ASEC 2022

Proceeding Paper

Study on Affect by Calculation Algorithm for Material Probability Curve to Roughness Parameters of Plateau Surface †

Sho Nagai [1], Ryo Sakakibara [1] and Ichiro Yoshida [2,*]

[1] Major in Mechanical Engineering, Graduate School of Science and Engineering, HOSEI University; e-mail@e-mail.com (S.N.); e-mail@e-mail.com (R.S.)
[2] Department of Mechanical Engineering, Faculty of Science and Engineering, HOSEI University
* Correspondence: yoshida.ichiro@hosei.ac.jp; Tel.: +81-042-387-6033

† Presented at the 3rd International Electronic Conference on Applied Sciences; Available online: https://asec2022.sciforum.net/.

Abstract: Industry requires effective evaluation methods for quality control of automobile parts and bearings. The ISO standard defines the calculation of roughness parameters from material ratio curve ("MRC") and material ratio curve on normal probability paper ("MPC") as effective methods for evaluating surfaces with excellent lubrication and frictional characteristics. ISO 4287 specifies the slice method as a calculation method for MRC. The analysis time of the slice method is long due to the large amount of calculation. Therefore, ISO 21920-2 specifies the use of the sort method. The Sort method reduces analysis time significantly due to the small amount of calculation. The previous study revealed that errors occur in the MRC by the sort method compared to the slice method. However, the previous study concluded that the errors were acceptable compared to the time cost. In addition, the plateau surface is a surface with excellent sliding property. The roughness parameters of the plateau surface have to be calculated from MPC. However, the difference between MRCs calculated by the sort and slice methods increases as both ends approach in the case of expression on normal probability paper. Therefore, the results of roughness parameters calculated by each MPC are expected to be different. This study reports the results of investigation about the affect that increasing differences have on the roughness parameters. We aim to contribute to the establishment of a highly effective evaluation method by verifying the validity of using the sort method in the calculation of MPC.

Keywords: material ratio curve; material probability curve; sort method; slice method; ISO 21920-2; ISO 4287; plateau surface; roughness parameter

Citation: Nagai, S.; Sakakibara, R.; Yoshida, I. Study on Affect by Calculation Algorithm for Material Probability Curve to Roughness Parameters of Plateau Surface. **2022**, *4*, x. https://doi.org/10.3390/xxxxx

Academic Editor(s):

Published: 1 December 2022

1. Introduction

The automotive industry is required to reduce the environmental load and improve the performance of mechanical parts. Therefore, effective evaluation methods are required for the quality control of automotive parts. The International Organization for Standardization (ISO) specifies roughness parameters obtained from the material ratio curve (MRC) and material ratio curve on normal probability paper (MPC) as effective evaluation methods for surfaces with excellent lubrication and friction characteristics [1–4]. Figure 1a,b show the MRC and MPC, respectively. In ISO 4287 [5], the standard method for calculating the MRC is the slice method [6]. Owing to the large amount of calculation, the analysis time of the slice method is long [4,7,8]. Therefore, to significantly reduce analysis time, ISO 21920-2 [9] specifies the use of the sort method that requires the small amount of calculation. A previous study [8,10–12] revealed that the differences in calculation of the two methods leads to errors in the MRC calculated by the sort method compared to that of the slice method. In addition, the previous study concluded that the error was within an acceptable range, considering the short analysis time of the sort method [12]. On the other hand, the MPC, not the MRC, is used to evaluate surfaces with excellent sliding properties [3,9]. However, when plotted on a normal probability paper, the difference between the MRCs calculated using the sort and slice methods increases as one approaches the two ends of the paper. Therefore, the roughness parameters calculated from the MPCs by the slice and sort methods may be different results. This study reports the effect of an increase in errors on the roughness parameters. We aim to contribute to the establishment of an effective evaluation method by verifying the validity of using the sort method in the calculation of MPC.

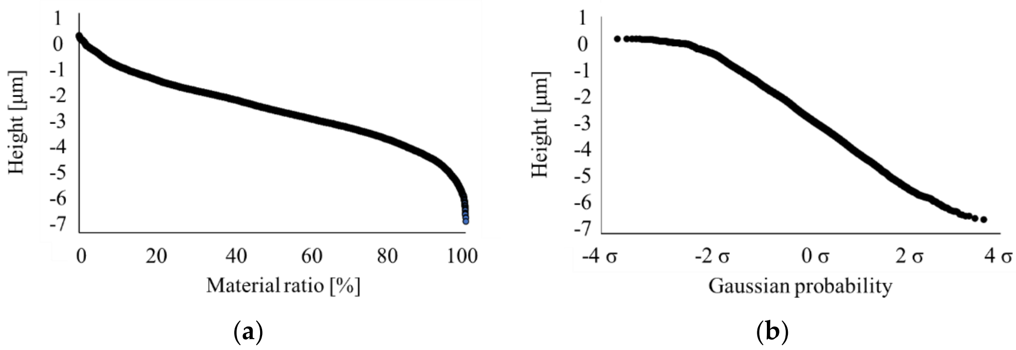

Figure 1. MRC and MPC: (**a**) MRC; (**b**) MPC.

2. Errors Owing to MRC Calculation Method

The MRC is a curve representing the ratio of the material and void parts of the surface profile with respect to the height direction [9]. ISO 4287 specifies the slice method as the method for calculating the MRC [5]. The steps for calculating the MRC by the slice method are as follows:

1. Set the slice height;
2. Calculate the intersections of the roughness curve and the slice height;
3. Calculate the length of the material part between intersections;
4. Sum the lengths of the material parts;
5. Calculate the material ratio MR by substituting the sum of the lengths of the material parts *L* and evaluated length *E* into Equation (1).

$$MR = L/E \times 100 \quad (1)$$

The slice method calculates the ratio of the material and void parts of the roughness profile from intersections of the slice height and roughness curve. Therefore, an increase in the number of data points increases the number of intersections, which in turn increases the calculation time. Furthermore, the calculation time increases owing to an increase in the number of times the roughness profile is sliced. Therefore, ISO 21920-2 [9] specifies the sort method to reduce the calculation time. The steps for calculating the MRC using the sort method are as follows:

1. Sort the roughness data in descending order;
2. Calculate the material ratio MR by substituting the evaluated length *E*, rank *N*, and pitch Δx into Equation (2).

$$MR = (\{(N-1) \times \Delta x\})/E \times 100 \quad (2)$$

The sort method only calculates Equation (2) after sorting the roughness data in descending order. The calculation time of the sort method is shorter than that of the slice method because the sort method requires fewer calculations per height. Therefore, ISO 21920-2 [9] recommends using the sort method to calculate the MRC. However, the differences in the calculation of the two algorithms can lead to errors in the MRC. Figure 2 shows the error in the MRCs by the slice and sort methods. Figure 2 shows that the maximum error is 0.16%. A reason for the error is that in the case of a series of data points of the same height (hereafter referred to as "continuous points"), the occurrence of duplicate counts leads to erroneous calculations. The Previous study developed an improved sort method to solve this problem of calculating contiguous points [8,10–12]. As a result, the improved sort method eliminated errors due to continuous points. In addition, the analysis time of the improved sort method reduced to less than 1/10,000 compared to that of the slice method. Therefore, the previous study [12] concluded that the error of the improved sort method relative to the slice method were acceptable with respect to the analysis time.

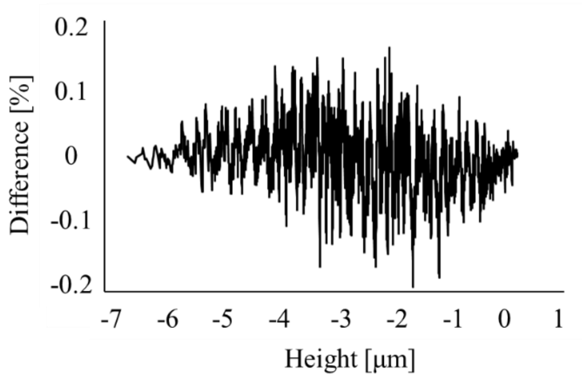

Figure 2. Error in MRCs by slice and sort methods.

3. Influence on the Evaluation Method for Plateau Surfaces

Plateau surfaces have excellent sliding properties. Because the plateau surface consists of, in the roughness, a plateau region where the convex part is smoothed and a valley region where the concave part remains. The plateau region reduces friction and plays the load-bearing role, whereas a valley region acts as an oil reservoir. The plateau surface have high sliding properties due to these roles. Evaluation of the plateau surface requires using the MPC [9,13]. In Figure 3, the area circled in red on the MPC represents the plateau region and green represents the valley region. The steps of the evaluation method for the plateau surface are as follows:

1. Convert the roughness curve to an MRC;
2. Convert the MRC to a MPC;
3. Fit straight lines to the plateau and valley regions on the MPC.

The roughness parameters *Rpq* and *Rvq* are the absolute values of the slopes of the respective straight lines calculated using the abovementioned procedure. Figure 4 shows that the error of the MRC by the slice and sort methods increases by conversion to the MPC. The reasons for this are as follows. The interval between the data points in the MPC increases as one moves away from the center of the x-axis. Therefore, on normal probability paper, the errors at both ends of the MRC become significantly larger. In addition, the increase in the errors is more pronounced on the plateau region side of the MPC. Therefore, the straight lines fitted on the MPCs calculated by the slice and sort methods may not coincide. Thus, this study investigates the effect that an increase in errors give to the calculated results of the roughness parameters in the plateau region.

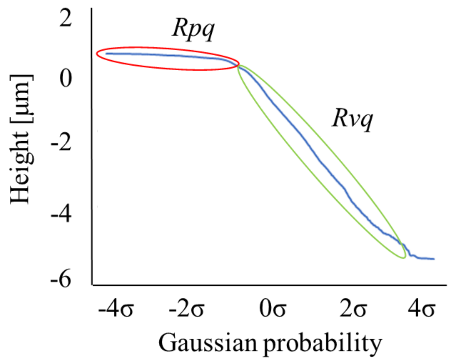

Figure 3. MPC and roughness parameters of the plateau surface.

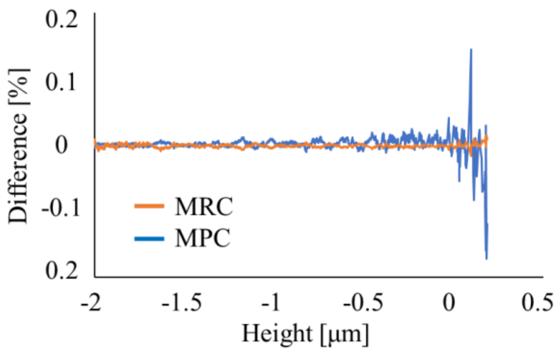

Figure 4. Increase in error owing to the conversion of MRC to MPC.

4. Experiments and Results

The experiment investigates the difference in the *Rpq* values calculated from MPCs by the slice and sort methods. The sample used in the experiment is a roughness profile of a sufficiently worn plateau surface. Table 1 shows *Rpq* values obtained from the MPCs calculated by the slice and sort methods. Table 1 shows that *Rpq* values obtained from the MPCs calculated by the sort and slice methods do not differ largely. Hence, the calculation of the MPC by the sort method is expected to have no significant effect on the results of the roughness parameter calculation for the plateau region.

Table 1. *Rpq* values obtained from the MPCs calculated by the slice and sort methods.

	***Rpq* in Slice Method [µm]**	***Rpq* in Sort Method [µm]**
Sample 1	0.29	0.29
Sample 2	0.25	0.25
Sample 3	0.07	0.07
Sample 4	0.06	0.06

5. Conclusions

This study investigated the effect on the roughness parameters of the plateau surface due to the increase in errors from the conversion of MRC to MPC. The following summarizes the results and future prospects of this study. The increase in error from conversion to the MPC is considered to have little effect on the evaluation of the plateau surface with respect to a sufficiently worn surface. In future studies, we will further verify the validity of using the sort method for the calculation of MPC in the evaluation of plateau surfaces by increasing the number of samples with plateau surface profiles.

Author Contributions:

Funding:

Institutional Review Board Statement:

Informed Consent Statement:

Data Availability Statement:

Conflicts of Interest:

References

1. Pawlus, P.; Reizer, R.; Wieczorowski, M.; Krolczyk, G. Material ratio curve as information on the state of surface topography-A review. *Precis. Eng.* **2020**, *65*, 240–258.
2. Yoshida, I.; Tsukada, T.; Arai, Y. Characterization of Three-Stratum Surface Textures. *J. Jpn. Soc. Tribol.* **2008**, *53*, 99–111.
3. *ISO 13565-2:1996*; Geometrical Product Specifications (GPS)-Surface Texture: Profile Method; Surfaces Having Stratified Functional Properties-Part 2: Height Characterization Using the Linear Material Ratio Curve (JIS B 0671-2: 2002).
4. Arai, Y.; Yoshida, I.; Tsukada, T. A Method to Derive the Material Ratio Curve of Surface Texture. *Proc. JSPE Semest. Meet.* **2007**, 703–704. (In Japanese)
5. *ISO 4287:1997*; Geometrical Product Specifications (GPS)-Surface Texture: Profile Method-Terms, Definitions and Surface Texture Parameters (JIS B 0601: 2013).
6. Okamoto, J.; Nakayama, K.; Sato, M. *Introduction to Tribology*, 1st ed.; Saiwai shobo: Tokyo, Japan, 1990; pp. 10–11. (In Japanese)
7. Machida, H.; Yoshida, I. Proposal of Calculating Method for Material Ratio Curve of Suface Texture. In Proceedings of the 5th International Conference on Science of Technology Innovation, Nagaoka University of Technology, Niigata, Japan, 30–31 October 2020; STI-9-31, p. 80.
8. Machida, H.; Nagai, S.; Yoshida, I. Study on a Computational Algorithm for Material Ratio of Surface Texture. In Proceedings of the 6th International Conference on "Science of Technology Innovation", Nagaoka University of Technology, Niigata, Japan, 22 October 2021; STI-9-28, p. 104.
9. *ISO 21920-2:2021*; Geometrical Product Specifications (GPS)—Surface Texture: Profile—Part 2: Terms, Definitions and Surface Texture Parameters.
10. Machida, H.; Yoshida, I.; Kondo, Y. Proposal of Computational Algorithm for Calculating Material Ratio of Surface Texture. In Proceedings of the ASEC2021, Online, 15–31 October 2021.
11. Machida, H.; Yoshida, I.; Kondo, Y. Proposal of Computational Algorithm for Calculating Material Ratio of Surface Texture. *Eng. Proc.* **2021**, *11*, 1–6.
12. Machida, H.; Nagai, S.; Yoshida, I. Study on a Computational Algorithm for Material Ratio of Surface Texture. *Trans. GIGAKU* **2022**, *9*, 09017-1–09017-7.
13. Yoshida, I. Surface Roughness-Part 2, How to Use and Clues of the Surface Texture Parameters. *J. Jpn. Soc. Precis. Eng.* **2013**, *79*, 405–409.