Development of GE4i Cylindrical Grinder

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The medium size cylindrical grinder, which is one of our company's main machine tools, has been fully remodeled to suit the needs of the customer, leading to the development of the G5i series grinder. The G5i series includes the GE4i (large variety/small lot type), the GL4i (medium variety/medium lot type), and GL5i (small variety/large lot type), which are composed of the same common components, such as a bed called the platform. The recently developed GE4i was designed under the concept of "a machine with which anyone can easily make high-grade monozukuri", and answers customer needs for improved dimension accuracy through the reduction of thermal strain, which is the cause of dimensional change. Furthermore, the GE4i is a grinder that not only achieves stable accuracy including improved circularity, surface and roundness, but also has enhanced operability and safety, as well as environmental friendliness.

***Key Words**: cylindrical grinder, reduction of heat distortion, the stable accuracy, operativity, safety*

1. Introduction

Monozukuri in Japan is facing issues such as decreases in working population and skilled technicians, and a relocation of production abroad. In line with these environmental changes, customer needs have changed. Since grinders are conventionally used in the final finishing process, skilled technicians' experience and intuition are heavily depended upon, making grinders a form of production equipment that relies upon skills. Due to environmental changes, however, there is an increasing need for machines that are not dependent on skills. JTEKT offers medium size cylindrical grinders GE4, GL4S, SelectG, GL4E, and GL5III, but developing a new value-added series has become an urgent matter in order to respond to customer needs such as that mentioned above.

The newly developed G5i series includes GE4i (large variety/small lot type), GL4i (medium variety/medium lot type), and GL5i (small variety/large lot type), and consists of a common bed, etc. called a platform. (**Fig. 1**). The aim of using the common platform is to produce the same product repeatedly, leading to improvements in quality and profits due to decreased costs. For customers using conventional medium size cylindrical grinders, spare parts including motors and ball screws are commonized. For further value-added improvements, dimension accuracy has been improved by reducing thermal distortion of the bed, etc. to achieve stable grinding accuracy, a machine factor that does not rely upon skills.

Moreover, straightness, surface, and roundness have been improved in addition to dimension accuracy in order to achieve stable grinding accuracy (**Fig. 2**).

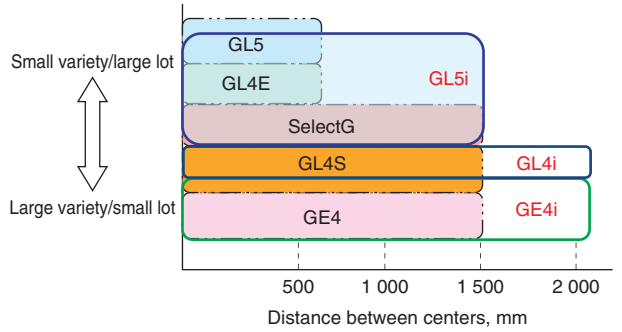
We have fully remodeled the CNC cylindrical grinder GE4 for the first time in 20 years and developed a new CNC cylindrical grinder GE4i that offers improved operability and safety and is environmentally-friendly, to respond to the need for a machine that does not rely upon skills (**Fig. 3**).

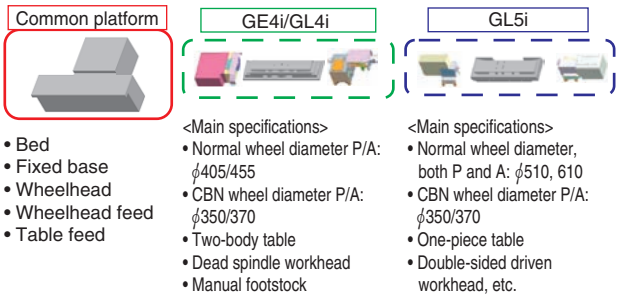
2. Approaches to stable grinding accuracy

① Improvement in dimension accuracy

Thermal distortion that affects dimension accuracy is caused by temperature changes of the room where a machine is installed, heat generated by grinding, and heat generated by machinery and equipment including motors and pumps.

For temperature changes of the room where a machine is located, increasing the bed mass to raise its heat capacity has conventionally been an effective method. For GE4i, however, we verified the CAE analysis and temperature distribution of the actual machine against room temperature changes to contrive the bed shape and rib layout, minimizing thermal distortion. Furthermore, the bed has a symmetrical shape to minimize distortion (**Fig. 4**).





Model \ Distance between centers (mm)		250	320	500	630	1 000	1 500	2 000
GE4i	P			○		○	○	○
	A			○		○	○	○
GL4i	P			○		○	○	○
	A			○		○	○	○
GL5i	P	○	○		○	○	○	
	A	○	○		○	○	○	

○Available model

Fig. 1 G5i series

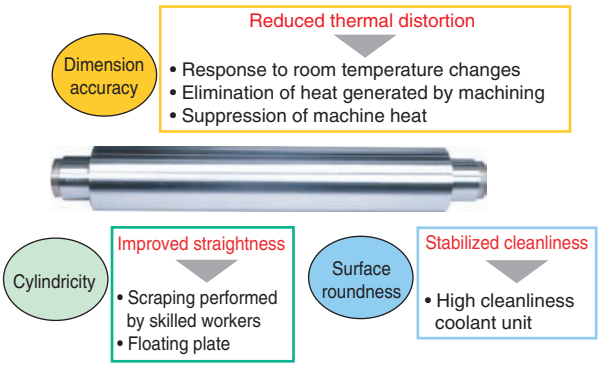


Fig. 2 Stable machine accuracy

Fig. 3 GE4i Cylindrical grinder

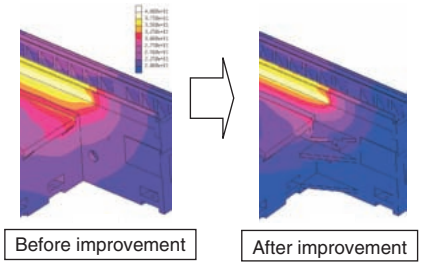


Fig. 4 CAE analysis (bed part)

Regarding heat generated by grinding, the heat is transmitted to the bed, which is a coolant route between the wheelhead and table, causing the relative position of the wheelhead and table to change. We utilized CAE analysis for GE4i to create a coolant route less vulnerable to heat, reducing the change of the relative position of the wheelhead and table. Moreover, we created air space between the isolation cover and bed to reduce thermal effects. Due to the new structure that is less vulnerable to room temperature changes and heat generated by machining, dimensional change during grinding has been reduced by 30% for GE4i, compared with the conventional machine.

We reduced machine heat by improving the heat release property of the wheelhead, a heat-generating factor, achieving a 30% reduction in wheelhead distortion for GE4i, compared with the conventional machine.

To further achieve high grinding accuracy, we have adopted the linear scale, contact-type sensors (mounted on a JTEKT cylindrical grinder for the first time) that control the relative distance of workpiece, and wheelhead, improving the positioning accuracy of the workpiece and wheelhead. The contact-type sensors also help shorten warm-up time.

We made these evaluations by simulating the customer's plant environments and by using the actual machine in our large-sized environmental test room. We performed machining as we altered the temperature in the test room, checked machining results and thermal distortion, and made a series of improvements (**Fig. 5**).

Fig. 5 Large-sized environmental test room

As a result, we have substantially improved the dimensional change at the time of work commencement and work resumption for the newly developed GE4i, compared with conventional machines. For customers requiring higher accuracy, we will offer packages according to required accuracy, providing an "accuracy and price" that meet customer needs (**Fig. 6**).

② Improvement in cylindricity

To improve cylindricity, since the degree of straightness needs to be improved, and wear of the sliding surface needs to be prevented, "scraping" was carefully performed by skilled technicians. We have also increased the rigidity of feed screws, reducing errors in the feed direction. In addition, by attaching a floating plate that absorbs the "runout" of feed screws, the tortuous feed of the table has been decreased, improving the cylindricity of workpieces (**Fig. 7**).

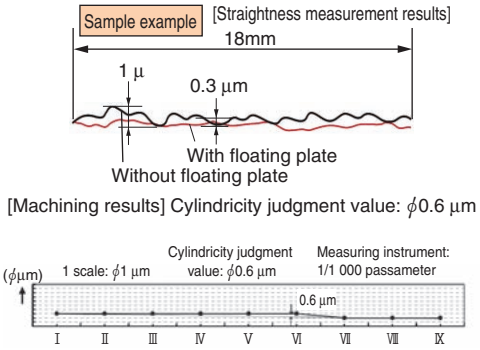


Fig. 7 Effect of floating plate

③ Surface quality/Roundness

To improve surface quality of workpieces for GE4i, we have developed a high cleanliness coolant feed system utilizing a cyclone method as an alternative to paper filters (**Fig. 8**). Without filters, residual foreign material in coolant is 5 ppm. This system has achieved high cleanliness, allowing only 5 mg of foreign material per 1 L, and not only reduced scratches and poor roundness, but also suppressed the spread of bacteria, and greatly extended the coolant replacement cycle. Furthermore, the cyclone method is a zero emission technology and thus environmentally friendly (**Fig. 9**).

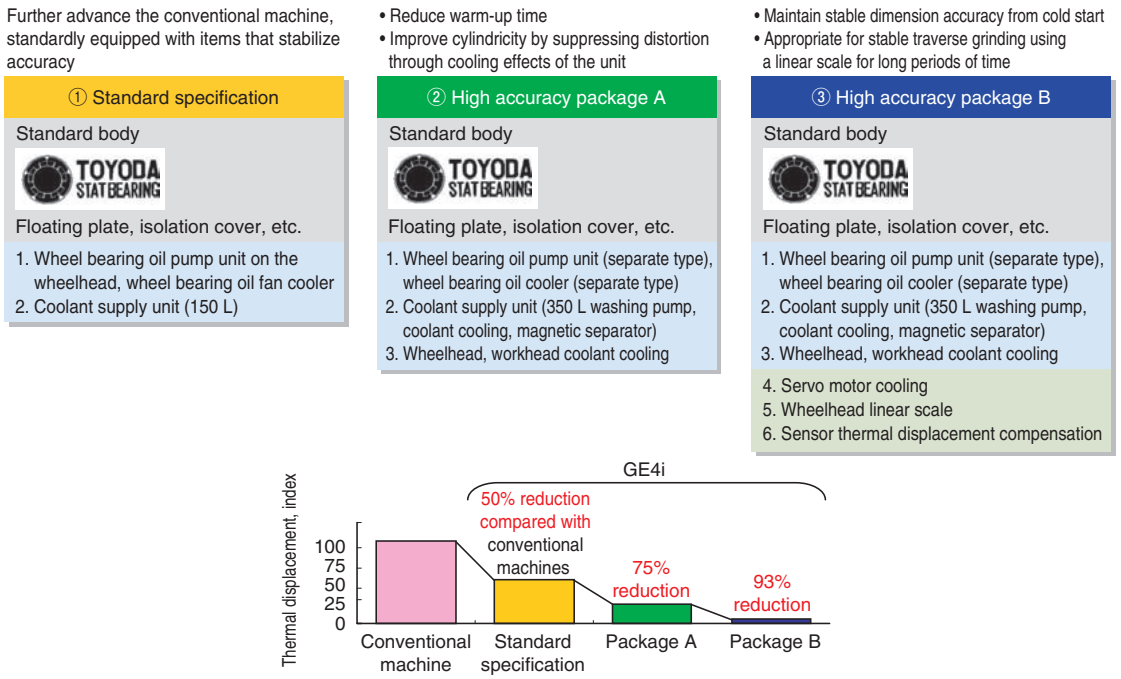


Fig. 6 The dimensional change at the time of work commencement and work resumption (Comparison of package specification)

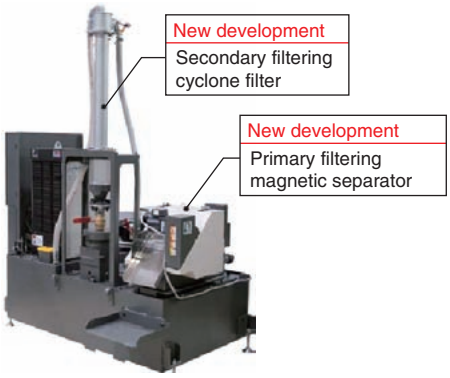


Fig. 8 High cleanliness coolant feed system

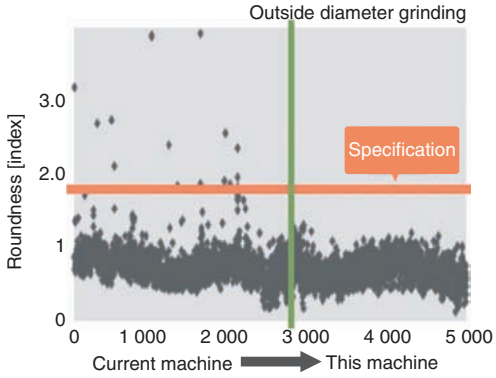


Fig. 9 Reduction of poor roundness

3. Approaches to improving operability

JTEKT began developing control units in the 1970s and has made improvements so that the units can provide full performance, along with the usability of machines. GE4i is equipped with a newly developed TOYOPUC®-GC70, providing 5 times faster calculation speed compared with conventional machines, with a substantial reduction in size.

As an approach to improving operability, a teaching-based machining programming method is used. Unlike the conventional data entry method, which is susceptible to human error (incorrect input), this method allows teaching while visually checking the machine, an entry method in which input errors are unlikely to occur. Although the conventional machine takes a long time for data entry and confirmation (debugging), GE4i requires approximately a quarter of the time compared with the conventional machine, achieving a substantial reduction. In addition, operation functions including the automatic workpiece rigidity detection function and automatic grinding condition setting function are available to determine grinding conditions, while the conventional machine depended on skilled technicians to select rigidity from large, medium, or small based on their experience. The functions to automatically detect rigidity and determine grinding conditions have been added for GE4i so that even beginners can select rigidity by entering workpiece length and diameter.

A function to prevent erroneous operations in manual operation has also been added. For example, when multiple machines such as lathes are used simultaneously, erroneous operations are likely to occur because each machine has different usage methods (feed direction, etc.). As a preventive measure, a function to display the feed direction on the CNC screen in teaching operation has been added, whereby an arrow is displayed in color according to the travel direction while the NC axis is moving, preventing erroneous operations.

Furthermore, icons have been added to the operation buttons on the CNC screen, which was conventionally letters only, so that the machine can be used internationally by beginners with ease. A language change function has also been added to enable the CNC screen to be displayed in multiple languages with the touch of a button.

Regarding the manual handle (manual pulse generator), we responded to the customer need of "operating a CNC automatic machine with a handle at the front of the machine, just like a hydraulic machine" and have developed a handle that imitates the sensation in one's hands when operating a hydraulic machine (**Fig. 10**).

The swiveling angle display of the table used for taper grinding has been changed from the conventional analog taper angle adjustment using a dial gauge, to the digital angle display using a sensor. The entire range of the swiveling angle of the table cannot be measured by the conventional dial gauge-based adjustment method, but this is achievable with the sensor-based method of GE4i, rendering the conventional position adjustment using a dial gauge unnecessary, resulting in shorter operation time.

Fig. 10 Manual handle at front of machine

Table 1 Main specifications

Item		Unit	Spec	GE4Pi-50 GE4Ai-50	GE4Pi-100 GE4Ai-100	GE4Pi-150 GE4Ai-150	GE4Pi-200 GE4Ai-200
Distance between centers		mm	Common	500	1 000	1 500	2 000
Runout on table		mm	Standard	ϕ320			
			Option	ϕ400			
Grinding diameter		mm	Common	ϕ0 to ϕ300			
Load mass between centers		kg	Common	150			
Wheel	Wheel O.D. × I.D.	mm	Standard	Type P: ϕ405×ϕ127			ϕ405×75×ϕ127
				Type A: ϕ455×ϕ127			
			Option	Type P only: ϕ510 × ϕ203.2			
	Maximum width	mm	Standard	75			
			Option	100 (ϕ405, ϕ455) /50 (ϕ510)			
	Surface speed	m/s	Standard	30			
			Option	45			

4. Approaches to safety and the environment

For safety, we have added a function to separate the wheel from the workpiece in case of power failure (**Fig. 11**).

Moreover, we have installed a machine cover over a general purpose grinder to prevent mist from scattering, paying consideration to the environment as well as safety (**Fig. 12**). This machine cover has a center distance of 500mm and a wide opening of 1 480mm, making setup change easier. A cover height of 1 490mm allows a view of the entire machine, making this machine safe, and with a concern for lighting, a skylight has been added for more visibility (**Fig. 13**).

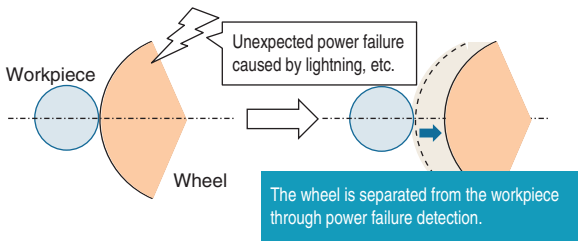


Fig. 11 Safety measures when power failure occurs

Fig. 12 The cover specification

Fig. 13 Skylight

5. Specifications

The main specifications of GE4i are shown in **Table 1**.

6. Conclusion

As seen above, GE4i is “a machine with which anyone can easily achieve high-grade *monozukuri*”, providing stable grinding accuracy and improved operability, and paying consideration to safety and the environment. Operators, however, are still not free from adjustments. We will further strengthen our efforts and aim to develop a machine that does not require operators to perform adjustments.

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