Introduction of Products

Horizontal Machining Center NX400

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As we have developed a new model for machining center to be core of engine manufacturing line as Komatsu NTC's leading product aiming at "high-speed and rigidity", "energy and space saving", "automatization and unmanned operation" and "productivity improvement" as well, the details are described here.

***Key Words**: Machining center, NX400, High-speed, High rigidity, Energy saving, Automatization, Unmanned operation, Smart line*

1. Introduction

Komatsu NTC has been involved mainly in business of manufacturing and selling (marketing) of cutting work line for engine parts. Seeking for a manufacturing system synchronized with assembly as the next generation manufacturing line, a smart line to achieve DANTOTSU (unique and unrivaled) productivity and quality has been delivered to Komatsu Oyama Plant and started its operation in 2019. (Refer to **Fig. 1**)

In addition to introduction of jig fully-automated initial setup, in-process measurement, automated exchange of tooling and centralized line management system with a large screen, a technology to monitor manufacturing state has been built by associating machining data, precision of processed products and tool information with the system.

As we have developed a horizontal machining center NX400-667 (refer to **Fig. 2**) to be core of the manufacturing line, its overview is introduced here.

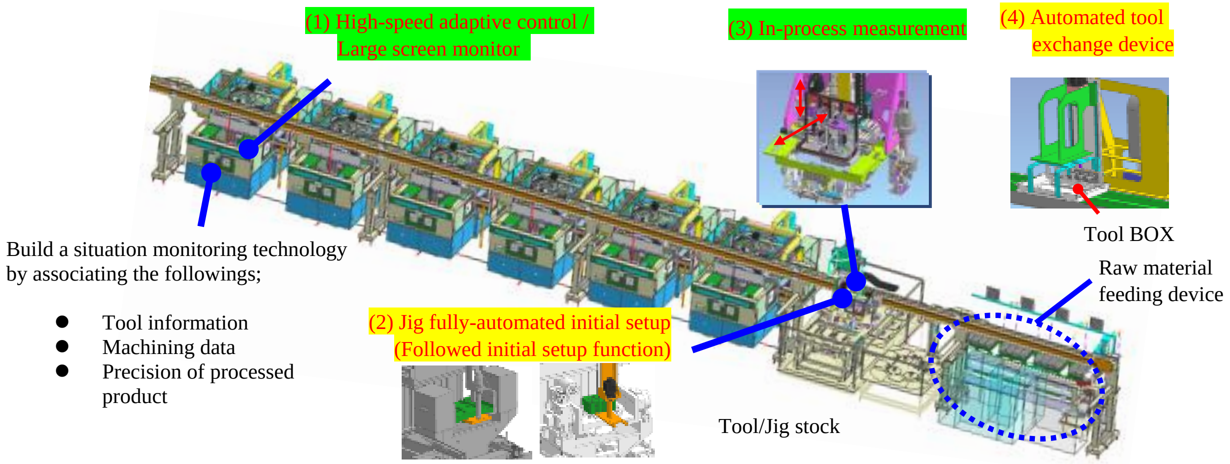
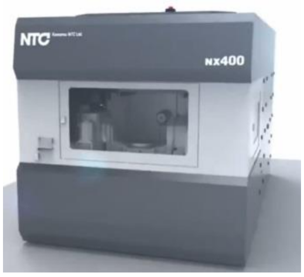


Fig. 1 Overview of Smart Line



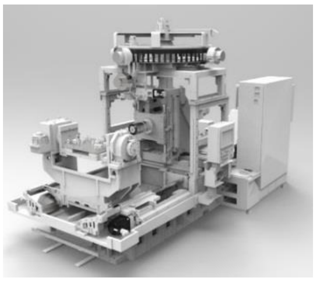


Fig. 2 Horizontal machining center NX400-667

2. Overview and characteristics of machine

Machining center is a machine tool capable of various machining works by mounting tools required for hole and surface machining on the main spindle such as drill, reamer or milling and rotating them for cutting work, while performing Auto Tool Change (ATC) using a tool holding device called as magazine. As shown in **Fig. 3**, a tool holder to be mounted on the main spindle is called as #50, #40 and #30, respectively, according to size of the holder. Since machining center often uses tool holders with different sizes depending on the materials of work piece to be processed and cast iron is frequently used as a material for engines of construction machinery and trucks, a large machining center with a size called #50 tends to be used for processing them.

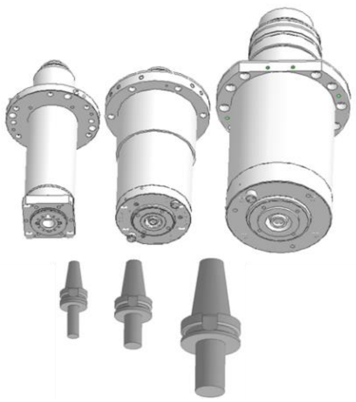


Fig. 3 Main spindle and tool holder size

In case of automobile engine of which Komatsu NTC has a good track record, on the other hand, as aluminum alloy with relatively good cutting performance is used as the material, downsized machining center of #40 is often used. Characteristics of #40 compared with #50 include an advantageous capability to reduce non-operation time such as time required for travel and tool exchange due to the small structure and light weight, whereas there is a demerit of low rigidity.

Structure of a general machining center is shown in **Fig. 4**. It is generally equipped with orthogonal three axes (X, Y, Z-axes) for machining feed and an additional axis parallel to the Y-axis (B-axis) for parts position indexing, i.e. four axes in total.

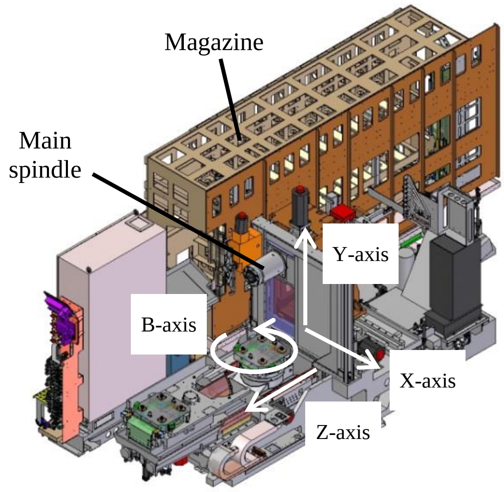


Fig. 4 Structure of machining center

One of characteristics of NX400 is its capability of indexing five-axes machining due to an additional tilting axis (A-axis) parallel to the X-axis in addition to the four axes. (Refer to **Fig. 5**) Since transport of parts as well as their removal from and installation on fixed jig is automatically performed in the transfer line, it is possible, with A-axis, to set transport direction and sticking surface to top face to secure stable transport, resulting in improvement of working ratio. In addition, as it is also possible to index optimum position by setting longitudinal direction of parts in horizontal direction and combining with B-axis, machining is possible with an optimum system including tools. (Refer to **Fig. 6**)

By processing with an optimum system in addition to enhancement of machine rigidity based on review of structure such as main spindle and column, it becomes possible to process parts with #40 machine, one size smaller than #50 machine, which had been required for processing such parts before.

We have worked on development for casting engine machining line for construction machinery and trucks adopting #50 size machining center aiming at achieving “high speed and rigidity”, “saving of energy and space”, “automatization and unmanned operation” and “productivity improvement” in order to adopt machining center of #40 size, which has high machine availability and productivity.

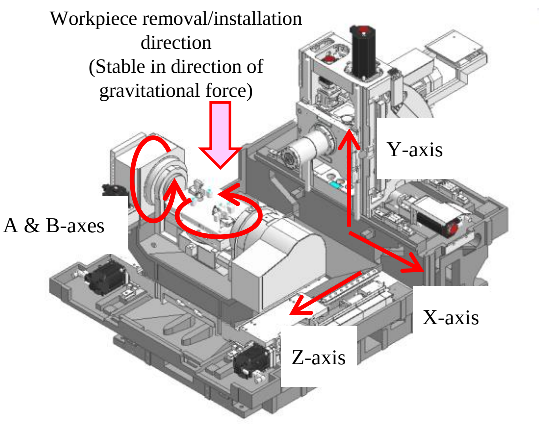


Fig. 5 NX400 structure

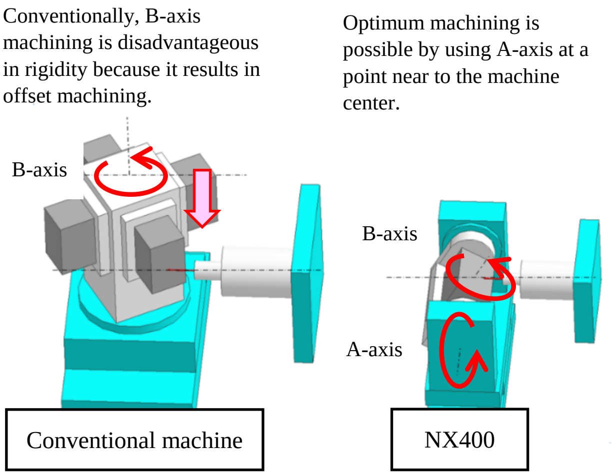


Fig. 6 Example of A & B additional axes machining

3. Aims of Development

3.1 High rigidity / Saving space

Rigidity of machining center is almost proportional to size of the structure. Therefore, structure of #50 with a larger main spindle is larger than #40 showing higher rigidity but its installation space also tends to become larger. The development model is aimed to achieve to suppress installation space to a level of #40 while securing rigidity of #50 class machine.

3.1.1 Increased rigidly of main spindle unit

Main spindle of machining center is supported by a structure called as column. Rigidity can be increased by making column width wider but it also makes travel object larger, resulting in leaving the width of machine no choice but to increase. The development model has suppressed the machine width to equivalent level of conventional machine of #40 by arranging a magazine at upper part which is arranged lateral to the machine while adopting a larger column than conventional machine of #40. (Refer to **Fig. 7**)

3.1.2 Increased rigidly of Z axis unit

1.35 times of rigidity has been secured for a single unit by increasing the size of A-axis table to hold workpiece. Simultaneously, improvement of drive system's rigidity has been sought for by adopting tandem drive with two motors for Z-axis drive. (Refer to **Fig. 7**) Tandem drive greatly contributes to improvement of drive shaft durability because load to be applied to ball thread is dispersed.

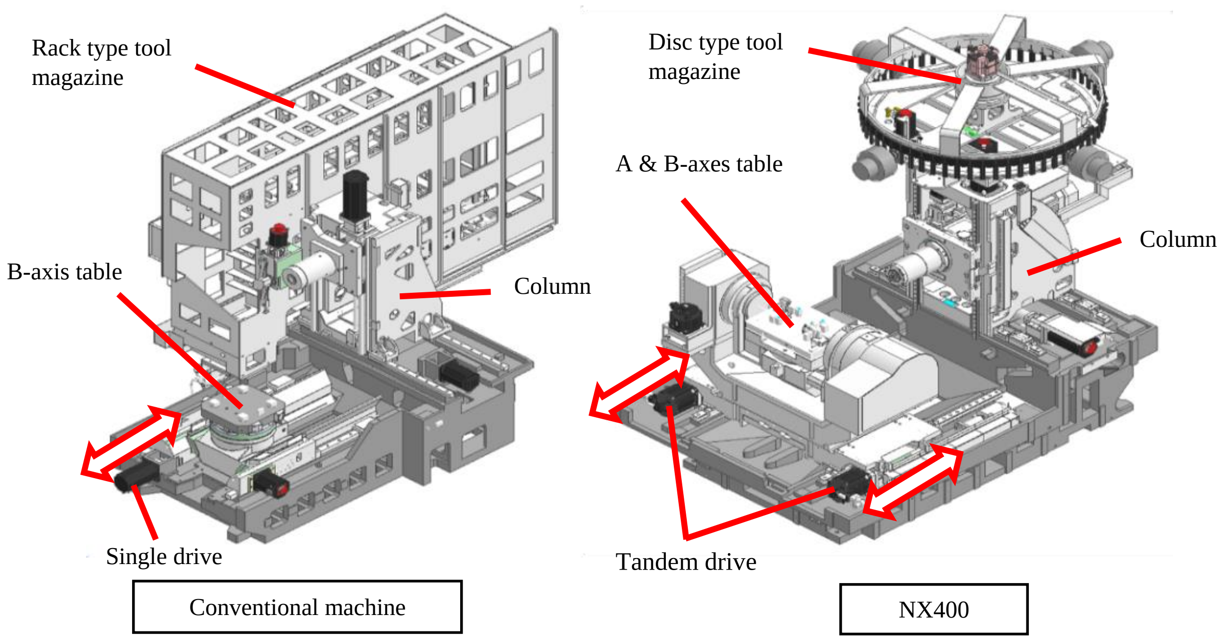


Fig. 7 Structure comparison with conventional machine

Due to achievement of the high rigidity as described above, about 1.5 times of mechanical rigidity of #40 and almost equivalent mechanical rigidity of #50 has been secured compared with that of our conventional machine. (Refer to **Fig. 8**)

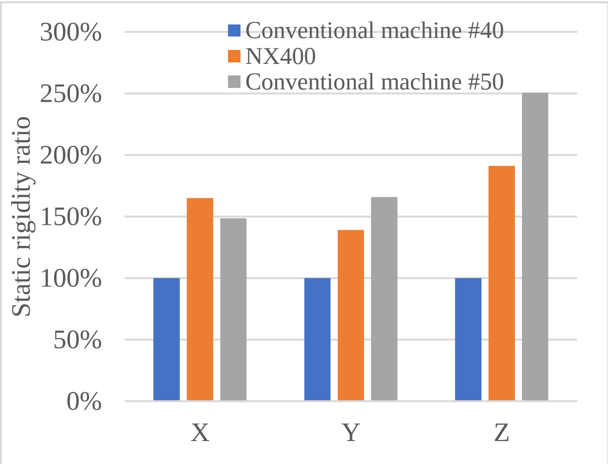


Fig. 8 Mechanical rigidity comparison

4. Energy saving and speed-up

4.1 Energy saving

As electricity to be used for a coolant pump accounts for more than 50% of that of machining center, reduction of electricity to be used by the coolant may have great impact on energy saving. In case of conventional model, power consumption level was high because chips were discharged with a huge quantity of coolant using a large pump. The current model has improved chips discharging efficiency even with a small quantity of coolant by changing a cover of machining area into a flat shape with less unlevel surface condition.

In addition, fine control of coolant discharge has become possible by adding an inverter to the coolant pump and arranging a solenoid valve by each application. (Refer to **Fig. 9** and **10**)

The graph shows quantity of coolant used during elapsed time within one machining cycle indicating quantity of used coolant on the vertical line and time base on the horizontal line. Making it possible to downsize the coolant pump of a conventional machine by making discharge by a necessary amount at required timing, reduction of electricity used by the coolant pump has been achieved by 50% together with the inverter control.

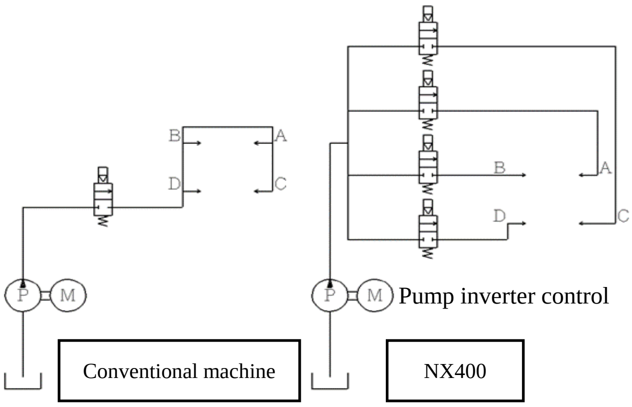


Fig. 9 Outline of coolant circuit diagram

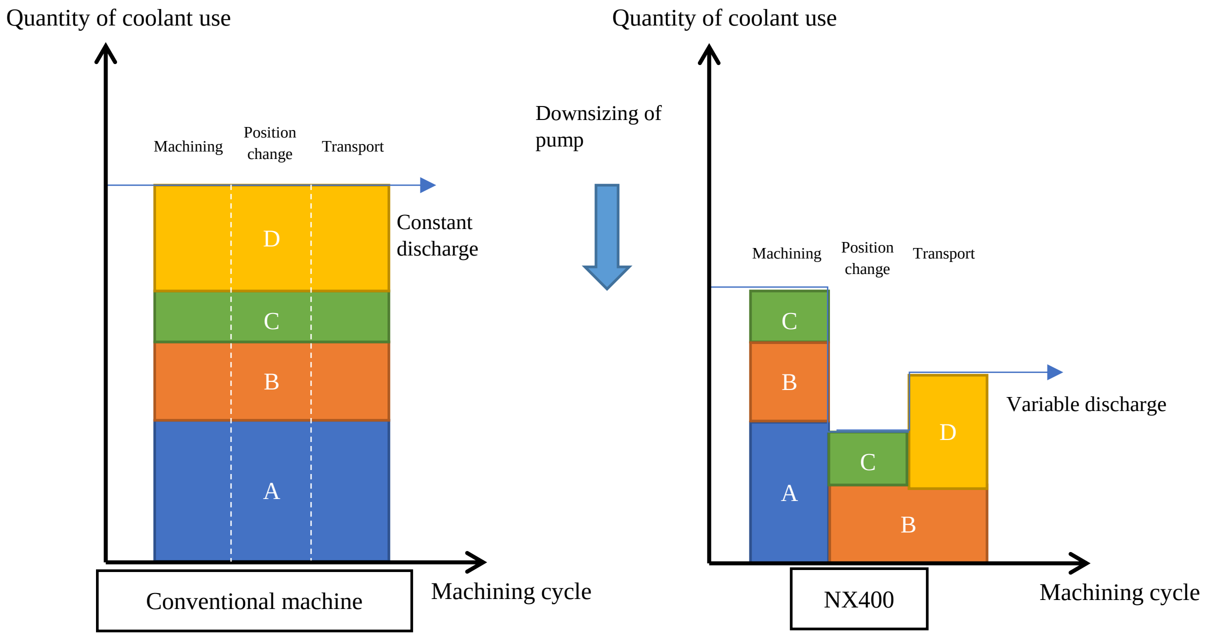


Fig. 10 Overview of discharge control

4.2 Speed-up

An example of machining time breakdown of a machining center is shown in **Fig. 11**. As it shows that non-machining time makes up more than 50% of the whole, it is understandable that it is important to shorten the non-machining time in order to enhance productivity. Efforts on speed-up have been made for rapid traverse and ATC which make up higher percentage among others.

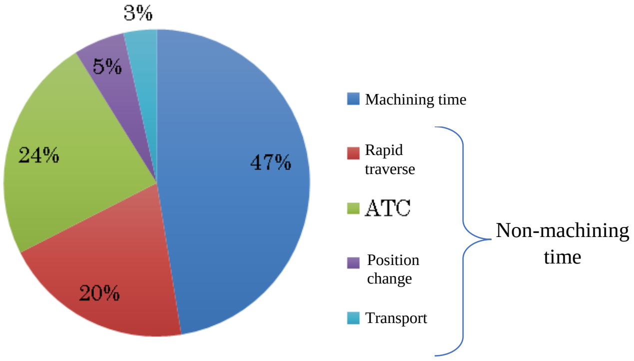


Fig. 11 Breakdown of machining time

4.2.1 Speed-up of rapid traverse

Due to its large travel body, machine of #50 is hard to increase rapid traverse speed of each axis. Even though travel body has become larger and heavier in order to increase rigidity in case of the NX400, rapid traverse speed and acceleration has been increased, compared to #50, from 50 m/min to 60 m/min and by 1.5 times, respectively, and reduction of rapid traverse time by 50% has been achieved as well.

4.2.2 Speed-up of ATC

Overview of ATC device is shown in **Fig. 12**. In this procedure, an S-shaped arm called as ATC arm replaces a tool of the following process with a tool of main spindle.

In order to shorten the replacing time, it is effective to reduce swing radius of the ATC arm. The development model has reduced swing radius by 30% and increased rotation speed by 30% compared with that of conventional machine by reviewing arrangement of ATC device in addition to arrangement of magazine on upper part. Conventionally, it is common to unclamp a tool from the main spindle hydraulically, however, it is also required to shorten unclamping operation time (one second or less) by hydraulic piston. The development model has adopted a mechanism to halve the unclamping operation time compared with hydraulic pressure using NC motor. By the improvement as described above, reduction of ATC time by 50% has been achieved for conventional #50.

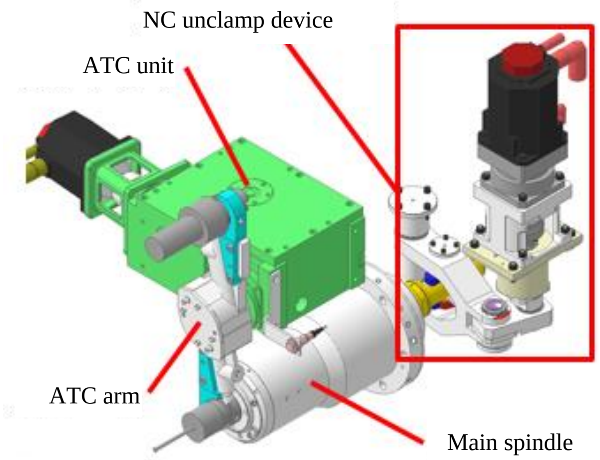


Fig. 12 Overview of ATC device

4.3 Energy saving effect

Energy saving effect is shown in **Fig. 13**. Compared with conventional #50, electric power per time and machining time has been reduced by 40% and 20%, respectively, achieving reduction of totally used electricity by 52%.

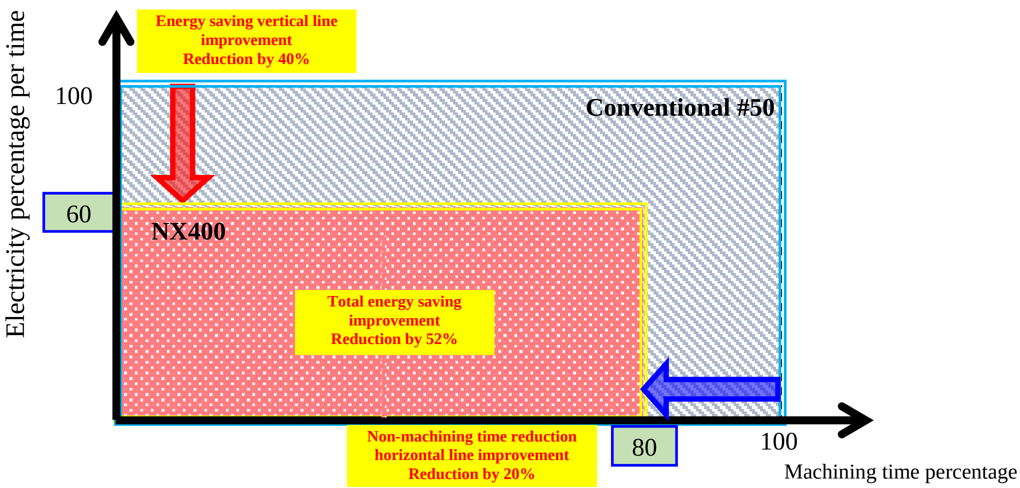


Fig. 13 Energy saving effect

5. Conclusion

Komatsu NTC has worked on machine development conventionally targeting on aluminum alloy processing for automobile. By the current machine development for cast iron machining, the model has become a machine having both high rigidity almost same to that of #50 and top level of productivity among #40 machines. We are convinced that the machine becomes a powerful product for expanding sales in casting parts machining field domestically and overseas as well.

Introduction of the authors

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[A comment from the authors]

While we have introduced a machining center which plays a core role in a smart line this time, we had various new experiences in transport device composing the line and automatization elements which couldn't be introduced in the paper and new problems have also come in sight. We hope to create such products taking advantage of these experiences that contribute to the society such as "productivity improvement" and "energy saving and automatization".