Dimensional Defect Prevention System

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An Auto-sizer is a contact-type diameter measurement device used in the in-process direct sizing grinding cycle, a special feature of the cylindrical grinding process. Because this is a contact-type measuring device, when foreign materials such as abrasive grains or machining chips in the coolant are trapped between the contact measuring terminal and the workpiece, they cause diameter dimensional defects. This newly developed system can detect foreign material interference by monitoring the dimensional data by CNC during the grinding process in real time by means of the Auto-sizer, and then remove the foreign material via forward/backward movement of the Auto-sizer head to prevent diameter dimension defects.

***Key Words**: cylindrical grinder, in-process direct sizing grinding cycle, foreign material interference detection, diameter dimension defective*

1. Introduction

The in-process direct sizing grinding cycle is a processing cycle characteristic of grinders wherein the dimension of the workpiece is monitored during the grinding operation with an Auto-sizer while the feed rate and the spindle speed are so controlled that the workpiece is finished to the prescribed dimensional accuracy. The Auto-sizer is a contact type measuring device which, if used in-process, is exposed to environment of coolant which includes such foreign materials as chips and abrasive grains. When such a foreign material in the coolant is trapped between the workpiece and the contact, dimensional defects may occur. To counter this problem, a foreign material interference detection function integrated in the Auto-sizer control unit has been traditionally used, which comprises of a system that removes the foreign material as instructed by the Auto-sizer control unit. In recent years, however, mainstream grinders have been CNC type machines in which the Auto-sizer control unit is integrated into the CNC system. Therefore, JTEKT has developed a dimensional defect prevention system integrated into the Auto-sizer signal processing system of the JTEKT CNC GC50 with improved accuracy for foreign material interference detection and enhanced operability.

2. Development Objective

The GC50, which incorporates a high-speed/high performance CPU as well as increased memory capacity, has sufficient processing capability available for other functions besides the basic functions of positioning and speed control. As such, this extra capability has been allocated for enrichment of applications such as the visualization function (for diagnosis) that allows for storage of the servomotor operation and cycle times for each cycle, which is a feature that sets this product apart from the competition.

Integration of the Auto-sizer control unit function into the CNC is just one of such applications, and its addition of the dimensional defect prevention system by means of this foreign material interference detection function further strengthens the distinguishing factors of this product among competing CNC or CNC equipped grinders.

[Target Effects]

While the frequency of foreign material interference in actual direct sizing varies widely depending on the operating environment, it occurs as frequently as 5 to 50%. In most cases, however, the interference or trapping of foreign material is as transient as 0.1 seconds or less, hence in majority of these cases the workpiece is finished to prescribed dimensions. It is in the following cases that the workpiece ends up in defective dimensions.

① In case the foreign material remains trapped until the process is finished.
② In case that grinding stock removal is not enough when the foreign material is dislodged.
③ In case the dimensions are already too small when the foreign material is dislodged.
④ In a multi-wheel grinding, the taper signal TA1 or TA2 is activated due to instantaneous trapping of foreign material during a taper compensation process.

Practically, dimensionally defective workpieces produced in this way are estimated to be 0.2 ~ 0.8% of

all the workpieces processed. Although it is ideal that dimensional defects due to foreign material interference be completely prevented, we set the target for this system at 90% reduction of dimensional defects due to foreign material interference falling in the above four patterns, in view of conceivable difficulty in control because of external disturbances such as runout in the workpieces.

3. Direct Sizing Grinding Cycle

The dimensional defect prevention system is a system that works effectively in a grinder incorporating direct sizing grinding cycle. The system structure and the direct sizing grinding cycle are illustrated in **Figs. 1** and **2**, respectively.

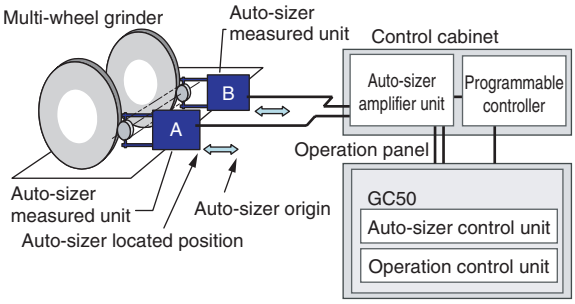


Fig. 1 System structure

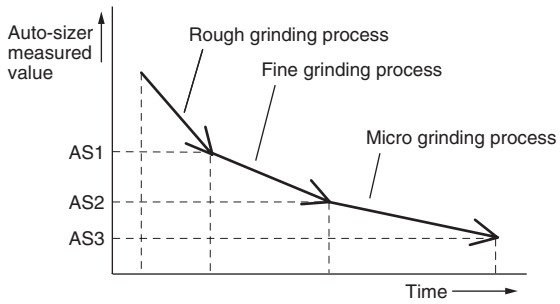


Fig. 2 Direct sizing grinding cycle

3. 1 System Structure

The direct sizing grinding cycle is controlled collaboratively by the Auto-sizer, the programmable controller and the GC50. The Auto-sizer is composed of the Auto-sizer measured unit and the Auto-sizer amplifier unit. The Auto-sizer measured unit is equipped with two contacts, the upper and the lower, which come in touch with the OD of the workpiece to measure the outside diameter of the workpiece. The Auto-sizer measured unit is so designed that it can travel between the "Auto-sizer origin" and the "Auto-sizer located position" by using a hydraulic cylinder, which is controlled by the programmable controller. The measurement results are then sent in analog signals to the Auto-sizer amplifier unit, then after being amplified to a prescribed level, to the GC50, which controls the grinding conditions based on the Auto-sizer measured values.

The system shown in **Fig. 1** is that of a multi-wheel grinder, as an example, having two Auto-sizer measured units, A and B, though there are some systems that contain only one Auto-sizer measured unit.

3. 2 Direct Sizing Grinding Cycle

The direct sizing grinding cycle is a method of grinding wherein the grinding conditions, such as grinding speed, are changed at a few points at which the measured dimensions have reached preset values (AS1 – AS3 in **Fig. 2**). These different grinding processes are called the rough grinding process, the fine grinding process and the micro grinding process. As the process comes closer to the finished dimension, the grinding conditions are changed, such as slower grinding speed, so as to secure grinding accuracy.

In the grinding cycle shown in **Fig. 2**, the rough grinding continues until the Auto-sizer measured value reaches the preset value AS1, and thereafter the grinding conditions are changed to those of the fine grinding process. Likewise, when the preset value AS2 and AS3 have been reached, the grinding conditions are changed accordingly.

4. Dimensional Defects due to Foreign Material Interference in Direct Sizing Grinding Cycle

Taking a multi-wheel grinder for example, actual cases of dimensional defects are described below. The multi-wheel grinder is illustrated in **Fig. 3**.

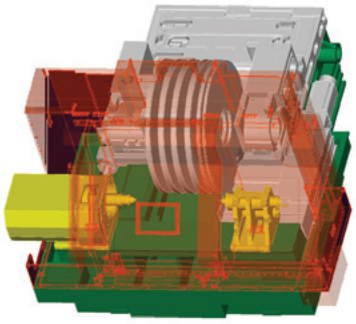


Fig. 3 Multi-wheel grinding machine

On the multi-wheel grinder, the grinding process starts with the wheel spindle tilted at a preset angle against the workpiece center line as illustrated in **Fig. 4**, followed by various grinding processes including a taper compensation grinding process until the workpiece OD on the right and left sides become identical. During this cycle, the Auto-sizer control unit in GC50 calculates the taper value from the workpiece diameters at the Auto-sizer measured units A and B (the taper value equals the difference between the diameters measured at the Auto-

sizer measured units A and B). The Auto-sizer measured unit also keeps comparing the measured taper value with preset trigger values, TA1 and TA2. When the measured taper value reaches either of these preset values, the taper signal coded as the same TA1 or TA2 is turned ON.

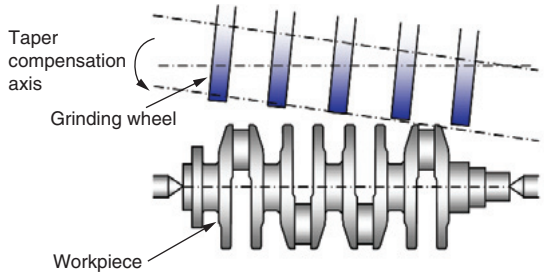


Fig. 4 Grinding condition of multi-wheel grinding machine

Next, the process cycle of the multi-wheel grinder in normal operation is described below. **Figure 5** shows the normal operation cycle diagram of a multi-wheel grinder. After starting wheelhead rapid feed advance, the 1st rough grinding, and subsequently the 2nd rough grinding, are conducted. From the 2nd rough grinding, the Auto-sizer measured units on both sides are advanced to the Auto-sizer located positions and the direct sizing grinding cycle is started.

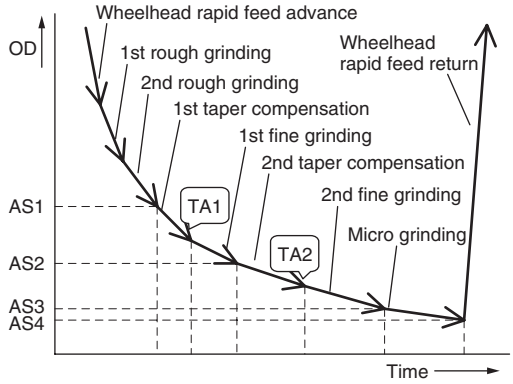


Fig. 5 Grinding cycle of multi-wheel grinding machine

The triggering conditions for each of the subsequent grinding processes are listed below:

(1) Transition from the 2nd rough grinding to the 1st taper compensation grinding is triggered by the Auto-sizer signal AS1 of either the right side Auto-sizer measured unit B or the left side Auto-sizer measured unit A switching to the ON state.

(2) Transition from the 1st taper compensation process to the 1st fine grinding process is triggered by the taper signal TA1 switching to the ON state.

(3) Transition from the 1st fine grinding process to the 2nd taper compensation process is triggered by the Auto-sizer signal AS2 of either the right side Auto-sizer measured unit B or the left side Auto-sizer measured unit A switching to the ON state.

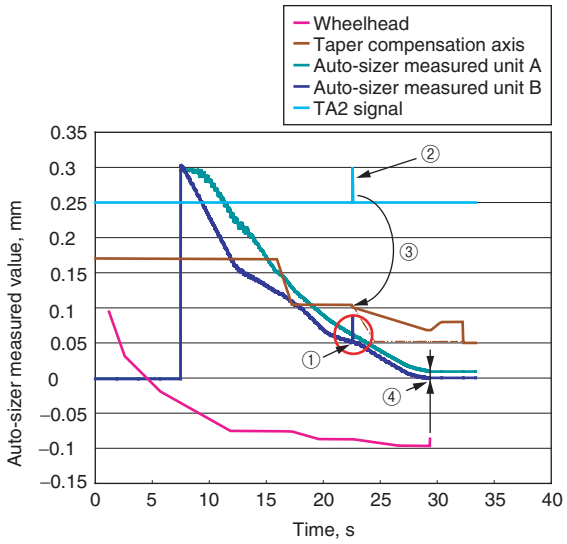
(4) Transition from the 2nd taper compensation process to the 2nd fine grinding process is triggered by the taper signal TA2 switching to the ON state.

(5) Transition from the 2nd fine grinding process to the micro grinding process is triggered by the Auto-sizer signal AS3 of either the right side Auto-sizer measured unit B or the left side Auto-sizer measured unit A switching to the ON state.

(6) Completion of micro grinding process is triggered by the Auto-sizer signal AS4 of either the right side Auto-sizer measured unit B or the left side Auto-sizer measured unit A switching to the ON state.

When the micro grinding process is completed, the wheelhead moves fast backward, and the process is finished.

If a foreign material is trapped instantaneously between the workpiece and the contact of the Auto-sizer measured unit B during the 2nd taper compensation process, the measured dimension on the Auto-sizer measured unit B becomes transiently larger than that on the Auto-sizer measured unit A, as shown in **Fig. 6** ①, and the taper value temporarily changes to negative. Then, the Auto-sizer control unit judges that the preset TA2 value has been reached, and immediately turns ON the taper signal TA2 as shown in ②. Detecting this TA2 ON signal, as shown in ③, the operation control unit stops the 2nd taper compensation process and turn on the 2nd fine grinding process with discrepancy between the measured values on the Auto-sizer control units A and B. In this way, the workpiece has diameter difference as shown in ④ when it is finished, causing it to be rejected as a dimensional defect.



① Foreign material interference
② Taper signal TA2 turned ON by foreign material interference
③ 2nd taper compensation is suspended by an erroneous signal due to foreign material interference
④ Process is finished in a state of right/left diameter difference generated by incomplete 2nd taper compensation

Fig. 6 Auto-sizer signal condition when a foreign material is trapped

5. Dimensional Defect Prevention System

The process flow of the dimensional defect prevention system is described below. In the direct sizing grinding cycle of a multi-wheel grinder, the grinding is conducted by advancing the wheelhead while keeping the direct sizing of the workpiece by the Auto-sizer measured units A and B advanced to the "Auto-sizer located positions." When, after starting the direct sizing grinding cycle, the dimensional defect prevention system is activated by instruction from the operation control unit, the Auto-sizer control unit starts to monitor for discontinuous change in dimensions due to foreign materials (checking the process against foreign material interference) in addition to the sizing dimension calculation process and the Auto-sizer signaling process.

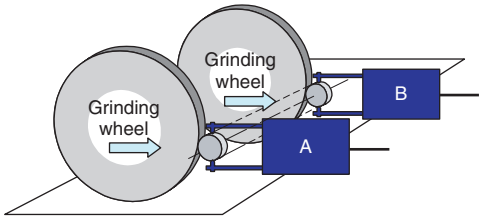


Fig. 7 Normal direct sizing grinding condition

When foreign material interference happens as shown in **Fig. 8**, the Auto-sizer control unit, which detects a discontinuous dimensional change, stops the direct sizing processing while keeping the on-going Auto-sizer signal alive. Taper signal is also kept alive during taper compensation. Thus the phenomenon as described in the previous **Section 4** can be prevented. In the case of instantaneous trapping of foreign material shown in **Fig. 8**, the sized increase in dimension is immediately followed by its reduction to an extent much smaller than that by grinding. The Auto-sizer control unit judges this change as dislodging of the foreign material, and resumes the Auto-sizer signaling process as well as the monitoring for foreign material interference. Thus the normal grinding operation as shown in **Fig. 7** is resumed to complete the remaining process cycle.

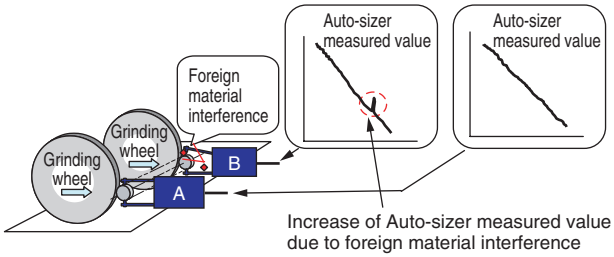


Fig. 8 Auto-sizer measurement value when a foreign material instantaneously is trapped

If the foreign material stays trapped for a preset period of time, t, or longer, as shown in **Fig. 9**, the foreign material removal cycle as shown in **Fig. 10** is activated.

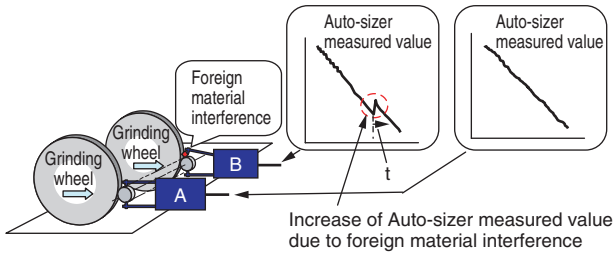


Fig. 9 Auto-sizer measurement value when a foreign material is trapped for a long time

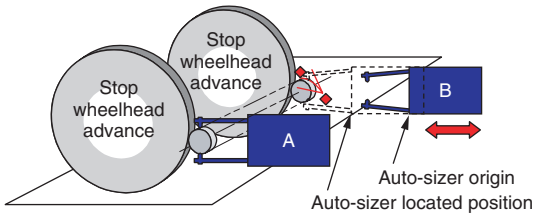


Fig. 10 Removal cycle of a foreign material

The foreign material removal cycle starts by ceasing the grinding by stopping the forward movement of the wheelhead. Subsequently, the Auto-sizer measured unit is moved from the "Auto-sizer located position" to "Auto-sizer origin" followed by the "Auto-sizer located position." As this movement temporarily separates the contact from the workpiece, the trapped foreign material can be removed. After the Auto-sizer measured unit starts measuring at the "Auto-sizer located position," the wheelhead feeding is reinstated. Thus, after completing the foreign material removal cycle, the remaining process cycle is complete.

6. Improvement Effects of the Dimensional Defect Prevention System

The dimensional defect prevention system was installed on a multi-wheel grinder, and a study was conducted to verify the frequency of dimensional defects due to foreign material interference before and after the installation of the system. Test conditions are summarized in **Table 1**. The number of samples and the total numbers of foreign material interference incidence as well as the total number of dimensional defects experienced during the ten-day test period are shown in **Table 2**. **Figure 11** shows the overall defect ratio based on the number of samples and the total number of defects. **Figure 12** shows the ratio of dimensional defects against the incidence of foreign material interference from the total number of foreign material interference and dimensional defects. From **Figs. 11** and **12**, it is evident that the addition

of the dimensional defect prevention system reduced dimensional defects due to foreign material interference to approximately 1/10. Particularly, the taper defects due to transient trapping of foreign material during the taper compensation process were reduced from ten cases to zero, resulting in 100% prevention.

Table 1 Test conditions

Item	Description
Test machine	GM63Ⅱ
Test period	2007/03/27～2007/04/05
Auto-sizer contact	R0.5 diamond Contact pressure 100～150 g

Table 2 Number of foreign material interference and dimensional defective occurrences to the total number of samples

	Prevention system ineffective	Prevention system effective
No. of sample	1 750	1 250
Total number of foreign material interference incidences	96	103
Instantaneous foreign material interference out of taper compensation	69	74
Lasting foreign material interference out of taper compensation	4	10
Instantaneous foreign material interference in taper compensation	21	16
Lasting foreign material interference in taper compensation	2	3
Total number of defects (right-left diameter difference of 5 μm or over)	12	1
Defects due to lasting foreign material interference out of taper compensation	2	0
Defects due to instantaneous foreign material interference in taper compensation	10	0
Defects due to lasting foreign material interference in taper compensation	0	1

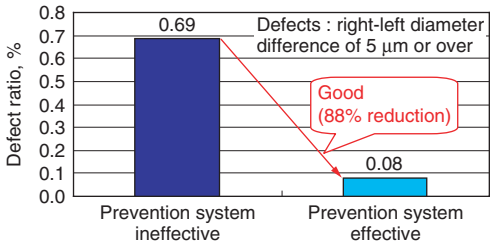


Fig. 11 Ratio of defects to the total number of samples (lateral difference of 5 μm or greater)

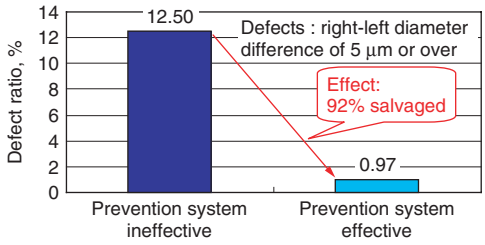


Fig. 12 Ratio of defects to the total number of foreign material interference samples

7. Conclusion

While foreign material interference has conventionally been counted as one of the causes of dimensional defects in grinding process, the visualization functionality of the GC50 has achieved remarkable improvements thanks to its success in visualizing the state of the foreign material interference and enhancement of the accuracy detection method. Down the road, we would like to further promote the evolution of the GC50 to achieve the goal of "only one" grinder through beefing up of the visualization functions in such areas as machine's processing conditions and deterioration.



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