Effect of the abrasive grain distribution on surface roughness

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Abstract. When the ground surface is demanded to be smooth, it is required to make the grinding conditions optimum. To optimize the grinding conditions, relationship between grinding conditions and ground surface roughness must be revealed. Therefore, it has been attempted to reveal the effect of grinding conditions on the roughness of ground surface over the years. From previous researches, it becomes possible to estimate the ground surface roughness with statistical grinding theory. However, in the statistical grinding theory, some parameters are still unknown. In this study, effect of the random coefficient, which is one of parameters used in theoretical grinding theory, is investigated and effect of the abrasive grain distribution is revealed.

Introduction

Industrial products are demanded to be high precision and low cost [1~3]. And grinding process is one of the often-used machining methods. Therefore, the roughness of the ground surface should be smoothed. In previous studies, statistical grinding theory was proposed. And the relationship between grinding conditions and ground surface roughness was investigated. As a result, it becomes possible to optimize the grinding conditions so that to make the ground surface smooth. However, some grinding parameters are not considered in the grinding theory. To increase the accuracy of theoretical analysis, it is required to consider the more grinding parameters. In this study, effect of the random coefficient, which is one of parameters used in theoretical grinding theory, is investigated and effect of the abrasive grain distribution is investigated.

Statistical Grinding Theory

In this study, roughness of ground surface is investigated by statistical grinding theory [4~6]. Relationship between workpiece and grinding wheel is shown in **Fig. 1**. In this figure, O is axis of wheel rotation. And AX is ideal ground surface. An arbitrary cross sectional profile perpendicular to the wheel feed direction is defined as a reference section. When the reference section moves to the position of OA, position of grain cutting edge is defined as (θ, δ). θ is angle between the reference section and grain cutting edge. δ is distance from surface of grinding wheel to grain cutting edge. When the grinding is carried out, the grain cutting edge positioning (θ, δ) will cut the reference section at height H. The height H can be calculated by following equation.

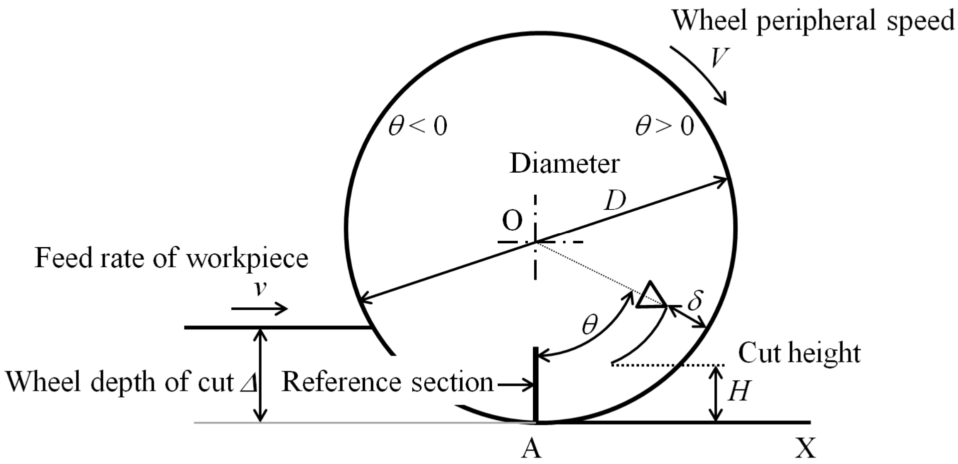


Figure 1 Grinding model

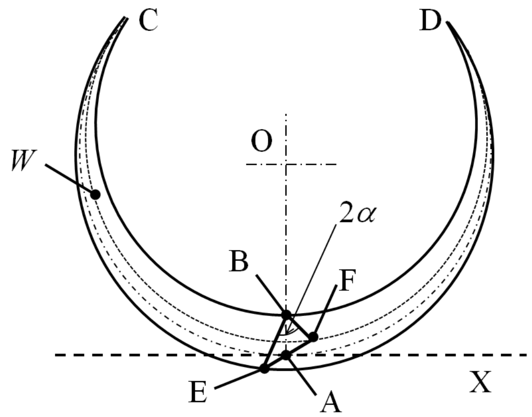


Figure 2 Constant-height cutting line

$$H = \delta + \frac{D}{4}\left(\frac{v}{V}\right)^2 \theta^2 \qquad (1)$$

In this equation, D is diameter of the grinding wheel, v is feed rate of workpiece and V is wheel peripheral speed. When the height H is fixed, the curve drawing the relationship between δ and θ calculated by equation (4) is called constant-height cutting line. The constant-height cutting line is shown in **Fig. 2** as a curve CBD. Shape of the abrasive grain is approximated by conic shape whose vertex angle is α, and the cutting will carry out at the side surface of the conic shape. Therefore, the abrasive grains on the 2 surfaces, CBDE and CBDF, also cut the reference section at the height H. The area circumscribed by 3surfaces, CBDE and CBDF and surface of grinding wheel, is named W. When the abrasive grain exists in the W, the abrasive grain cuts the reference section at the height lower than H. And when the cutting height H becomes minimum value H_m, we have following equation [7, 8].

$$W_m(D, H_m, \alpha, V, v) = nW_0 \qquad (2)$$

In this equation, W_m is volume of W, n is random coefficient, W_0 is volume of grinding wheel occupied by one abrasive grain. W_m can be calculated by geometrical method and following equation can be calculated.

Table 4 Simulation conditions

Width of grinding wheel	mm	5
Diameter of grinding wheel	mm	115
Wheel peripheral speed	m/s	25
Feed rate of workpiece	mm/s	83
Depth of cut of the grinding wheel	µm	20
Grain diameter	µm	44, 60, 80, 100
Half vertical angle	°	60
Number of grains (Grain percentage %)		300000 (8.45%) 400000 (11.3%) 500000 (14.1%) 600000 (16.9%) 700000 (19.7%) 800000 (22.5%) 900000 (25.2%)

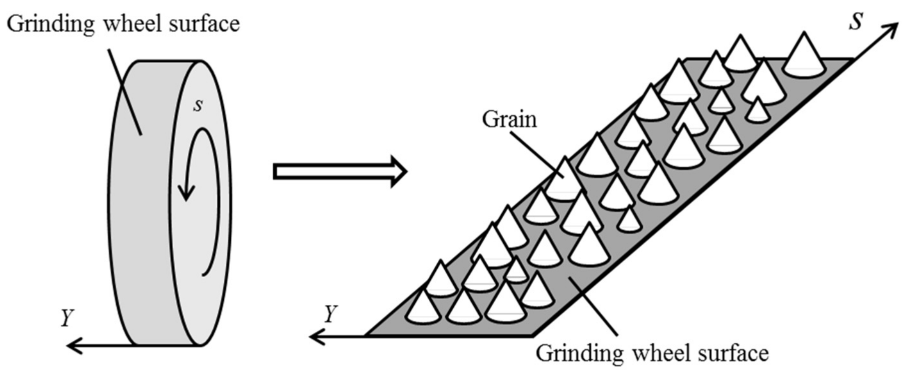


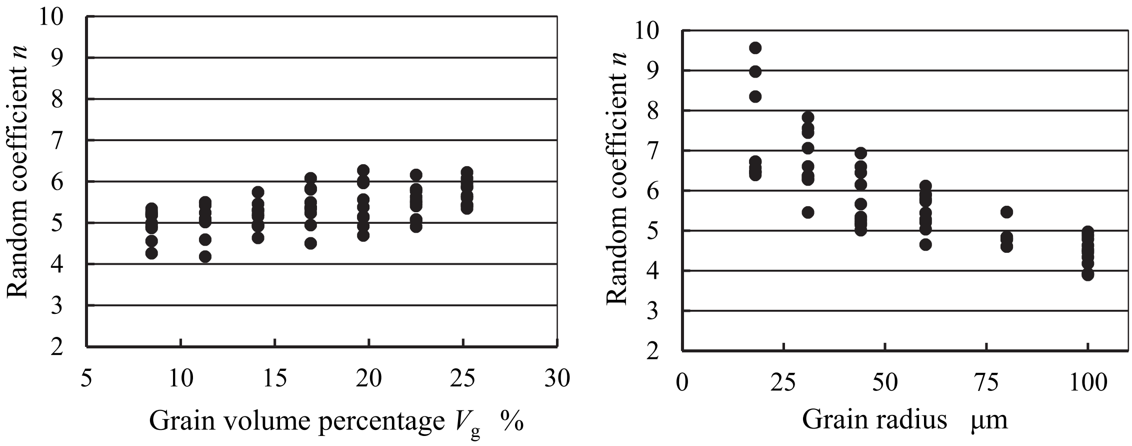
Figure 3 Model of grinding wheel surface

$$\frac{16}{15}\frac{V}{v}D^{0.5}{H_m}^{2.5}\tan\alpha - \frac{64}{105}\frac{V}{v}D^{-0.5}{H_m}^{3.5}\tan\alpha = nW_0 \qquad (3)$$

In the equation (3), unknown parameter is only H_m. Therefore, minimum cutting height H_m, in other words maximum height roughness, can be calculated by equation (3).

Random coefficient

The random coefficient n is number of abrasive grain in the volume W_0. And random coefficient n is considered as the constant number 3.3 regardless of grinding wheel specification [9]. However, it is considered that the volume W_0 should be changed by specification of grinding wheel and random coefficient n is not constant number. To reveal the effect of specification of grinding wheel on random coefficient n, grinding simulation was carried out. Simulation conditions are shown in **Table 4**. Shape of abrasive grain is approximated to conical shape. And abrasive grains are placed on the surface of grinding wheel randomly as shown in **Fig. 3**. From the profile of fig. 3, cross sectional profile of ground surface is approximated. And random coefficient n is calculated by the cross sectional profile of ground surface. **Fig. 4** shows relationship between calculated random coefficient n and grinding conditions. It is found that the grain size and concentration of grinding wheel affect random coefficient n. However, calculated random coefficient n is far from 3.3.



(a) Effect of concentration (b) Effect of abrasive grain radius

Figure 4 relationship between grinidng conditions and random coeficient
(Distribution of abrasive grains is uniform)

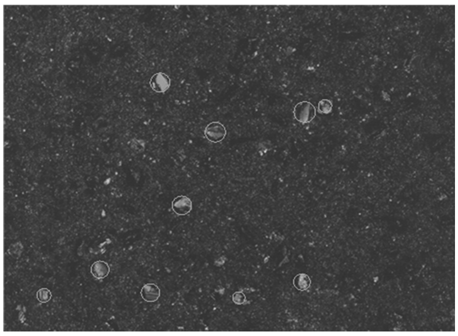


Figure 5 Observation of grinding wheel surface

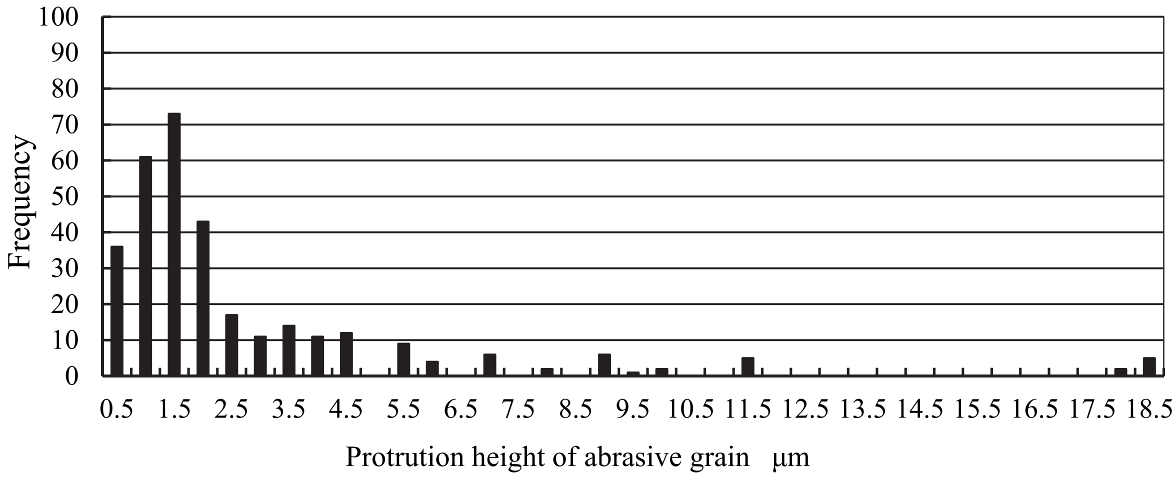
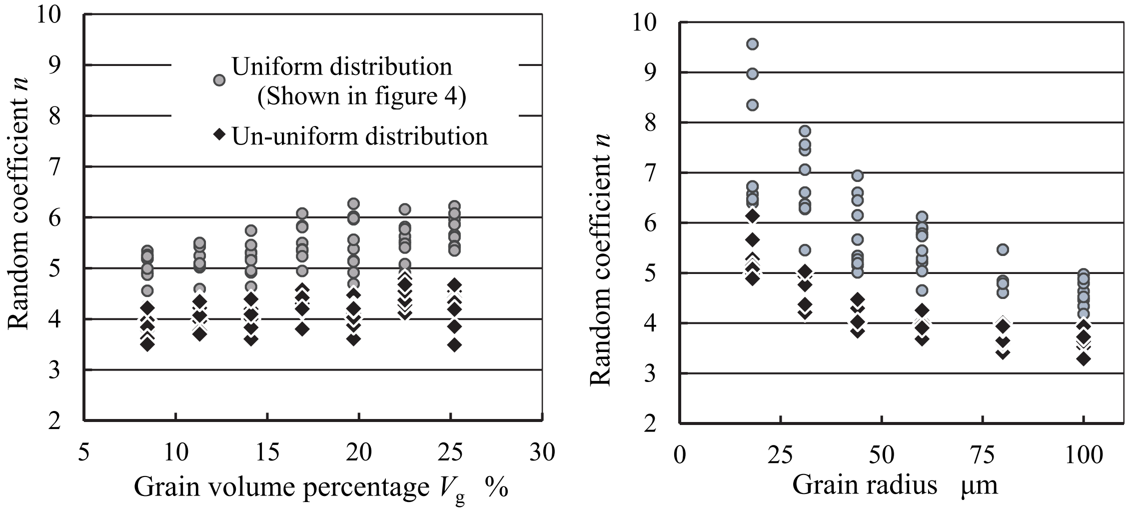


Figure 6 Histogram of actual protrution height of abrasive grain

Effect of abrasive grain distribution

To make calculated random coefficient n closer to the actual value, distribution of abrasive grains is considered. **Fig. 5** shows grinding wheel surface. From this picture, dimension occupied by an abrasive grain is measured, and protrusion height of abrasive grain is estimated from this dimension. **Fig. 6** shows histogram of protrusion height of abrasive grain. It is found



(a) Effect of concentration

(b) Effect of abrasive grain radius

Figure 7 relationship between grinidng conditions and random coeficient
(Distribution of abrasive grain is un-uniform as shown in figure 6)

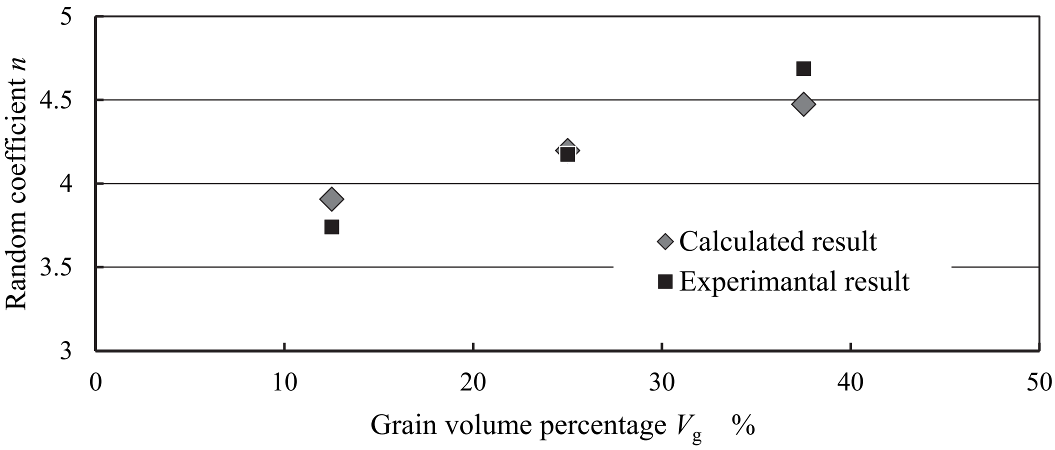


Figure 8 Comparison of experiment result of n and calculation result of n

that the protrusion height is not uniform. Based on the result shown in Fig. 6, calculation of random coefficient n is carried out again. **Fig. 7** shows result. It is found that the calculated random coefficient n becomes small. The actual value of random coefficient n was measured experimentally and compared with the calculation result in **Fig. 8**. It is confirmed that the actual value of random coefficient n and the calculation result agree well. Therefore, when the distribution of abrasive grain is taken into account, the ground surface roughness can be calculated with high accuracy.

Summary

To make the theoretical analysis of ground surface roughness high precision, random coefficient n is investigated in this paper. And following results are obtained.

1. The random coefficient n is not constant number. And relationship between grinding conditions and random coefficient n is revealed.
2. Distribution of abrasive grains must be considered to make the theoretical analysis of ground surface roughness high precision.

References

[1]Tsunemoto KURIYAGAWA, Nobuhito YOSHIHARA, Yongbo WU and Katsuo SYOJI, 2001, Journal of the Japan Society for Precision Engineering, Vol.67, No.8, pp.1316-1320 (in Japanese)

[2]Nobuhito YOSHIHARA, Tsunemoto KURIYAGAWA and Katsuo SYOJI, 2003, Journal of the Japan Society for Precision Engineering, Vol.69, No.12, pp1792-1796 (in Japanese)

[3]Nobuhito Yoshihara, Shin Fujimura, Naohiro Nishikawa, Masahiro Mizuno and Toshirou Iyama, Advanced Material Research, Vol.35, 2011.

[4]Seiki Matsui and Katsuo SHOJI, 1968, Journal of the Japan Society for Precision Engineering, Vol.34. No.11, pp.743-748 (in Japanese)

[5]Seiki Matsui and Katsuo SHOJI, 1970, Journal of the Japan Society for Precision Engineering, Vol.36. No.2, pp.115-119 (in Japanese)

[6]Seiki Matsui and Katsuo SHOJI, 1971, Journal of the Japan Society for Precision Engineering, Vol.37. No.10, pp.708-714 (in Japanese)

[7]Nobuhito Yoshihara, Jiwang Yan and Tsunemoto Kuriyagawa, 2010, Journal of the Japan Society for Precision Engineering, Vol.76, No.7, pp.781-785 (in Japanese)

[8]Nobuhito YOSHIHARA, Kyohei HOROYA, Naohiro NISHIKAWA, Masahiro MIZUNO and Toshirou IYAMA, Proceedings of the 6th International Conference on Leading Edge Manufacturing in 21st Century, CD-ROM, 2011.

[9] S. Matsui and K. Syoji, 1973, Technology Reports, Tohoku Univ., Vol.38, No.2, pp.615