

Introduction of Product

Introduction of Turning & Broaching Machine Model GPR250B-2

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Targeting “Environmental friendliness and energy saving,” “Automation and man-hour saving” and “Higher productivity,” the turning and broaching machine, which is a strategic commodity of the machine tool business of Komatsu Machinery Corporation, has undergone a model change. Sales activities for the new turning and broaching machine were launched in 2009. The technologies and features of the new machine are described.

Key Words: Crankshaft, GPR250, Noise, Environment, Automation, Man-hour saving

1. Introduction

The main business activities of the machine tool business of Komatsu Machinery Corporation are the manufacture and sale of machines to process engine crankshafts. Its crankshaft milling machines, the key products of the Company, feature high precision and productivity, as well as “Dantotsu” (outstanding) economic efficiency. Previously, these milling machines were manufactured and sold in their product series as crankshafts for automobiles and trucks. However, from 2005, milling machines to machine super large crankshafts for ships have been developed and manufactured and crankshafts as large as 13m in size and 50 tons in weight are now machined. Komatsu Machinery has now become the world’s sole manufacturer handling crankshaft milling machines ranging from small to super large as its products.

Meanwhile, Komatsu Machinery has also been promoting system integration in its business negotiations with carmakers to sell crankshaft milling machines themselves, as well as machines in the pre- and post-crankshaft machining processes. This boosts Komatsu Machinery sales and benefits users in greatly reducing the man-hours of production engineers required for process design, supplying workpieces for test cutting and witnessing factory tests and inspections.

The turning and broaching machine was developed in 2004 and has served as the core of system integration together with crankshaft milling machines. It has undergone a model change targeting “Environmental friendliness and energy saving,” “Automation and man-hour saving” and “Higher productivity” as outlined below. (See **Fig. 1**)



Fig. 1 Turning and broaching machine Model GPR250B-2

2. Machine Overview and Features

The turning and broaching machine is a flexible unit that combines the functions of a turning machine (lathe) and turn broach machine, capable of machining main journals, front shafts and rear flanges of crankshafts.

Rotating five disc-type cutters, the turn broach machine is a high-productivity machine that machines main journals in five locations simultaneously. (See Fig. 2)

The machine is equipped with a chuck in each left and right sides, which clamps rear end or front end of a workpiece to process both ends of the workpiece (each chuck clamps and unclamps the one of workpiece ends alternately). Many tips can be mounted onto a disc-type tip holder allowing automated and versatile machine operation for extended hours.

Utilizing these features, for example, significant process integration is possible, e.g. machining done by six processes that can now be done by three. (See Fig. 3)

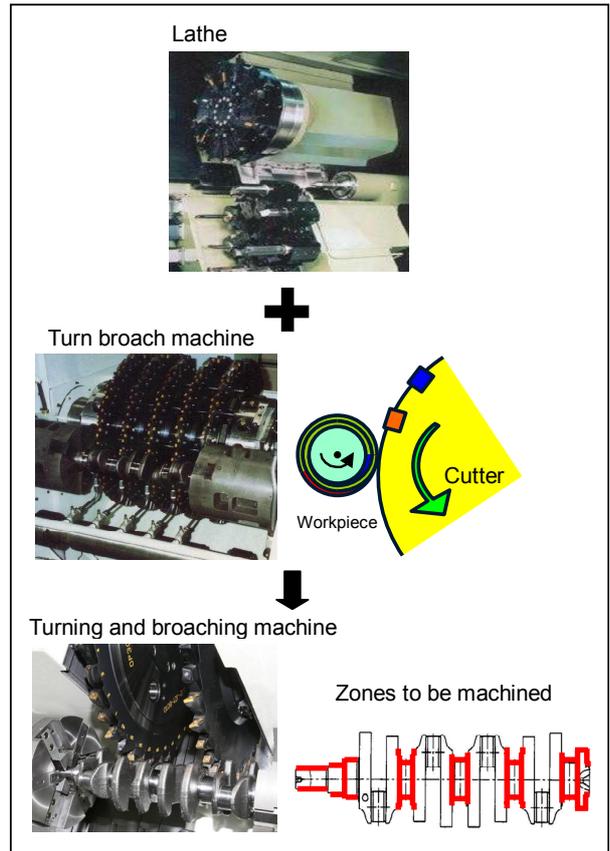
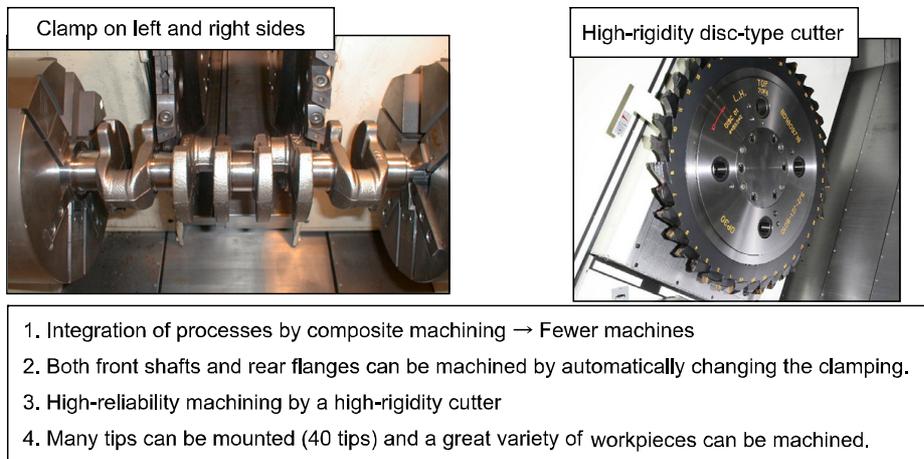


Fig. 2 Machine overview



1. Integration of processes by composite machining → Fewer machines
2. Both front shafts and rear flanges can be machined by automatically changing the clamping.
3. High-reliability machining by a high-rigidity cutter
4. Many tips can be mounted (40 tips) and a great variety of workpieces can be machined.

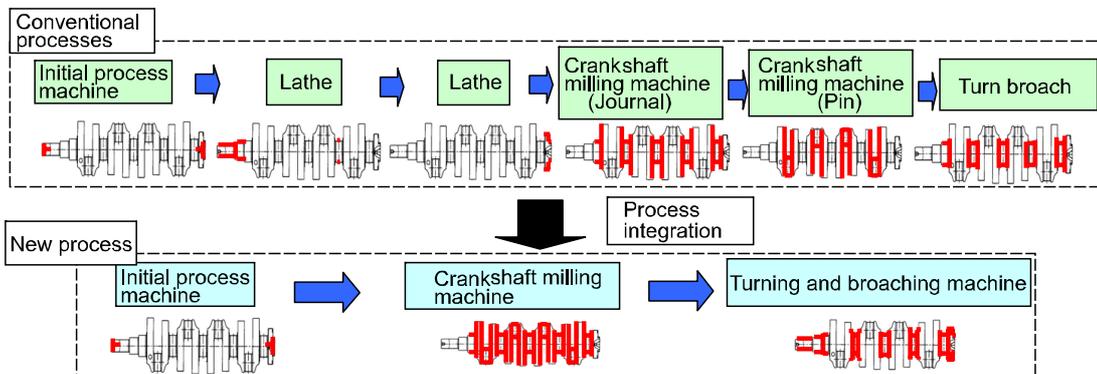


Fig. 3 Features and example of process integration

3. Aims of and Means for Development

The development work was performed with environmental friendliness, energy saving, automation, man-hour saving and higher productivity in mind to provide Dantotsu merchandise power as that in crankshaft milling machines. Specific aims and means for the development work were set out as outlined in **Table 1**.

Table 1 Aims of and means for development

Aim		Means
Environmental friendliness	Noise reduction	<ul style="list-style-type: none"> Higher bed rigidity, higher rigidity of main spindle Enhanced cover air tightness Optimum air blowing of chips
	Reduced consumption of lubricating oil	<ul style="list-style-type: none"> Slide way changed to LM guide Use of self-lubricating devices
Energy saving	Less air blowing	<ul style="list-style-type: none"> Optimum air blowing of chips Change shapes of parts in which chips are deposited
	Longer intervals for tool change	<ul style="list-style-type: none"> More tips mounted (30 → 40)
Automation and man-hour saving	Elimination of quality checks	<ul style="list-style-type: none"> Enhanced measurement accuracy of tips Resistance to thermal displacement caused by ambient temperature
	Shorter operation when cutting is not done	<ul style="list-style-type: none"> Higher units feeding speed Shorter time for clamp changes
Higher productivity	Longer interval for tool change	<ul style="list-style-type: none"> More tips mounted (30 → 40)
	Improved product appearance quality	<ul style="list-style-type: none"> Design using round corners and edges
Cost reduction Higher quality	Fewer parts used	<ul style="list-style-type: none"> Simplified structure Integrated parts used Fewer zones to be lubricated

4. Actual Development Tasks

The development tasks are described in the following in detail.

4.1 Noise Reduction

This machine is a lathe and generates low noise compared with a crankshaft milling machine. However, further noise reduction is always demanded as a means of improving the working environment. As a development task, 75dB (A)eq was set as the target for this model change by reducing the average value of 78dB (A)eq obtained when investigating equivalent noise values of former models by 3dB (A)eq. The noise energy had to be halved to achieve the reduction of 3dB (A)eq.

As a specific noise reduction technique, the machine noise is

roughly divided into its vibration noise during cutting and the noise emitted by the air blower during the air blowing of chips. The vibration noise was reduced by improving the structures of the cutter and machine, especially by increasing the rigidity of the bed. The air blowing noise was reduced by minimizing the amount of air blown and air blowing time. The machine covers were improved to mitigate the propagation of generated noise to the outside of the machine.

4.1.1 Change in structure

To increase the bed rigidity, the conventional structure of a sheeting frame + casting slide base as at present is changed to a monolithic sheeting bed structure. During this change, analysis of the thermal displacement caused by the change in ambient temperature was performed as described later. At the same time, an FEM rigidity analysis was also performed to double the rigidity compared with former models. (See **Fig. 4**)

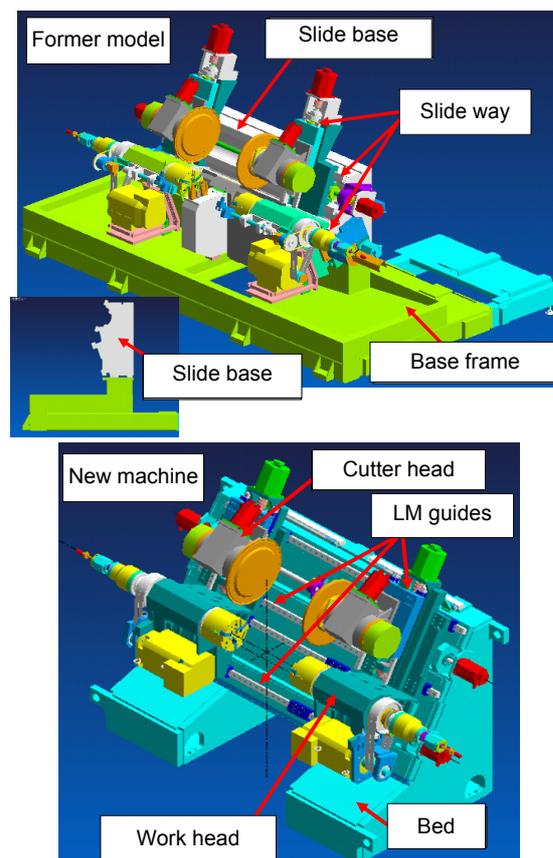


Fig. 4 Bed structure and units

4.1.2 Air blowing of chips

The former models continually blew air from the start to end of cutting. Air is not blown by the new model during the indexing of the machining unit, during which process a workpiece is not cut. (See Fig. 5)

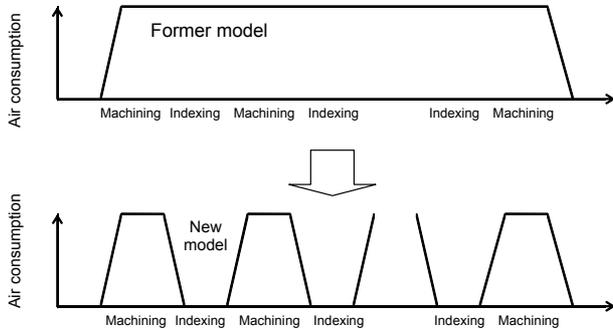


Fig. 5 Air blowing timing of chips

4.1.3 Result in noise reduction

Through these changes, noise could be reduced to 74.6dB (A)eq in the same machining that generated 78dB (A)eq, achieving a noise reduction of 3dB. (See Fig. 6)

Machine	dB(A)		
	Ambient noise	Maximum noise	Equivalent noise
Former model	70	83.3	77.9
New model	69	78.5	74.6

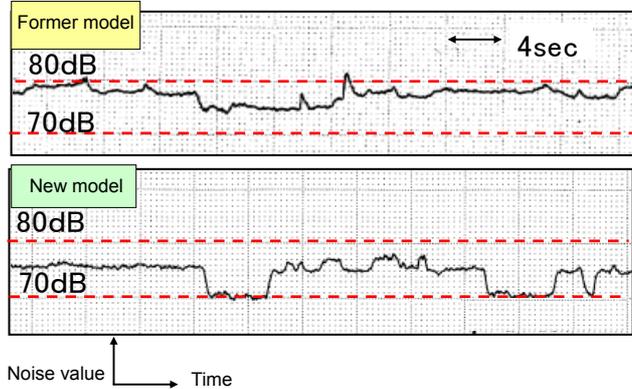


Fig. 6 Comparison of noise values of former and new models (Only part of the whole machining for 140s is shown)

4.2 Energy Saving

Energy saving has been strongly demanded by users recently in terms of reducing their production cost and promoting environmental friendliness.

As energy saving targets, the new model set targets of reducing the consumption of lubricating oil and air by 50 and 30% respectively. Consumption of lubricating oil on sliding surfaces is reduced by changing the slide way type to linear motion (LM) guides. The latter and ball screws are now fitted with a self-lubricating device to further reduce lubricating oil consumption.

Conversely, as mentioned earlier, air consumption is reduced by reducing the air blowing duration for the air blowing of chips.

As a result, compared with the former model, consumptions of lubricating oil and air could be reduced by 60 and 32% respectively. (See Fig. 7)

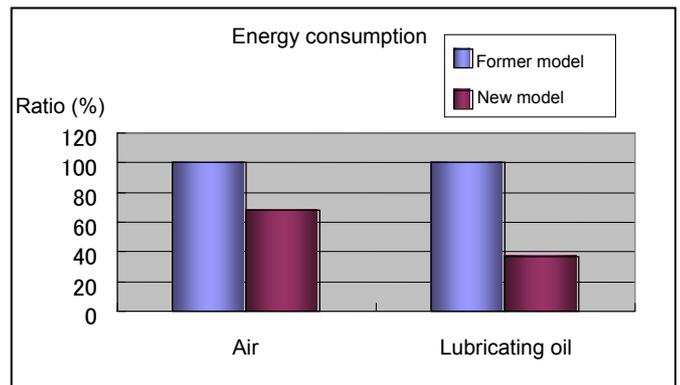


Fig. 7 Comparison of energy consumption

4.3 Automation and Man-hour Saving

4.3.1 Longer interval for tool change

The turning and broaching machine mounts many tips on cutters that are disc-shaped. When they reach the end of their service life, the tips and disc-type cutters are changed by the operator by suspending them via a hoist.

The former model mounts 30 tips onto a one cutter, while the new one mounts 40 tips by increasing the cutter diameter. Thanks to this change, the tool changing interval is lengthened by 30% and operator man-hours for tool changes are reduced.

Needless to say, a longer tool changing interval results in higher productivity.

4.3.2 Elimination of quality checks (Measurement of tips)

This machine mounts 40 tips onto a one cutter. Forty tips are mounted in a tool room onto the disc-type cutter body to an accuracy of within several to 20 μ m. However, if workpieces are machined without correcting tip mounting errors after the cutter are mounted on the machine, machining errors peaking at 40 μ m in diameter are caused. To prevent these, a function is provided to automatically measure tip positions after the cutters have been installed on the machine.

In the recent model change, the number of tips mounted on a one cutter body was increased from 30 to 40, which inevitably lengthens the time for automatic measurement of tip positions. Consequently, a challenge was made to further shorten the time required for this automatic measurement without deteriorating the measurement accuracy by setting 5 minutes per cutter as a minimum target for measuring time as was the case before with the former model.

Tests at an approaching speed during measurement, at acceleration to and deceleration from this speed and at an approaching distance were made, meaning the measuring time could be reduced to 8.4 minutes for two cutters. (Two cutters are installed, one each on the left and right; each of which is mounted with 40 tips.)

The measurement accuracy of tips could also be improved from the “influence of 0.02mm on the diameter of workpieces to be machined” as before to an “influence of 0.012mm.” (See Fig. 8)

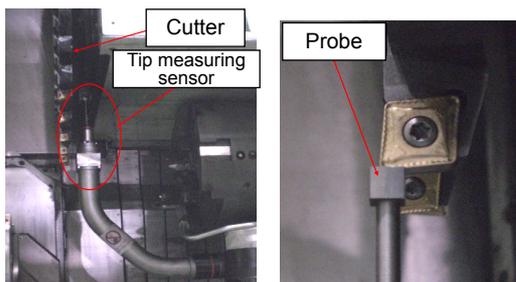


Fig. 8 Tip measurement

4.3.3 Elimination of quality checks (Anti thermal displacement measure)

Stable machining accuracy is an important factor in reducing the number of quality checks required to be performed on workpieces by operators.

As illustrated in Fig. 9, the former model mounts cutter and work heads onto different planes that are 40° apart. This structure is called the George Fischer type, named after an American machine tool manufacturer, and known for its resistance to thermal displacement caused by ambient temperature variation.

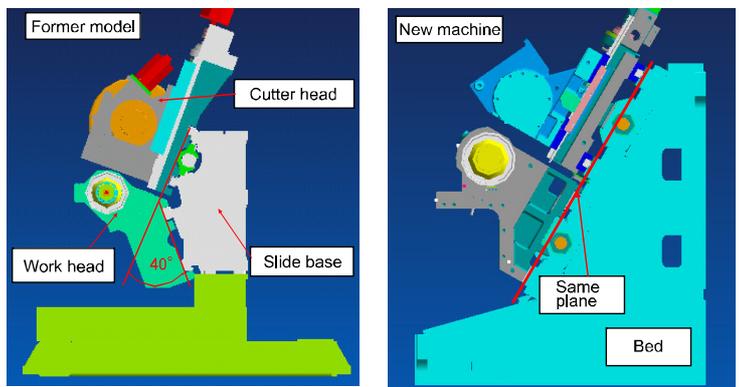


Fig. 9 Comparison of bed (Slide bed)

The model change substitutes different planes that are 40° apart with a single plane to increase the rigidity of the bed and for ease of fabrication. However, this structure encounters the problem of being prone to thermal displacement compared with former model.

An FEM analysis of thermal displacement was performed with various sheeting structures to produce a bed with a monolithic structure and the same plane but resisting thermal displacement. Based on temperature data of a former model and displacement measurement data, analysis has shown that air temperature differences near the front and rear sides of the bed significantly affect bed deformation. Using these temperature differences as a boundary condition, an FEM analysis was conducted to determine the optimum sheeting structure. At the same time, the configuration of the covers was improved to reduce differences in air temperature near the front and rear sides of the bed. (See Fig. 10)

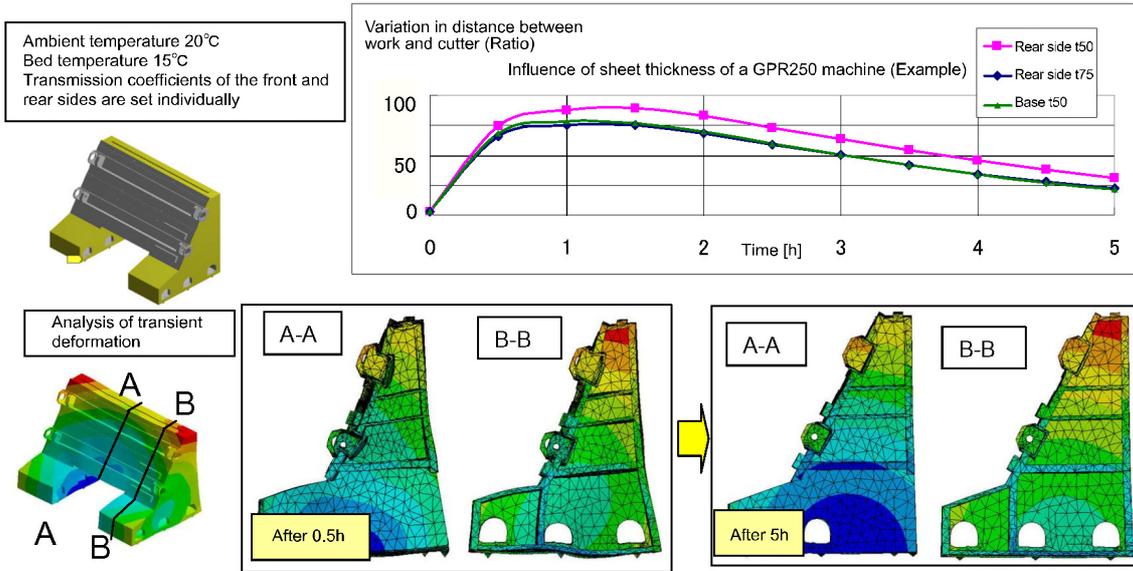


Fig. 10 Example of thermal displacement analysis

Additionally, also incorporated is a correction technique to correct variations in the relative distance between a cutter and workpiece by sensor measurement, even if this varies due to thermal deformation of the bed. (See Fig. 11)

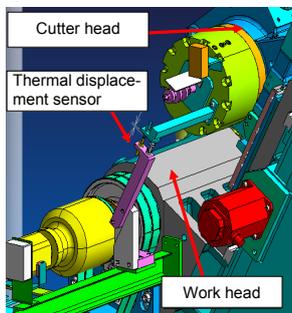


Fig. 11 Thermal displacement sensor

Thus viewed, a 20% reduction in thermal displacement compared with the former model was achieved by combining a composition of bed components that resist thermal displacement and a correction function by a thermal displacement sensor.

As one example, Fig. 12 plots amount of variation in machined workpiece diameter and the ambient temperature at the time of machining.

In this test, one portion of whole machining portion was processed hourly, which took 32 hours to finish the workpiece.

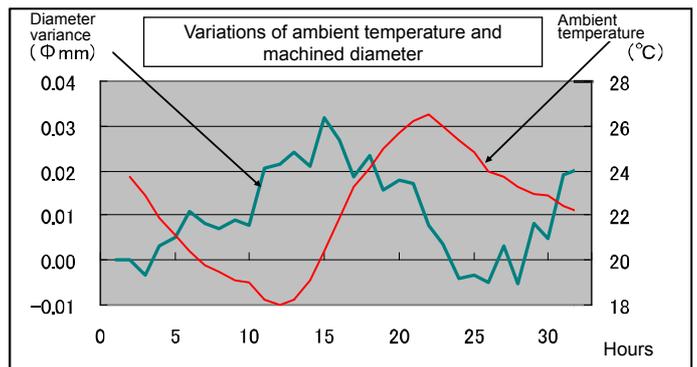


Fig. 12 Variations of ambient temperature and machined diameter

4.4 Higher Productivity

4.4.1 Higher axis speed

The rapid feed speeds of the cutting axis and indexing axis were increased from 18 to 25m/min, while that of the rest indexing axis was increased from 12 to 25m/min compared with the former model, to shorten the time during non-cutting operations.

4.4.2 Faster workpiece clamp changing time

In the proposal made for this machine to integrate various processes illustrated in Fig. 3, the clamp changing operation for workpieces becomes vital.

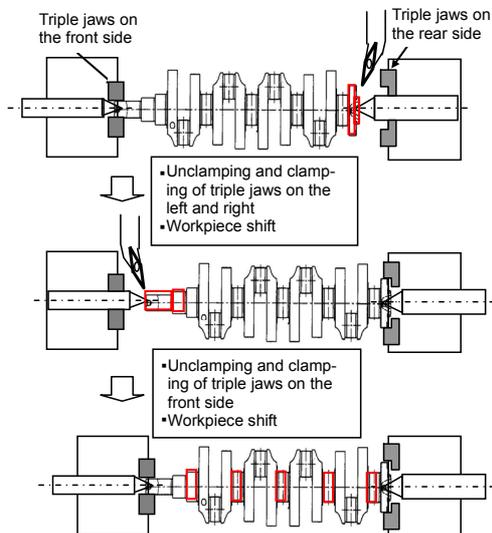


Fig. 13 Clamp changing operation

A reduction in this clamp changing time shortens the time needed while cutting is not performed, thereby contributing to a higher productivity. In former models, triple jaws are moved to the unclamping edge full stroke when unclamped. In the new model, the moving stroke is shortened to an intermediate position in which the jaws are actually unclamped. This reduction in the moving stroke shortens the time for both unclamping and clamping operations. Furthermore, the operation speed of the triple jaws is increased and the time needed for clamp changes reduced by 35%. (See Fig. 13)

A 15% reduction in total time for non-cutting operations could be achieved by increasing the unit feeding speed and reducing the clamp change time.

4.5 Refined Product Appearance Design

It cannot be denied that evaluation on the product appearance designs of former models was low compared with machines made in Europe. This evaluation was considered not very important provided the machines were sold in Korea and Japan. However, in sales activities in the United States, Europe and China, product appearance designs became a major factor. In the model changes of crankshaft milling machines made in 2006, entirely new designs were created through the cooperation of the Corporate Design Department. These new designs are also incorporated in the latest model change of the turning and broaching machine.

The new covers are not only beautifully designed, but also excel in safety because the covers have rounded corners and edges and there are fewer projections such as bolt heads, knobs and handles. (See Fig. 14)



Fig. 14 Product appearance design

4.6 Fewer Parts Used

The number of parts used in the machines was reduced during the model change to reduce cost, including shortening the lead time needed for assembly and to ensure stable quality. A reduction of more than 30% in the number of parts used in the machine compared with the former model was set as a target. In end, a 37% reduction in purchased parts was achieved by simplifying the structures, integrating parts, including fewer lubricating zones and other measures. A 33% reduction was achieved in reducing parts in total when bolts and nuts are included, while SVM improvement could also be accomplished through these reductions.

5. Conclusion

“Overseas activities” and “System integration” are key words of the machine tool business of Komatsu Machinery Corporation in increasing its sales. The former models of the turning and broaching machines required improvement in terms of QCD compared with crankshaft milling machines which were highly competitive. The recent model change has improved the QCD of turning and broaching machines and refined their product design to a level comparable with the designs of machines manufactured by other manufacturers inside and outside Japan. Consequently, the new machines have emerged as powerful strategic system integration machines for sales promotion inside and outside Japan for the first half process of crankshaft machining together with crankshaft milling machines.

Introduction to the writers



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[A few words from the writers]

“Improved work environment,” “Energy saving” and “Higher productivity” were achieved in developing a model change machine for crankshaft milling machines in 2007. The new machine incorporates this approach and technique.

During the development process of the new model, new know-how for thermal displacement analysis, a design technique to reduce the number of parts and other techniques and know-how could be gained. Many new experiences that could not be described in the limited space allocated to this report were also gained.

These technologies and experiences will be utilized in future development projects.