proceedings

MDPI

Proceedings

Surface roughness evaluation method of inner surface of engine bore by RANSAC and least squares method†

Sho Nagai [1], Ichiro Yoshida [2,*] and Ryo Sakakibara[3]

[1] HOSEI University, Graduate School of Science and Engineering, Major in Mechanical Engineering;
[2] HOSEI University, Faculty of Science and Engineering, Department of Mechanical Engineering;
[3] Formerly of HOSEI University, Graduate School of Science and Engineering, Major in Mechanical Engineering ;
* Correspondence : yoshida.ichiro@hosei.ac.jp; Tel.: (+81)042-387-6033
† Presented at the title, place, and date.

Abstract: Analysis methods for plateau surfaces have been defined in the ISO standards, JIS, and previous studies. Sakakibara et al., the authors of the previous study, proposed a method based on the concept of RANSAC. This method achieved high analysis accuracy for plateau surfaces by setting detailed conditions. However, the process of setting the optimal conditions is performed manually, which reduces the productivity owing to the manpower and man-hours required. In this study, we propose a new method for automating the setting of the conditions. This method, which does not require human intervention, is expected to contribute to the improvement of productivity at production sites.

Keywords: material ratio curve; material probability curve; plateau surface; least squares method; RANSAC

Citation: Lastname, F.; Lastname, F.; Lastname, F. Title. *Proceedings* **2021**, 68, x. https://doi.org/10.3390/xxxxx

Published: date

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

1. Introduction

The inner surface of an automobile engine bore requires high sliding properties because the piston slides inside the cylinder. For this reason, the bore surface is finished by plateau honing as shown in Figure 1. The plateau-honed surface has a plateau region and a valley region. Each region has a different requirement specification and is therefore evaluated using a material ratio curve. The slope of the straight line that is fitted to the slope of the part of the material ratio curve corresponding to the plateau and valley regions is the parameter value [1]. Therefore, several analytical methods were proposed because it is important to detect the slope of a straight line with high validity [2-5]. This study proposes a new linear fitting method based on the concept of RANSAC and least squares method. In addition, because the industrial world demands improved productivity, this study aims to develop a method that does not require human intervention.

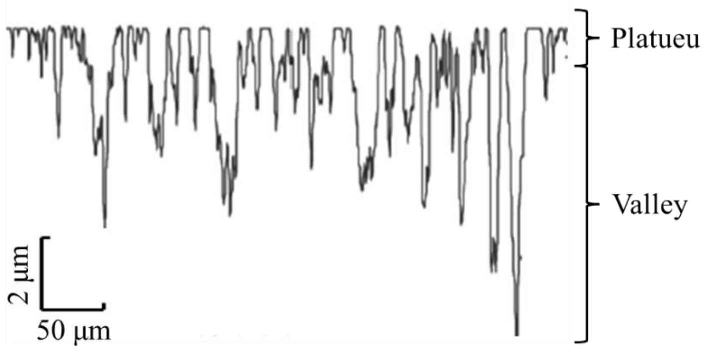

Figure 1. Plateau honed surface.

2. Proposed method applying RANSAC and least squares method

The algorithm of the proposed method, which applies the RANSAC concept, is as follows:

1. Two points are randomly extracted from the material ratio curve, and the model line is calculated from the two randomly extracted points.
2. The number of data points within the tolerance (inliers) from the model line is counted.
3. The best model is the one in which the number of inliers is greater than the specified value and the total error between the acceptable data and the model line is the smallest.

This step is performed at each slope of the plateau and valley regions. The three conditions to be set in advance are the boundary position between the plateau and valley regions on the material ratio curve, the tolerance, and the number of inliers. In Sections 2.1 and 2.2, we describe the determination of these three conditions.

2.1. Determination of Boundary Position using Least Squares Method

The calculation procedure of the method developed by this study to locate the boundary is as follows:

1. The material ratio curve is scanned one point at a time from the edge, and the straight line that is fitted to each range is calculated using the least squares method.
2. The change in the slope of the line produces an extreme value.
3. The local maximum point with the largest difference from the neighboring local minimum point among several detected extremes is set as a feature point.
4. The point on the material ratio curve corresponding to the feature point is determined to be the boundary position.

The boundary positions on the material ratio curve corresponding to the feature points are shown in Figure 2 [6].

2.2 Automization of Setting of Tolerances and Number of Inliers

The proposed method based on the RANSAC concept seek manually the best combination in order to have the property that the accuracy of straight-line detection varies depending on the combination of the tolerance and the number of inliers. Therefore, the straight line is detected for all combinations of each value. Automization of the setting of tolerances and number of inliers is achieved by selecting a model line with an even smaller error from the model lines calculated for each combination.

3 Experiment

In this study, the validity of the newly developed algorithm was verified by applying it to the surface profile data of samples that were slid 0 to 10000 times. Figure 3 shows the results of the material ratio curve and the detected straight lines for samples that were slid 0, 5, 10, 50, 100, and 500 times, and the straight lines coincide with the plateau and valley regions.

4 Conclusion

This study developed a method that applied the concept of least squares method and RANSAC to contribute to the improvement of productivity at production sites. Because this method requires the setting of three conditions, we developed an algorithm to identify these conditions. However, the developed algorithm for identifying the boundary position has a problem that it is not fully automated. In the future, we aim to develop a new method to solve this problem.

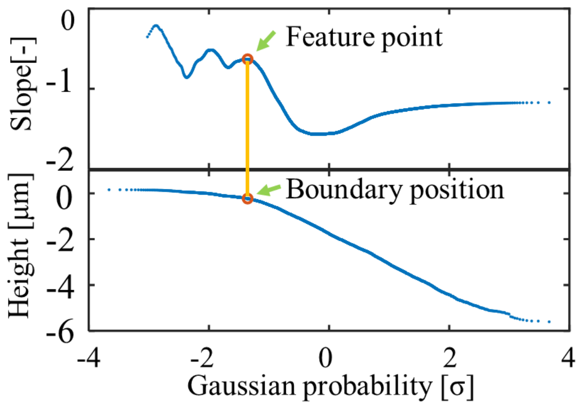

Figure 2. Detection result of feature point.

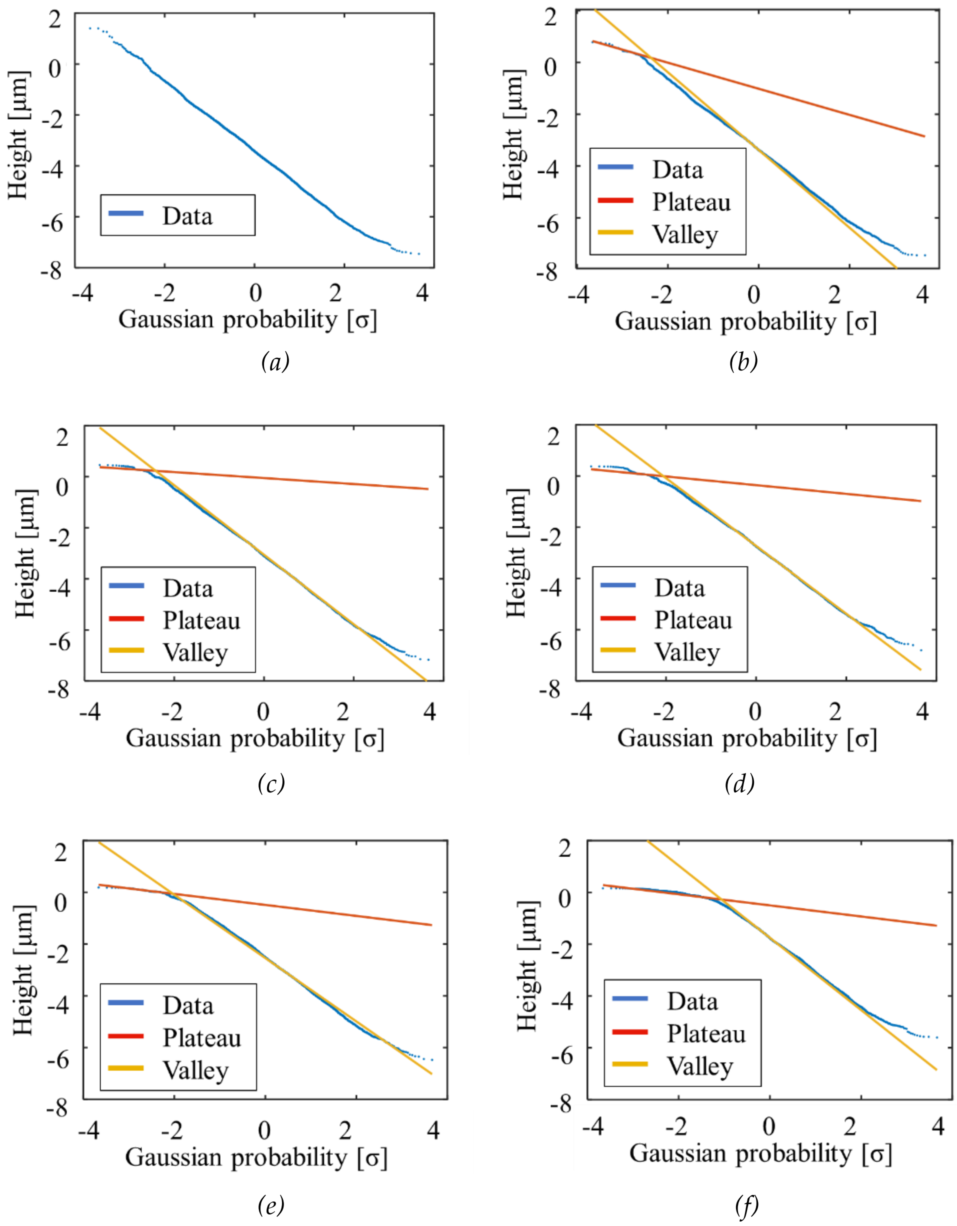

Figure 3. Detection result of straight line: (a) 0 time; (b) 5 times; (c) 10 times; (d) 50 times; (e) 100 times; and (f) 500 times.

5. Acknowledgments

This work was partly supported by the Precise Measurement Technology Promotion Foundation (PMTP-F).

References

1. Yoshida, I.; Tsukada, T.; Arai, Y. Characterization of three-stratum surface textures, *Japanese Journal of Tribology*, **2008**, Vol. 53, pp. 99–111. Available online: https://www.researchgate.net/publication/297936036_Characterization_of_three-stratum_surface_textures (accessed on 1st September 2021).
2. ISO 13565-3:1998 Geometrical Product Specifications (GPS) - Surface texture: Profile method; Surfaces having stratified functional properties-Part 3: Height characterization using the material probability curve.
3. YOSHIDA, I.; KONDO, Y.; WAKATSUKI, G.; NUMADA, M. Study of a Plateau Surface Evaluation Method Using a Fast M-Estimation Type Hough Transform,International Journal of Automation Technology, *International Journal of Automation Technology*, **2019**, *Vol. 13,* pp. 118-123.
4. Sakakibara, R.; Yoshida, I.; Kondo Y.; Numada, M.; Yamashita, K. A Proposal of Hyperbolic Fitting Method by Applying the Properties of Functions for Plateau Surface Analysis in ISO13565-3, *Nanomanufacturing and Metrology*, **2020**, *Vol. 3,* pp. 1-11.
5. Sakakibara, R.; YOSHIDA, I.; Nagai, S.; KONDO, Y.; Yamashita, K. Surface roughness evaluation method based on roughness parameters in ISO 13565-3 using the least-squares method for running-in wear process analysis of plateau surface, *Tribology International*, **2021**, *Vol 163*, pp. 1-9.
6. Nagai, S.; YOSHIDA, I.; Machida, H.; KONDO, Y.; Sakakibara, R.; K.; Yamashita, K. Study on surface roughness evaluation method of inner surface of engine bore using RANSAC method and least squares method, Abrasive Technology Conference 2021, 2021, ABTEC-U-C44, p. 215 (in Japanese).