Introduction of Product

Introducing Crankshaft Miller Model GPM170F-5

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The crankshaft miller, a leading product of the machine tool business of Komatsu Machinery Corporation, has been model-changed targeting "Improved working environment," "Energy saving," "Enhanced flexibility" and "Enhanced productivity." The new miller was introduced into the market in 2007. The background, technologies and features of the new product are described.

Key Words: *Crankshaft, GPM170F-5, Variable pitch rest, uniform-load cutting, noise, vibration*

1. Introduction

Since a model change in 1983 to an internal system of a fixed work type, the crankshaft miller for machining of engine crankshafts has won high evaluation as a high precision and high productivity machine. At present, a market share of almost 100% is maintained in Japan and Korea. Demands for a flexibility and energy saving feature have risen highly recently reflecting customer requests and market variations.

A model change has been made for the first time in 13 years and Type 5 (**Fig. 1**) has been developed targeting "Working environment improvement," "Energy saving," "Enhanced flexibility" and "Enhanced productivity." The new miller is overviewed in the following.

Fig. 1 Crankshaft miller GPM170F-5

2. Aims and Means of Development

The Komatsu crankshaft miller fixes a work and clamps the area near the machining part of a work by a rest. This assures high support rigidity of the work. Additionally, the cutter support rigidity is also high thanks to a large-diameter cutter bearing and Komatsu's unique swing arm system (**Fig. 2**). As a result, high-precision machining is feasible even in heavy cutting. The configuration of the former model that features high reliability is retained. Under this basic structural configuration, development aims and means are set specifically as presented in **Table 1** targeting working environment enhancement, energy saving, enhanced flexibility and enhanced productivity.

The cutter is retained in the center of the swing arm. One end is supported by a large-diameter bearing and the other end is driven by a ball screw. A high support rigidity is obtained compared with conventional parallel operation. A large thrust is accomplished by the lever principle.

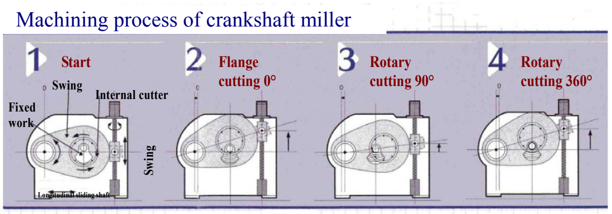


Fig. 2 Komatsu's unique "swing arm system"

Table 1 Development aims and means

Aim		Means
Working environment improvement	Low noise	Noise analysis (Campbell diagram) Machine rigidity analysis (Model analysis) Noise reduction by covers
	Enhanced dust collection efficiency	Change in dust collection route
	Measures for chips	Improved chip flow Improved chip outflow chute
Energy saving	Less air blowing	Chuck shutter added
	Less lubricating oil consumed	Adoption of equipment installed with self lubricating device
	Less power consumed	Adoption of energy saving equipment
Enhanced productivity	Flexibility	Adoption of variable pitch rest
	Cutting of works of different materials	Adoption of AC spindle motor
	Tool life	Uniform load cutting
	Enhanced correction functions	Addition of surface tilting correction
	Remote diagnosis	Smooth troubleshooting
Enhanced external quality	Enhanced design	Design with rounded corners
Pursuit of ease of manufacturing	Easy changes in built-to-order design	Standardization of designs
	Component standardization	Promotion of standard components
	Fewer piping parts	Review of hydraulic and lubrication routes

3. Development Status

The details of the status of the development are described below.

3.1 Noise Reduction

The crankshaft miller is a milling machine for heavy cutting and generates the highest noise in the line. A reduction in noise level is continually demanded. In the development work this time, "Noise analysis by the Campbell diagram" and "Modal analysis" were performed prior to the model change using a conventional machine. The Corporate Research Division provided its cooperation to this project. Optimization of the machine cover shapes was studied at the same time. In the end, 3dB (A) was reduced. This represents a great accomplishment of reducing noise energy to a half.

3.1.1 Noise analysis by the Campbell diagram

The Campbell diagram expresses noise characteristics such as resonance based on a rotating speed or sound frequency. Noise was measured with the miller while varying the cutter rotating speed and analysis was conducted accordingly. In the past, it was thought that "a cutting blade crash with a work generated noise so that sound of a frequency would increase at integer multiple of the crash frequency." The measurement result is shown in **Fig. 3**. The diagram shows that the noise frequency does not rise even though the cutter rotating speed rises and that a high value was registered at a specified frequency. It showed that noise would be reduced by determining the vibration mode of a machine at this specified frequency and by reinforcing the part in which deflection became large in this mode.

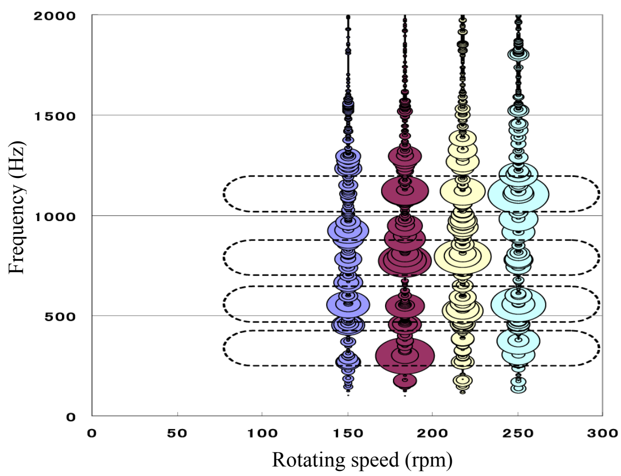


Fig. 3 Campbell diagram

3.1.2 Modal analysis

"Modal analysis" is a technique to determine a machine vibration mode. Pickups are mounted on various parts of a machine and vibration generated when the machine is excited is measured. Data of the different parts is totaled by a computer and behaviors of machine vibration are displayed in animation (**Fig. 4**).

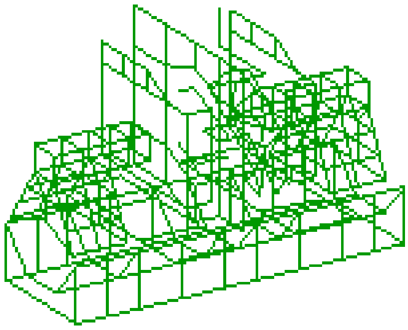


Fig. 4 Animation of modal analysis

Based on these results, sheeting and the welded structure of each part have been improved. Improvement of the work head is described in the following as an example. The modal analysis shows that the work head oscillated vertically greatly. As a measure against this problem, the thickness of the sheeting on the front side was increased and large ribs were added as illustrated in **Fig. 5**. As a result, an FEM analysis of the new structure shows that its rigidity increased by 60% (**Fig. 6**).

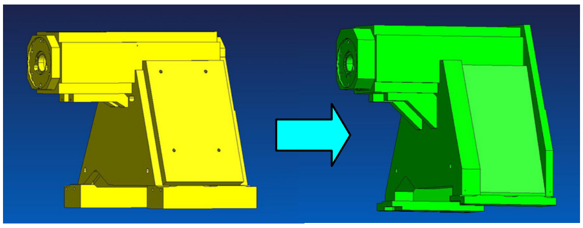


Fig. 5 Work head structure

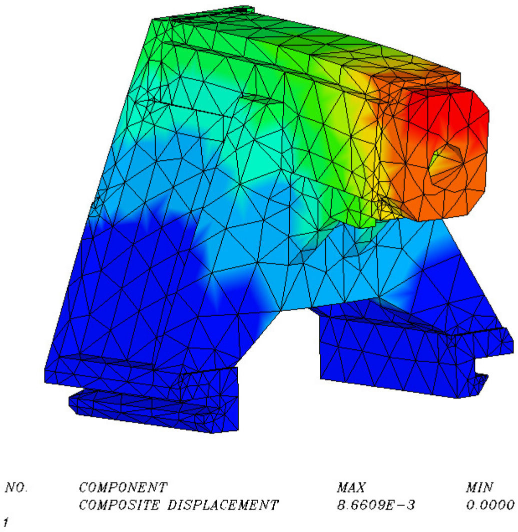


Fig. 6 Work head rigidity (FEM analysis)

3.1.3 Noise reduction by covers

The machine covers were improved by performing actual machining tests with them.

The machine covers can be grouped into covers inside the machine and into covers around the machine.

The covers inside the machine cover the important structure for cutter driving and moving. This structure is one of the areas which generate vibration most by excitation force caused by cutting. The covers on these parts were tested for hermeticity, for the type of sound-absorbing materials inside and whether or not a damping material is used. The tests showed that the damping material had only a limited effect and that an increase in hermeticity produced a large effect.

The cost was increased when the cover structure was changed to increase the hermeticity. However, eliminating the damping material lowered the cost (**Fig. 7**).

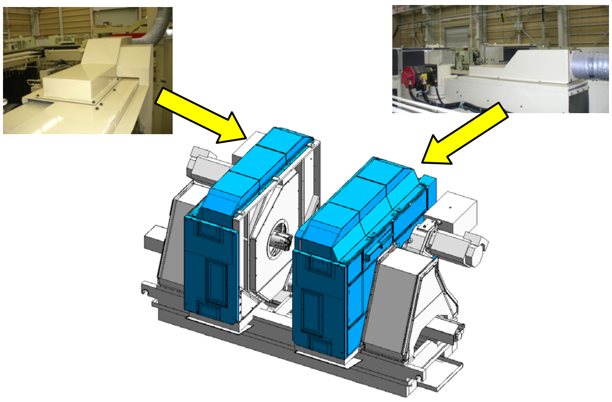


Fig. 7 Covers inside machine

To reduce noise around the machine, the upper part of the covers on the exteriors of the machine were rounded. This reduced diffraction noise also. A material that excelled in sound absorbing performance, in resistance to ambience, in anti-flame performance and in deterioration over time was adopted as the sound-absorbing material (**Fig. 8**).

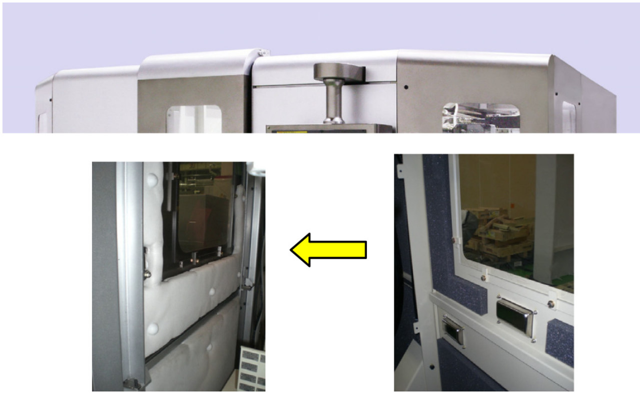


Fig. 8 Covers on outer periphery of machine

3.2 Energy Saving

The energy saving feature has been strongly demanded recently to lower the production cost of the user and to promote the efforts being made to be eco friendly.

The model change was made after measuring the energy consumption of conventional machines. Consumptions of electric energy, lubricating oil and air energy during a cycle to machine a pin and journal of a serial 4-cylinder crankshaft as a model cycle were measured.

Fig. 9 shows the measurement results, showing each energy converted into a monetary amount. The ratio of air is extremely high, 57%.

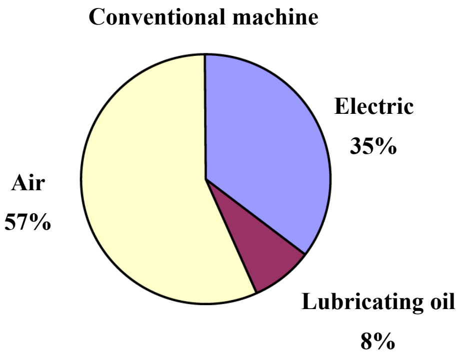


Fig. 9 Ratios of energy consumption

Air is consumed in blowing of the chuck part and in saddle blowing on left and right moving surfaces.

One crankshaft is machined in about 40 seconds in a model cycle. Air blowing in one model cycle is illustrated in **Fig. 10** and the amount of air consumed during chuck blowing is large.

The chuck in the miller runs through a recessed part in the front shaft of the crankshaft. Air is blown onto this part during machining to prevent metal chips from entering there. The air consumption can be reduced significantly if this air blowing can be eliminated.

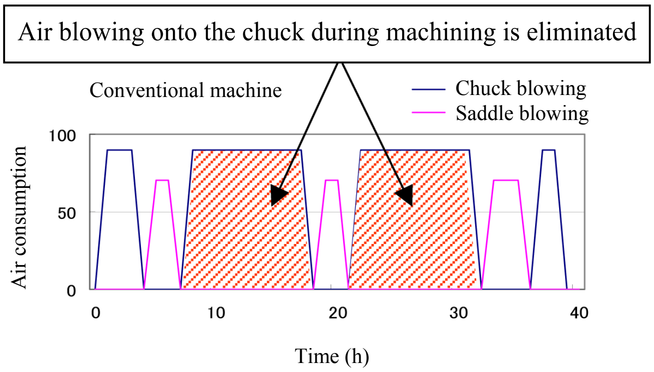


Fig. 10 Air blowing sequence

A shutter is added to the miller after the model change to prevent metal chips from entering into the chuck (**Fig. 11**).

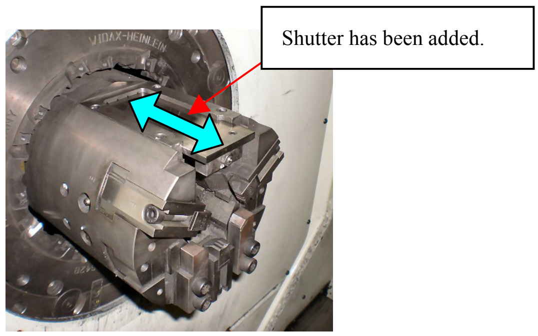


Fig. 11 Chuck shutter

At the same time, chip reservoirs in various parts of the machine are tilted sharper than before to eliminate air blowing. The model change was accomplished by 3D-CAD design. The reservoir inclination could easily be checked visually and this was very helpful.

The consumption of electric energy was reduced through a regenerating function when the cutter rotating speed is decelerated and by adopting hydraulic valves of an energy saving type. The consumption of lubricating oil was reduced by adopting self-lubricating devices with the LM guides and ball screws.

As a result, the overall energy consumption of air, electricity and lubricating oil was halved as shown in **Fig. 12**.

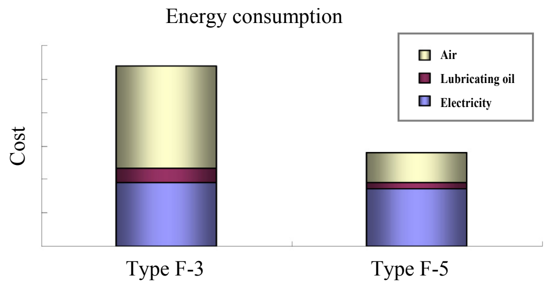


Fig. 12 Energy consumption

3.3 Productivity Enhancement

3.3.1 High spindle speed

The rapid feeding speed of the machining spindle was increased from 8m/min to 20m/min and the speed of the indexing spindle in the lateral direction was increased from 16m/min to 40m/min to increase the speeds of the spindles 2.5 times and to shorten the non-cutting time, compared with conventional machines.

3.3.2 Adoption of variable pitch rest

Miller operations at the users have become diverse. The users who operated the millers by manual initial setup before in volume production lines now wish to change to automatic initial setup to cope with frequent lot changes. The miller flexibility has been enhanced by developing a rest that clamps a work during machining and a variable pitch rest that can change the cutter pitch (**Fig. 13**).

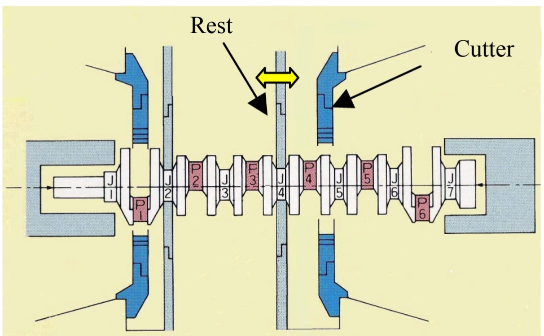


Fig. 13 Variable pitch rest

3.3.3 Adoption of AC spindle motor

In the production of a large variety of crankshafts, machining of works of different materials also becomes necessary. To meet this requirement, an AC spindle motor has been adopted, allowing easy changes in the spindle rotating speed and cutting speed by programming.

Works of various types and materials can be machined under optimum cutting conditions and tool life can be lengthened. The miller can be easily adapted to tools for high-speed machining in the future to increase productivity.

3.3.4 Enhanced automatic programming functions

Calculations and programming used to be accomplished manually to make the load an optimum load based on cutting load data, to shorten the machining time and to prolong tool life. A function has been added, instead, to fetch load data of the spindle from the machine and to make calculations by an automatic programming system, to automatically change the cutting speed and feed speed (**Fig. 14**). Cutting can be performed under an optimum cutting load without applying an overload to the tool, thereby lengthening the tool life.

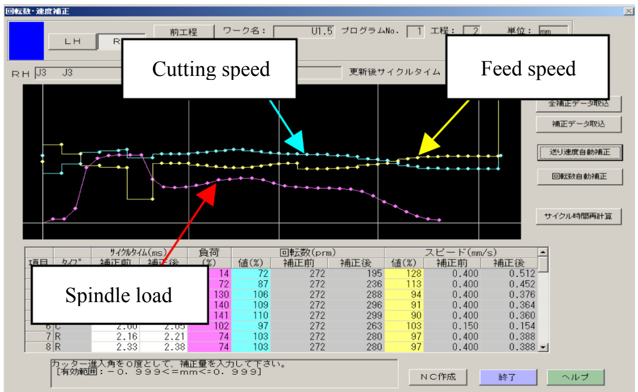


Fig. 14 Screen for correction of uniform-load cutting

3.3.5 Enhanced maintainability

As an optional function, remote diagnosis has been prepared to check the local condition more accurately in the case of a sudden failure of a machine delivered outside of Japan (**Fig. 15**). This function enables checking of the machine operation screen at a site, in an office. As a result, a complaint or a problem can be correctly and smoothly troubleshooted to shorten the restoration time by the user (mean time to repair - MTTR) and rate of machine utilization. In the case of a failure, the screen displays not only characters, but also the failed part for enhanced user convenience.

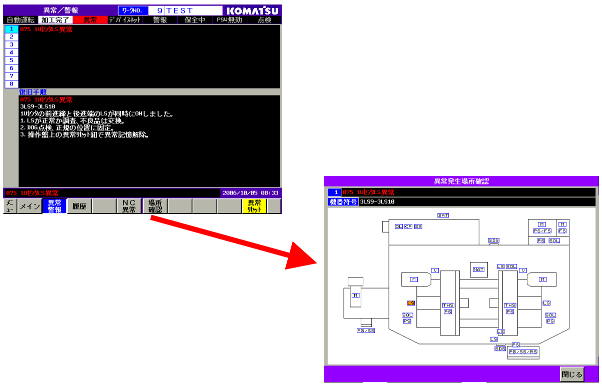


Fig. 15 Maintenance screen

3.4 Enhanced Product Appearance Design

The product appearance designs of conventional machines were evaluated as inferior compared with European machines. This evaluation was considered not very important in the marketing of millers in Japan and Korea. However, this factor has become a large factor in marketing activities in the United States, Europe and China. With the cooperation of the Corporate Design Department, the design has been revamped entirely to a new image (**Fig. 16**). The new covers are beautiful in design. The corners of the covers are rounded and the covers have fewer protruding objects such as bolt heads and grip handles, excelling in safety also.

3.5 Pursuit of ease of manufacturing

The model change pursued enhanced machine quality, as well as ease of manufacturing. The users of the machine are automobile manufacturers and each user has its own in-house standards, which need to be complied with. Standards are sometimes different from one plant to another even though the plants belong to one manufacturer. This necessitates more design time.

3.5.1 Improved covers around machine and method to mount operation panel

Since the work feeding height is specified, the thickness of the sheeting plates under the machine bed was changed. The covers around the machine had to be adjusted by vertically extending them. In the model change, other covers are provided in these parts to allow vertical adjustment without a design change (**Fig. 17**).

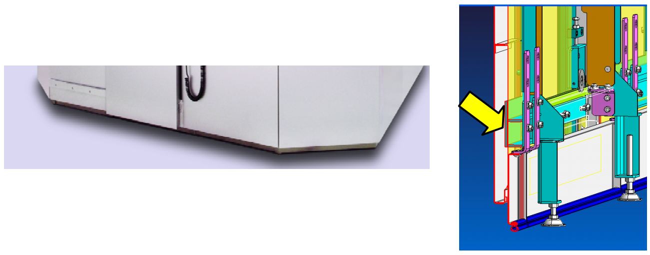
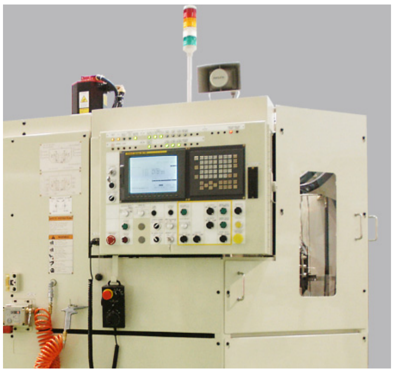


Fig. 17 Guards in bottom parts of outer periphery of machine

The height of an operation panel of the built-in type is specified, requiring changes in the covers around the operation panel. The new model mounts the operation panel away from covers and a change in panel mounting height can be met by changing only the length of the mounting pipe (**Fig. 18**).

Fig. 16 Product appearance design



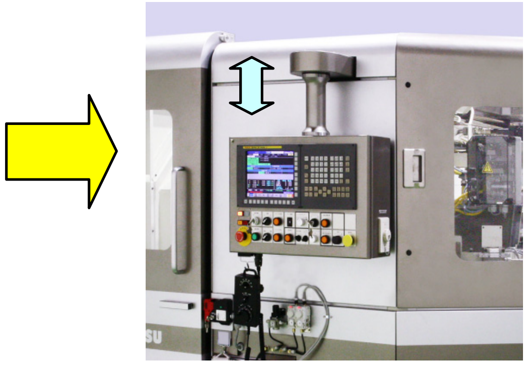


Fig. 18 Operation panel

3.5.2 Improvement in piping

In the past, specifications of the chuck to clamp a work varied greatly and shapes of pipes to supply hydraulic pressure and pneumatic pressure have been different. The chuck specifications have been greatly reduced in the model change necessitating fewer pipe types. Where option specifications are specified, standard-specification pipes are made to be used for option specifications without changing the pipe specifications, so that users need to add pipes for only the optional part (**Fig. 19**).

The piping routes have been reviewed and the number of joints and couplings has been reduced by 20% to improve the assemblability of the machine.

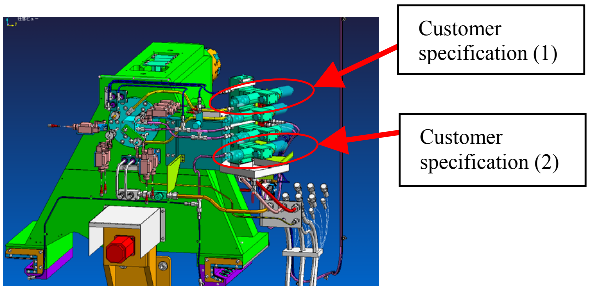


Fig. 19 Work head piping

4. Conclusion

At present, many of Japanese and Korean industrial manufacturers are purchasing machine tools from machine tool vendors discretely. However, the sale of systems in machining lines on a turn-key basis is becoming the principal mode of sale for the industrial manufacturers in North America, Europe and emerging markets such as BRICs. Komatsu Machinery Corp. is implementing a strategy of promoting sales of systems by selling full lines to machine crankshafts co-operating more closely with NTC. Crankshaft millers especially are Komatsu's leading machines in its product lineup in competition with the competitors. Komatsu Machinery Corp. will become a manufacturer that will make proposals on the crankshaft machining process to the automobile manufacturers throughout the world by further enhancing the strengths of its machine systems and competitive edge of the machines in the upstream and downstream processes.

Introduction of the writer

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[A few words from the writer]

Komatsu Machinery Corp. features a versatile lineup of crankshaft millers of the internal system, its leading products, ranging from 170F for passenger cars to 320F for trucks and construction machinery. The model change for 170F, which is a model sold in a large quantity, has indeed been the first model change in 13 years. Very satisfactory results were achieved in this development by soliciting the cooperation of other departments including the Corporate Research Division on noise analysis by Campbell diagrams, modal analysis and other analyses and Corporate Design Department on product appearance. Efforts will be continued to listen carefully to the voices of the users and markets as the needs diversify further, for application to higher models and to upgrade machines into better machines.

3D-CAD design was used in the design of built-to-order design activities of Komatsu Machinery Corp. 3D-CAD design still has many problems that need to be overcome, but will be used more through cooperation with the manufacturing sector.