

Development of In-Line-Type Machining Center "TOP Center F Series"

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Demands, particularly from automakers, for machines able to cope flexibly with volume fluctuations and while enhancing international competitiveness have been increasing. In order to satisfy such demands, we have carried out a full model change on our TOP center G series machining center, which was developed mainly for machining automobile parts, to create our new F series.

Key Words: *in-line-type machining center, compact, standardization, module*

1. Introduction

As the works processed by MC or NC machine tools are very diverse in their characteristics, it is desirable to select the most suitable machine tool for each particular work. However, such optimization is difficult by using the widely available multi-purpose machine tools on the market today, resulting in the selection of equipment that contains redundant functions and is too large for the particular work.

Recently, the demand for machine tools that can fit these specific needs has increased with the goal of building a more efficient manufacturing facility with superior cost performance.

2. Work Characteristics and Processing Equipment

The five main work characteristics referenced above are: (1) size, (2) material, (3) machining accuracy, (4) production volume, and (5) change-over frequency. The most appropriate equipment can vary widely depending on each of these characteristics.

The size of suitable machine tools naturally depends on the sizes of the work, whereas the required machine stiffness varies depending on the material of the work, such as aluminum, casting, and ferrous materials, due to their widely varying processing work loads. Depending on the accuracy requirement for the work, it is necessary to select a machine with suitable machine accuracy along with provisions protecting against accuracy deterioration due to thermal displacement. Also, depending on the volume of production and the frequency of change-over, the type of equipment selected varies significantly.

To be more specific, in case of a work whose

production volume is high with very low change-over frequency, process division is often performed and, in a drilling process for example, a machine which can simultaneously drill multiple holes is required. On the other hand, in case of a work with low production volume requiring frequent change-over, a machine with process integration features is preferred, e.g. a machine, having A and B axes in addition to XYZ axes, which can process a work from many different directions. So far, in order to provide equipment best fit for a specific work, a special purpose machine has been developed for each individual work. However, this approach has involved problems of high cost and long delivery time. Therefore, to help realize low cost and shorter delivery of such equipment that fits specific work, we have developed and introduced here TOP Center F Series machining centers comprised of several standard modules so that the best fit machine for each specific work can be constructed through the combination of these modules. The feed module includes a series of standard strokes for each axis, whereas the spindle module includes standard series of bearing sizes and taper sizes to meet various processing work loads. This module line up facilitates easily to make available combination of various machine specifications ranging from machines for large size and light duty to those for small size and heavy duty.

The standard modules are summarized in **Table 1** and examples of different modular combinations are shown in **Table 2**. Now, thanks to the development of these standard modules the development period has been shortened from the standard one year/one machine to 1.5 years/six machines.

Table 1 Standard module

Basic module	Bed			Column			Main spindle					Turn table		
	Width			C1 High stiffness	C2 Medium stiffness	C3	S1	S2	S3	S4	S5	Round table		Pallet
	B1	B2	B3				#40	#40	#30	#30	#30	T1	T2	T3
850	990	1 190	8 000 min ⁻¹	10 000 min ⁻¹	12 000 min ⁻¹	15 000 min ⁻¹	30 000 min ⁻¹	NC	90°index	□400				
Basic module	ATC							APC		Control panel		Hydraulic & pneumatic		
	#40				#30			Pallet size		E1	E2 (E1 + α)	H1	H2 (H1 + Temperature control)	
	S arm	Direct		Direct			P1	P2						
A1 26 arms	A2 10 arms	A3 16 arms	A4 5 arms	A5 10 arms	A6 16 arms	A7 20 arms	□300 Simple type	□400						

Table 2 Example of combinations

Bed	Column	Main spindle	Turn table	ATC	APC	Control panel	Hydraulic & pneumatic	
B2	C3	S3 #30	T1	A6	-	E1	H1	→ Small size processor for part A (#30)
B2	C3	S3 #30	-	A4	-	E1	H1	→ Small size processor for part B (#30)
B1	C2	S1 #40	T1	A5	-	E1	H2	→ Small size processor for part C (#40)
B3	C3	S3 #30	T1	A4	-	E1	H1	→ Large size processor for part D (#30)
B3	C2	S2 #40	T1	A2	-	E1	H2	→ Large size processor for part E (#40)
B3	C3	S3 #30	T1	A7	-	E1	H1	→ Large size processor for part F (#30)
B3	C1	S1 #40	T3	A1	P2	E2	H2	→ Large size processor for part G (#40)

3. Features of F-Series Machines

The product features of the #30 machine F3-Series developed first are introduced below.

3.1 Cost Reduction of Manufacturing Line

The machine is constructed with high strength and thin section casting and has been optimally designed for sufficient machine stiffness through a stiffness simulation analysis. It also incorporates stiffness increasing features without a size increase, such as the roller guide in place of the conventional ball guide, resulting in the ability to perform the process conventionally done with the #40 machine along with the processes of the #30 machine. For instance, in the case of aluminum cylinder blocks, many processes that used to be handled by the #40 machine have been switched to the #30 machine, increasing the ratio of processes performed with the #30 machine from 16% to 77%. The result was a 30% reduction of total line facility cost. Here, #30 and #40 represent tool sizes, generally standing for BT30 and BT40, respectively (Figs. 1 and 2).

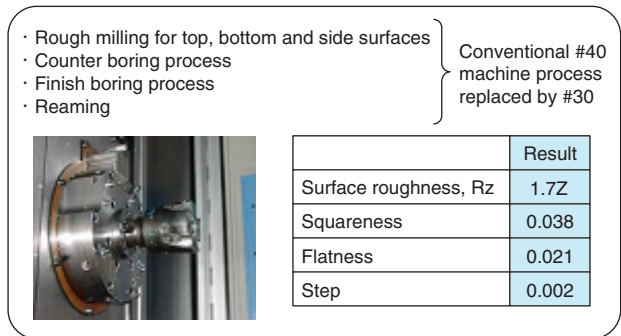


Fig. 1 Machining by conventional machine

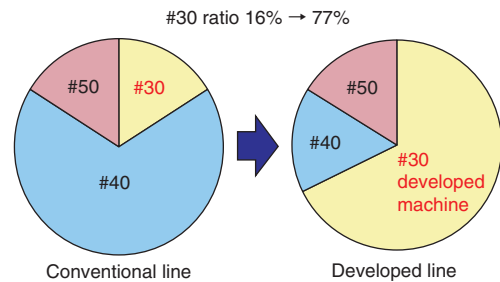


Fig. 2 Ratio of the number of machines

3. 2 Simple Structure Brought Improved Reliability

In order to reduce the facility cost as well as to ensure high reliability, the development of the F-Series was addressed with the design policy that the machine should be structured simply with only the minimum number of components required to provide its function.

For instance, F-Series machines incorporate various simplifications such as the elimination of the hydraulic system from the main spindle by a mechanical linkage of tool unclamp, the elimination of cableveyors on the movable piping and wiring, device communication for sensors, the elimination of the AC100 V power source.

As a result, the number of components has been reduced by 50% and 30% for the conventional #40 machine and the new #30 machine, respectively.

3. 3 Compactness

For compactness, the target of line space saving was addressed in two ways: compactness of the machine body through the use of smaller machine elements and a space saving machine layout.

3. 3. 1 Compactness of Machine Body through Down-sizing of Machine Elements

As an example of the technology used for down-sizing of element components, the technology incorporated for reducing the size of the control panel, which has a significant influence on the machine space, is introduced below. The amplifier for multiple axes is integrated into a small one-piece amplifier, reducing the amplifier size to a half of that found in conventional machines. In addition, the number of electrical parts and wirings are reduced by adoption of the device net communication to save wiring, a software safety circuit to reduce the number of relay parts, and the use of a printed board to reduce the number of terminals in the control panel (Fig. 3). Through these and other measures such as the down-sizing of coolant tanks and hydraulic devices, the machine space has been reduced to 57% of the conventional machine (43% reduction) (Figs. 4, 5 and 6).

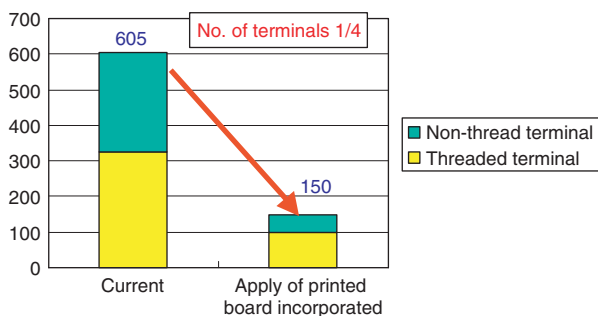


Fig. 3 Reduction of number of control terminals by use of printed board

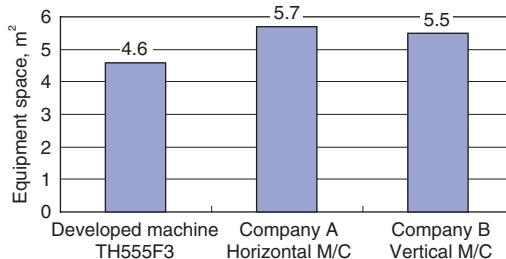


Fig. 4 Equipment space comparison with competitor's

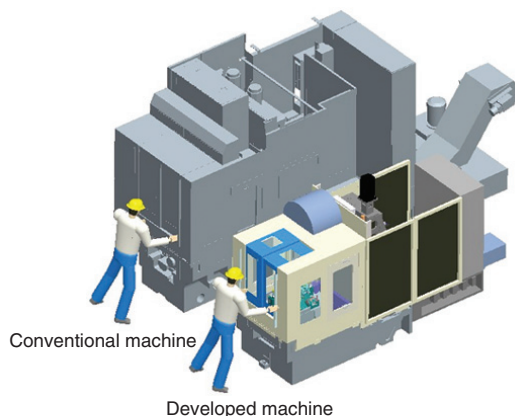


Fig. 5 TOP center F series

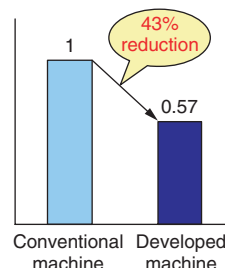


Fig. 6 Comparison of machine space

3. 3. 2 Line Space Saving

In addition to reducing the size of the machine body, the F-Series is also designed so that line space can be saved. To be more specific, the machines are divided into symmetrical R-spec.'s and L-spec.'s with the ATC location, motor, ball screw and other service related parts located on either the right or the left side. As this allows two machines to be laid out back-to-back as a unit, the line space has been reduced by 60% (Figs. 7 and 8).

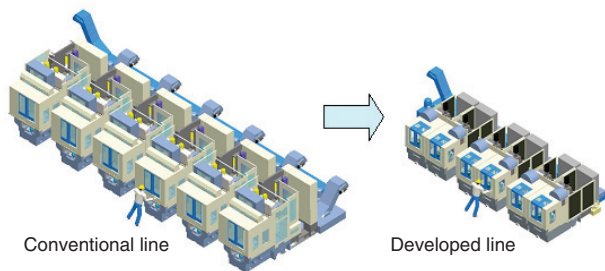


Fig. 7 Zero space between machines by R/L specifications

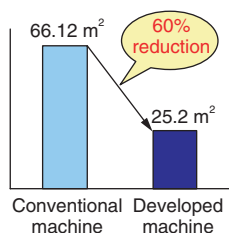


Fig. 8 Comparison of line space

3. 4 Energy Saving

In the development of F-Series, efforts were made to reduce coolant usage (30% less than that of conventional machines) in addition to the energy saving achieved by reducing the size from a #40 to a #30 machine and the elimination of the hydraulic power for the main spindle.

The following measures are incorporated for the reduction of coolant usage.

- (1) Minimization of the chip spreading range by reducing the size of the machine.
- (2) Improvement of chip disposal capability by increasing the inclination angle of the under-table chip disposal bed and the bed oil pan (Figs. 9 and 10).
- (3) Adoption of a low pressure-loss type coolant valve, and reduction of pressure loss on the coolant piping.
- (4) Reduction of coolant used for showering down chips through energy saving nozzles.

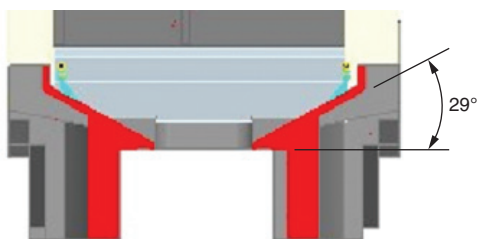


Fig. 9 Cross-section of oil pan (under table) of developed machine

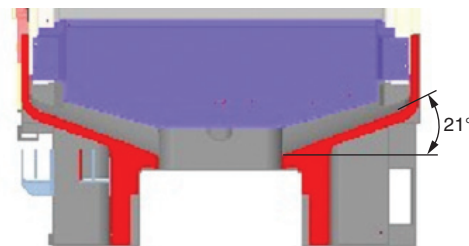


Fig. 10 Cross-section of oil pan of developed machine

4. Examples of Modular Combination

Examples of modular combination for manufacturing lines for small works are given below.

Small module machines with a 300mm X-axis stroke and a machine width of 990mm are selected in several R/L-spec. pairs. Through back-to-back installation of these pairs, the smallest line space for this class can be achieved (Fig. 11).

In another similar case, pairs of the same outer dimension machines, one with a #30 module spindle and the other with a #40 module spindle for different process work loads were selected to build up a flexible manufacturing line.

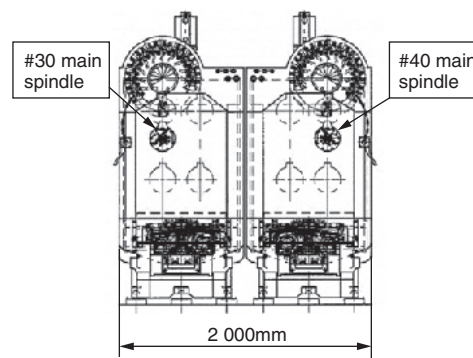


Fig. 11 Zero space between R/L machines

5. Main Specifications

Table 3 Machine specifications

Items		TH355F3L	TH355F4R
Stroke	X axis, mm	300	300
	Y axis, mm	550	550
	Z axis, mm	530	530
Feed	Quick feed, m/min	60	60
	Cutting feed, m/min	0.001~30	0.001~30
Main spindle	Spindle rotational speed, min ⁻¹	15 000	15 000
	Spindle end configuration	BT30	HSK-A63
	Spindle permissible thrust load, kN	2	5
ATC	Number of tools, pcs	5	5
	Mass of tools, kg	6	15
Electric motor	Spindle motor 30 minutes rating/continuous, kW	7.5/5.7	7.5/5.5
Performance/ Capability	Positioning accuracy, mm	±0.003/Total	±0.003/Total
	Repeat positioning accuracy, mm	±0.002	±0.002
Machine dimensions	Width, mm	1 190	1 190
	Depth (including tank), mm	3 850	3 850
Mass, kg		5 500	5 500

6. Machine Layout

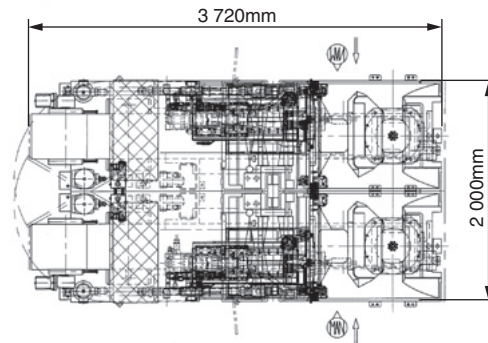


Fig. 12 Machine layout

7. Conclusion

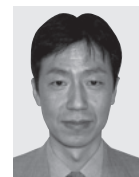
The development of the F-Series machining centers featuring compact and simple standard modules with minimal required functions has led to commercial sales of the #30 series since late 2006 and is planned to replace all other sizes including the #40 series with new series in 2007. We hope that this new F-Series will satisfy our customers' diverse needs.



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