction

In recent years, many activities to counter worldwide environmental problems such as global warming have been forwarded. Development of a new type of large cylinder volume diesel engines for heavy duty trucks and construction and agricultural equipment is progressing adamantly. In Japan, too, the demand for similar equipment is increasing in preparation for the new emission control law which will be enacted in 2010.

Furthermore, reasons such as the recently skyrocketing price of crude oil are increasing the demand for small, fuel efficient jet planes, called regional jets, as well as equipment for oil refining plants. The demand for equipment thereof is growing especially in Europe where vigorous efforts are spent to reduce the burning of fossil fuels by utilizing wind power generation as well as to protect the environment.

In the manufacturing facilities for this type of environment-related equipment, such processing machines that are capable of machining large sized parts in higher efficiency, and that have a larger processing range and a higher productivity than the conventional machines of today are greatly in demand.

2. Target of the Development of the FH1250SX

Traditionally, large sized parts have often been processed on an angular slide type machine which withstands heavy loads and features a high machining capability. The needs for heavy machining are still strong while the JTEKT horizontal spindle machining centers, such as the FA800S/1050S, in these manufacturing facilities have been doing reputable jobs.

In recent years, however, the demand for improved productivity through obtaining higher speeds from these heavy duty machining centers has increased along with the overall diversification of the requirements of these machines.

Therefore, we have developed a high stiffness, heavy duty horizontal spindle machining center, the FH1250SX, which is capable of machining large sized parts with any kind of material at high speed under high load, utilizing the technology developed in building the JTEKT linear guide machines FH-SX series of machines.

3. Features of the FH1250SX

The specifications of the FH1250SX are listed in **Table 1**, and its overall structure is shown in **Fig. 1**.

3. 1 Board Work Envelop

The FH1250SX, with a maximum work envelop of ϕ2 400mm and 5 000 kg maximum load on pallet, can accept the largest workpiece in its class, while it maintains the necessary and sufficient axis strokes.

This machine also boasts the fact that the minimum access distance from the table center to the spindle nose is kept at a mere 200mm, so that the workpiece can be processed as short a tool as possible.

The tool specifications for the machine include the maximum tool size of ϕ350mm diameter, an 800mm length, and 35 kg maximum tool weight. To apply the size of tools depending on workpiece size, it is possible to select the magazine from the chain type of 40-121 tools with the allowable tool moment of 29 N·m or the matrix-type magazine with its allowable tool moment of 50 N·m.

3. 2 High Speed, High Stiffness

In order to realize the combination of high speed and high stiffness, the FH1250SX uses a roller-type linear guide and sets the rapid feed rate at 42 m/min on all feed axes.

Table 1 Main specifications

				FH1250SX
Stroke	X-axis		mm	2 200
	Y-axis		mm	1 600
	Z-axis		mm	1 850
	Distance from the top surface of the pallet to the spindle center line		mm	100 – 1 700
	Distance from table center to the spindle nose		mm	200 – 2 050
	Height from the floor to the top surface of the pallet		mm	1 500
Table & pallet	Size of the pallet working surface		mm	1 250 × 1 250 (1 250 × 1 600)
	Workpiece limits	Maximum work envelop	mm	ϕ2 400
		Maximum height of the workpiece	mm	1 800
		Maximum load on pallet	kg	5 000
Feedrate	Rapid feedrate	X-axis	m/min	42
		Y-axis	m/min	42
		Z-axis	m/min	42
	Cutting feedrate		m/min	30
Spindle	Spindle output (15 minutes/continuous)		kW	30/22 OP: 37/30 OP: 30/25
	Spindle maximum speed		min^{-1}	6 000 OP: 8 000 OP: 15 000
Cutting tool	Maximum tool length		mm	800
	Maximum tool diameter		mm	350
	Maximum tool weight		kg	35
	Tool changing time		sec	4.0 (C-C)

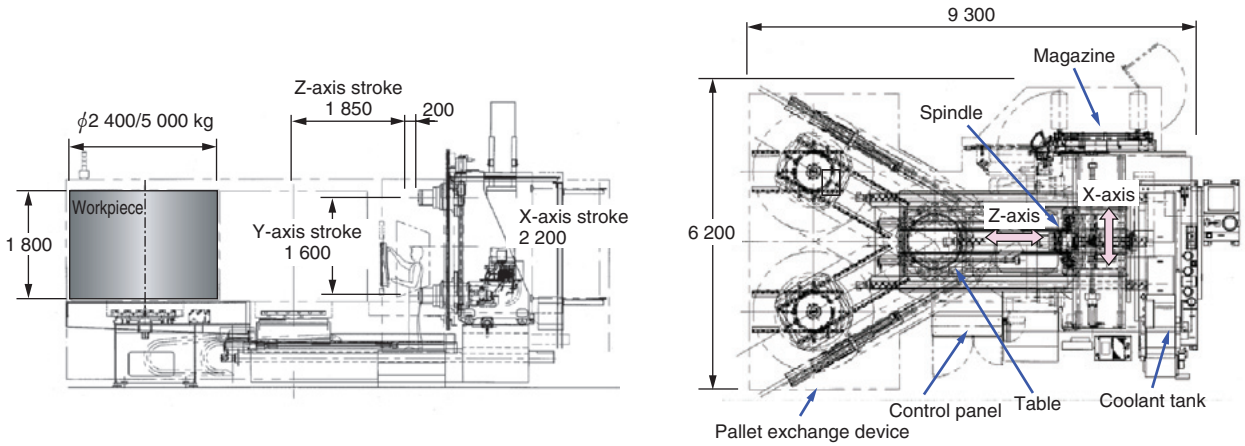

Fig. 1 Machine layout

Also, both Y and Z axes that are subject to significant machining reaction force, are structured by dual driven two ball screws. In order to ensure the sufficient stiffness on main structural elements such as bed, column and table that support these axes, the optimal rib layout has been studied by CAE and applied to them.

Furthermore, by increasing the number of the linear guide blocks from four of conventional to six as well as optimum layout of the linear guide and the ball screws, the stiffness of Y-axis body has been increased with the extended spindle stick-out distance, which brings the result of shorter distance from the table center to the spindle nose.

3. 3 Newly Developed 8 000 min^{-1} High Torque Spindle

This machine provides 6 000 min^{-1} built-in motor spindle as standard that is appropriate for iron and cast machining, and high-speed 15 000 min^{-1} spindle for aluminum cutting as optional.

Additionally, in 2007, a high stiffness, high torque 8 000 min^{-1} spindle has been newly developed and added to the lineup to cope with the needs for high torque machining such as cutting with large diameter tools.

This new 8 000 min^{-1} spindle is composed of a ϕ120mm angular contact ball bearing on the front side with the feature of JTEKT's unique preloading system to ensure optimum preload depending on the spindle rotational speed (a flexible valuable preload system, hereinafter referred to as F.V.P.S.). Thanks to this system, the spindle can keep sufficient supporting stiffness throughout the speed range from low to high speeds. This spindle stiffness, combined with a high power built-in motor with a maximum torque of 1 009 N·m, enables heavy duty machining with extremely high efficiency.

Figure 2 shows a comparison of stiffness at various spindle speeds resulting from the use of the conventional fixed position preloading method vs. the F.V.P.S. For the conventional fixed position preloading, the spindle stiffness increases followed by spindle speed, whereas with the use of the F.V.P.S, both the axial and radial stiffness increase dramatically in the low speed range where particularly high torque is generated. This indicates that the latter is a preloading system which is more suitable for machining under heavy load.

Table 2 Lineup of main spindles

Spindle end design		#50 (MAS, CAT, DIN, HSK)		
Rotational speed	min^{-1}	6 000	8 000	15 000
Output	kW	30/22	37/30	30/25
Torque	N·m	600	1 009	262.6
Bearing diameter	mm	ϕ110	ϕ120	ϕ100
Preloading system		Fixed position	F.V.P.S	Fixed pressure

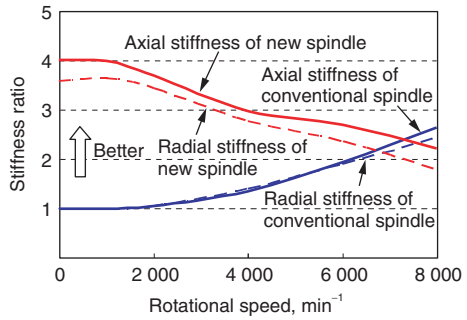

Fig. 2 Stiffness of new 8 000 min^{-1} spindle

3. 4 Low Thermal Displacement Design and Compensation Function

The structural elements, such as the bed and the column, of this machine are designed for thoroughly symmetrical geometry.

In addition, in order to build a machine structure which is immune to bending or warping due to fluctuations in room temperature, CAE-based thermal capacity analysis was repeated until the structural design was well balanced in terms of thermal capacity.

Figure 3 shows an example of the improvement in the balance of the thermal capacity by CAE. Before any improvements were made, the column had a smaller thermal capacity on the rear side than the front side. This bias caused the rear side to expand earlier when the room temperature rises, and as such there was a tendency for the column to incline forward. Therefore, not increasing the original mass of the column, the thermal capacity of the column is equalized by shifting the thickness of the casting from the area where the thermal capacity is higher to the areas where the thermal capacity is lower. As a result of this improvement, the forward inclining tendency at a 10℃ rise in temperature was reduced by 16% compared to the initial design in the concept stage.

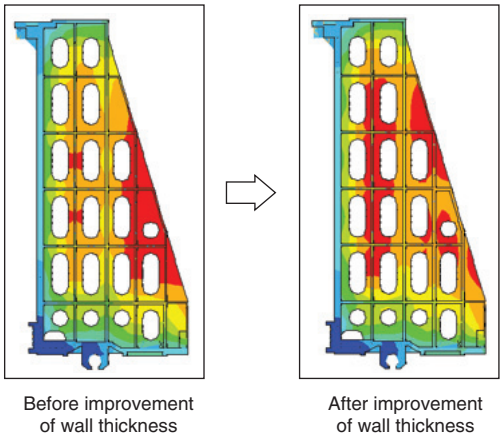

Fig. 3 Thermal well-balanced column

Also, this machine is provided with a ball screw thermal displacement compensation function (which directly measures the elongation of the ball screw and feeds it back into the CNC for compensation) as standard equipment, as well as an optional spindle thermal displacement compensation function (which directly measures the elongation of the spindle and executes real time compensation). These compensation functions ensure comprehensive protection against thermal displacement.

3. 5 Improved Accessibility and Maneuverability

Because operation of a large machine requires the operator to conduct such tasks as centering of the workpiece and checking of the machined surface inside

the machine, it is important to make sure that these tasks can be done both easily and safely. In this machine, to improve accessibility into the machine through the operator door, the coil conveyor inside the machine is located on each side of the table and the bed height is lowered to minimize the overstepping height from the operator door.

In addition, steps are provided in wide areas around the pallet exchange device taking into account accessibility to the workpiece so as to facilitate setup work.

The control panel is located on the left side so that the operator can operate it while watching the workpiece in the machine. The panel selected is a tilted type to facilitate program input and other operations, and it is universally swivelable so that its monitor can be checked from the inside of the machine.

Furthermore, a personal computer based CNC device is also employed, in pursuit of maximum maneuverability by utilizing a visually clear screen display and touch panel for input.

3. 6 Maintenance Function

This machine incorporates a diagnostic function which was newly developed based on the technology and numerous expertise that JTEKT has obtained through the building of our in-line NC specialized machines.

The fault diagnostic function shows a graphic presentation, such as a photograph and/or drawing, of the location of failure being occurred on the NC display screen as shown in **Fig. 4**. This display also shows the content of the alarm, the cause of the abnormality, and the method of restoration in a visually clear fashion so that a quick recovery of the machine and a reduction in overall maintenance time can be achieved.

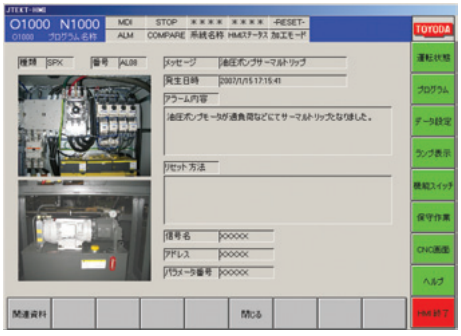

Fig. 4 Example of detailed alarm screen

The regular diagnostic function includes a display of the routine inspection items. In addition, it also displays information that promotes regular measurement of the machine installation level, pitch error, backlash, and more, together with a display containing an explicit explanation of measuring procedures, so as to support the maintenance of machining accuracy.

3. 7 Global Design, Compliance to Safety Standards

JTEKT has always practiced safe design in our machines in compliance with international standards. As far as this particular machine is concerned, while the operator door is designed large and tall, up to the ceiling, for the comfort and workability of the operators, it also ensures operator safety by disconnecting all the motors of devices to which a human is accessible while the door is open. Furthermore, all the doors through which a human passes are interlocked by a limit switch with an electromagnetic lock type key, making the coverage design taking account of both safety and user-friendliness.

For communication of the control devices, a fieldbus system is used in order to achieve improved reliability through a reduction in wiring as well as adaptability to global applications.

4. Conclusion

The change of the environment surrounding us, such as energy supply problems and global warming, are undoubtedly in progress. Also, the performance requirements for machine tools continue to change as time passes. We must cope with these changes. We would like to continue to address the development of further improved machines that match global trends both now and in the future.

K. IMANISHI*

* *Product Development Department, Machine Tools & Mechatronics Division Headquarter*