Sizing Method Based on Grinding Ratio in Heavy Grinding

Masumi IZUMI, Akio OCHI
Hiroshima Institute of Technology, Hiroshima, Japan

1. Introduction
In this study, sizing method due to the grinding ratio in heavy grinding is discussed. When using a conventional grinding wheel to grind hardened steels, residual stock removal due to the grinding wheel wear occurs. Therefore it is difficult to finish workpieces within a given tolerance in short time. One of the best solutions to achieve an efficient grinding process is to use super-abrasive grinding wheels. However, there is a pecuniary matter to use a costly grinding wheel in rough grinding. Accordingly, sizing method to grind a workpiece more efficient has been requested.

Grinding ratio is widely known as the volume ratio of a material removed to a wheel wear. Therefore grinding wheel wear is generated by the product of grinding ratio and volume of material removed. Assuming that the grinding ratio is a constant, it can easily calculate the radial wheel wear caused by removing the grinding allowance of workpiece. To cut a grinding wheel in a workpiece according to the estimated value of the grinding wheel wear, it can finish the workpiece efficiently and in a short time. This paper deals with a new sizing method based on the grinding ratio.

2. Nomenclature
Symbols are used in this study as follows.

\( W \): Grinding wheel wear (\( \mu m \))
\( b \): Wheel width (mm)
\( B \): Width of workpiece (mm)
\( L \): Length of workpiece (mm)
\( A_G \): Area of grinding wheel surface (mm\(^2\))
\( A_W \): Area of workpiece surface (mm\(^2\))
\( G \): Grinding ratio
\( H \): Desired grinding allowance (mm)
\( \gamma \): Common ratio to produce grinding wheel wear
\( Z \): Total setting depth of cut to remove a desired grinding allowance (mm)

3. Sizing method
Figure 1 shows a grinding wheel, a workpiece and symbols. Grinding ratio is given as equation 1 from the figure.

\[
G = \frac{BL(H-W)}{\pi DbW} \tag{1}
\]

Grinding wheel wear \( W \) is derived from Equation:

\[
W = \frac{BL}{\pi DbG + BL} H \tag{2}
\]
Where, common ratio \( \gamma \) is defined as equation (3) and assuming that the common ratio is a constant.

\[
\gamma = \frac{BL}{\pi DBG + BL} \quad (3-1)
\]

\[
= \frac{A_w}{A_G + A_w} \quad (3-2)
\]

Grinding wheel wear \( W \) to be produced to remove a desired height \( H \) is shown equation:

\[
W = \gamma H \quad (4)
\]

Where, Grinding wheel wear at the first grinding is indicated \( W_1 \) as equation (5).

\[
W_1 = \gamma H \quad (5)
\]

At the second grinding operation, \( W_1 \) will be the next residual stock removal instead of the \( H \). \( W_2 \) is generated to remove \( W_1 \). \( W_2 \) is presented by the product of common ratio \( \gamma \) and wheel wear \( W_1 \) as shown equation (6).

\[
W_2 = \gamma^2 H \quad (6)
\]

According to these grinding processes, grinding wheel wear \( W_n \) at the \( n \) th process is shown as equation (7), and then it is able to estimate wheel wear.

\[
W_n = \gamma^n H \quad (7)
\]

To finish a workpiece within a given tolerance, a residual stock removal due to the grinding wheel wear generated in every grinding processes should be removed. Therefore total setting depth of cut to finish a workpiece the tolerance \( Z \) is given as a sum of the grinding allowance \( H \) and grinding wheel wear \( W_i \) at the every process.

\[
Z = H + \gamma H + \gamma^2 H + \gamma^3 H + \ldots + \gamma^{n-1} H \quad (8)
\]

In the equation (8), numerical expressions after the second member show the sum of geometric series expression. And this equation is solved to the equation (9).
\[ Z = H + \gamma \frac{H}{1-\gamma} \] (9-1)
\[ = H + \frac{HW_1}{H-W_1} \] (9-2)
\[ = \frac{H^2}{H-W_1} \] (9-3)

And these derived equations are summarized as the table 1. This table shows grinding wheel wear to be generated to grind a desired grinding allowance according to the grinding processes. In the first grinding, setting depth of cut equivalent to a derided removal height is given. Grinding wheel wear \( W_1 \) is expressed by a product of common ratio \( \gamma \) and a derided removal height \( H \). In the second grinding, residual stock removal at the first grinding will be a setting depth of cut. And grinding wheel wear \( W_2 \) is presented by a product of \( W_1 \) and \( \gamma \). The sum of geometric series expressing the grinding wheel wears and the setting depth of cut are shown in the table 1.

The sums of these geometric series at the infinity in the table are calculated with setting depth of cut \( H \) and grinding wheel wear \( W_1 \) at the first grinding. If the grinding ratio \( G \) is a constant, these sums will not be exerted by the kind of a grinding wheel and a workpiece. The sum of the setting depth of cut at the each grinding process is the traveling value of the wheel spindle stock to be needed to remove a desired allowance.

Figure 1 shows the preset method. At the first process grinding wheel wear \( W_1 \) will be generated to cut the grinding allowance with the setting depth of cut. \( W_1 \) will be a residual stock removal at the next operation. Setting depth of cut to grind the residual stock removal at the one compensation is obtained by the grinding wheel wear \( W_1 \) and the allowance \( H \).

4. Change of grinding ratio

In this sizing method it is needed that grinding ratio \( G \) is a constant. Namely it can be seen that the grinding ratio doesn’t change at the first operation and the compensation. Therefore the change of the grinding ratio in a grinding cycle was confirmed experimentally.

Table 2 shows the measuring conditions. Figure 3 shows the photograph of the experimental setup.

Figure 4 shows measured results of changes of grinding ratio. Plots indicated by the line segment shows the same grinding cycle. The plot indicated by the mark @ in this figure will be explained first. These two plots show grinding ratio at the removal volume 2645mm\(^3\) and 2968mm\(^3\). In this experiment, grinding ratio changed 6.5 to 10. Like this measurement, grinding ratios were measured within the removal volume 5500 mm\(^3\), and then they were plotted in figure 4. From this figure, it is obviously that the grinding ratio changes widely.

Figure 5 shows frequency distribution of changes of a grinding ratio \( \Delta G \). Observed changes of grinding ratios range were -8 to 8, and changes from 0 to 4 showed the highest frequency. From this picture, grinding ratios seem to vary widely.
5. Effect of the sizing method

In order to confirm the effect of change of grinding ratio against the sizing method, grinding operation using the sizing method and that one not using the method are compared. Figure 6 shows a decrease workpiece height according the grinding process. The present sizing method was not used in this experiment. From this result, three grinding processes are needed to decrease the workpiece height within the 5 µm. On the other hand, figure 7 shows the effect of the present sizing method. At the grinding allowance of 350 µm, a workpiece which had an allowance of 350 µm was ground. After the first grinding process, residual stock removal of 49 µm due to the wheel wears remains. Sum of the setting depth of cut to remove this residual stock removal of 49 µm is calculated as 407 µm form equation (9-3). Namely the setting depth of cut 57 µm is needed to remove the residual stock of 39 µm in the compensation. This workpiece has ground within 1 µm by using the sizing method. By repeating the same grinding operation altering grinding allowance 200, 250 and 300 µm, this experiment has carried out. From this result, it is confirmed that the workpieces has ground within ±10 µm at the once compensation cycle.

6. Conclusion

In this study the sizing method based on a grinding ratio has been presented, and applied to the vertical spindle surface grinding. Results obtained in this experiment are as follows.

1) Workpieces are completely finished within the tolerance of 10 µm by the only one newly developed compensation cycle

2) This sizing method is very effective to finish the workpiece within a given tolerance especially in grinding of low Grinding ratio materials.