Rapid on-machine measurement of surface finish in repeated cylindrical grinding cycles

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Abstract

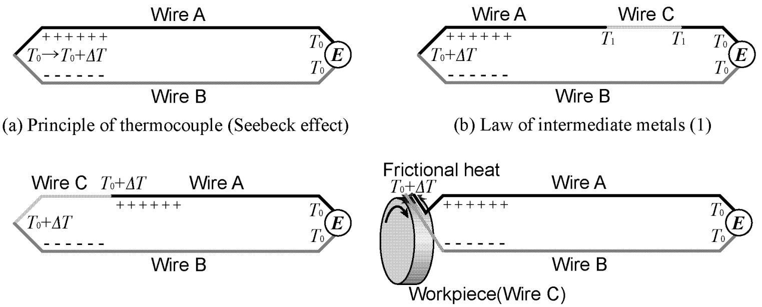
The surface finish is one of important evaluation items of grinding results as well as the form and size accuracy or the surface quality in grinding. The surface finish of the ground surface has never been measured after each grinding cycle because the measurement of the surface finish needs relatively a long duration by existing surface roughness testers and applications of surface roughness tester in each grinding cycle would affect mass-production processes. We propose a rapid on-machine measurement technique of the surface finish, which can check the surface finish of cylindrical workpieces rotating on cylindrical grinding machines in a split second just after each grinding cycle, and the usefulness without hampering mass-production grinding processes is shown in this study.

1. Introduction

In the actual manufacturing processes with grinding, the surface finish is measured by surface roughness testers in a post-processing step. Therefore, the surface quality of all parts in a manufacturing lot is actually judged based on the measured results of only few parts by the acceptance sampling. If the surface finish is measured immediately after each grinding process on machine tools, the surface finish of all manufactured parts can be checked. It's very useful from the viewpoint of not only the quality control of ground parts but also the control of grinding processes. We propose the novel rapid on-machine measurement of surface finish in cylindrical grinding and investigate its availability in repeated cylindrical grinding cycles.

2. Principle and measuring equipment

The measurement of surface finish utilizes the thermoelectric effect as the fundamental principle of thermocouples. Figure 1 shows the principle of surface finish measurement. The basic thermocouple circuit based on the thermoelectric (Seebeck) effect is shown in (a). When the temperature at either junction changes in a close circuit composed of a certain metal wire A and wire B of other materials, it will generate a voltage. When the wire C, which a different material from wires A and B, is set in the circuit with equal temperatures at both wire ends as shown in (b), the circuit generates the voltage as large as that without wire C [1]. When the wire C places between wire A and wire B as shown in (c), it doesn't affect the generated voltage, either. When a ground workpiece is replaced with wire C as shown in (d), the generated voltage means the temperature change at the points on finished surface contacting with both wires [2]. Furthermore when the workpiece rotates under a constant temperature in the contact with both wires on a machine tool, the EMF due to the frictional heat depending on the surface finish at the contact points is added in the voltage.



(a) Principle of thermocouple (Seebeck effect)

(b) Law of intermediate metals (1)

(c) Law of intermediate metals (2)

(d)Principle of novel surface finish measurement

Figure 1: Principle of surface finish measurement

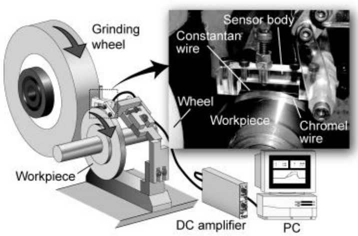


Figure 2: Rapid on-machine measurement system

Table1: Main measuring conditions

Workpiece	S45C (ϕ100 x 20mm)
Sensor wires	Chromel, Constantan (ϕ0.65mm)
Peripheral speed of workpiece	0.39m/s
Sensor load	0.65N
Lubrication	Soluble type coolant

Figure 2 shows the developed rapid on-machine measurement system. Chromel and constantan wires, having no junction with each other, are fixed on the sensor body made of acrylic resin with a certain tension, and each wire makes contact with just finished workpiece surfaces using available coolant to keep them in contact, rotating at the same speed in grinding process with a constant load. The sensor output, the electromotive force (EMF) generated in the thermocouple circuit, is transmitted to PC after amplification. Table 1 shows main conditions in surface finish measurement.

3. Results and discussions

Figure 3 shows the variations of output in measurement of different ground surface finishes. The sensor outputs increase rapidly at the moment of workpiece rotation to become almost constant with little noise within one second of workpiece rotation. The sensor outputs in measurement of ground surface with 0.8μm R_a is larger than that with 0.3μm R_a, and they vary with surface finish. Considering the variation of sensor output, the temperature at the contact point between ground surface and sensor wires increase to about several degrees in measuring of the surface finish. The sensitivity in relation to the surface finish increases with the workpiece speed [3].

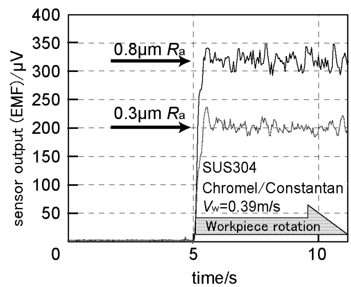


Figure 3: Variations of output in measurement

Figure 4 shows a comparison of time required for measurement of surface finish by the rapid on-machine measuring system with that by a general surface roughness tester soon after grinding operations. In the case of surface roughness tester, acquisition of surface finish data need much time after grinding operations. In addition, obtaining data of the surface finish needs more time for measurement at several points generally. On the other hand, in the case of the rapid on-

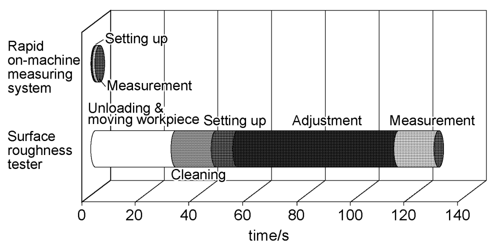


Figure 4: Comparison of time required for measurement of surface finish

machine measuring system, measuring operations are only setting a sensor on ground surfaces and measurement on grinders soon after grinding operations. Therefore the on-machine measurement saves significant evaluation time of the surface finish.

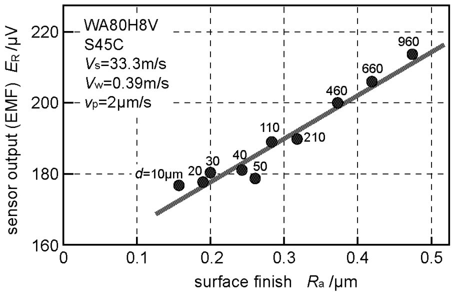


Figure 5: Relationships between surface finish and sensor output

Figure 5 shows relationships between the surface finish measured by a surface roughness tester and the sensor output of rapid on-machine measurement in repeated cylindrical grinding cycles. The total wheel depth of cut *d* is displayed besides each plot. The surface finish is about 0.15μm R_a after dressing and increases with increasing total wheel depth of cut. Such variations of the surface finish suggest the deterioration of acting wheel surface with an increase of the number of grinding cycles. The sensor output increases approximately linearly according to a variation of surface finish with the total wheel depth of cut. The rapid on-machine measurement can monitor the surface finish and might be applied to judge the optimum dressing timing in repeated grinding cycles of mass production.

4. Conclusion

The proposed on-machine measurement of surface finish can detect the variation of the surface finish in a split second just after each grinding cycle. It's very useful to the quality control of ground parts but also process control for optimum dressing timing in mass production. This study has been funded by A-STEP in JST.

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