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Behavior of Gaussian Profile Filters for Plateau Surface Structure, and Optimum Parameters †

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Abstract: The inner surface of engine cylinder liners has a plateau structure because of being required excellent sliding properties. To improve the tribological properties, the plateau surface consists of a smooth plateau region and valley region which serves as an oil reservoir for improving lubrication. The roughness of the plateau surface is measured and evaluated for improving fuel economy of engines in manufacturing job sites. For highly valid roughness evaluation of the plateau surface, filtering method is important. Therefore, ISO 21920-1 has stipulated that the plateau surface should be processed with the Gaussian regression filter (GRF) of ISO 16610-31. In addition, in previous research, the fast M-estimation Gaussian filter (FMGF) was proposed as a filter that overcomes the shortcomings of GRF. The proposed the FMGF is expected to be a better filter than the GRF because of including the robustness and the characteristic becoming equal output of the Gaussian filter. On the other hand, since the parameters of the robust profile filter have different suitable values for the normal surface or the plateau surface, their setting require human judgement. Therefore, the robust profile filters are not practical in manufacturing job sites because the parameters of the robust profile filters need to be set an optimum parameter manually, which takes time and effort. In this paper, we aim to improve the convenience of the robust profile filters in manufacturing job site by establishing guidelines for the selection of optimum parameters.

Keywords: surface roughness; plateau surface structure; robust profile filter; Gaussian regression filter; fast M-estimation Gaussian filter

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1. Introduction

The inner surface of an engine cylinder liner requires excellent sliding properties because the piston slides on it. Therefore, the inner surface of the engine cylinder liner has a plateau surface structure, as shown in Figure 1. The plateau surface structure has a plateau form because asperity is smoothed by wear or machining. Accurately evaluating the wear state of this plateau surface can support the fuel economy of a hybrid car engine. For highly valid roughness evaluation of the plateau surface, filtering method is important.

Therefore, ISO standard [1] specifies that the plateau surface should be filtered with a Gaussian regression filter (GRF) [2–5]. In addition, a previous study proposed the fast M-estimation Gaussian filter (FMGF) [6–8] as a filter that overcomes the shortcomings of the GRF. On the other hand, optimum parameter settings require human judgment because the GRF and FMGF have different optimum parameter settings depending on the wear progress. Therefore, these robust Gaussian regression filters (RGRFs) [9] are impractical in manufacturing job sites because the optimum parameter setting takes time and effort. This study aims to contribute to improving the convenience of RGRF in manufacturing job sites by solving these problems.

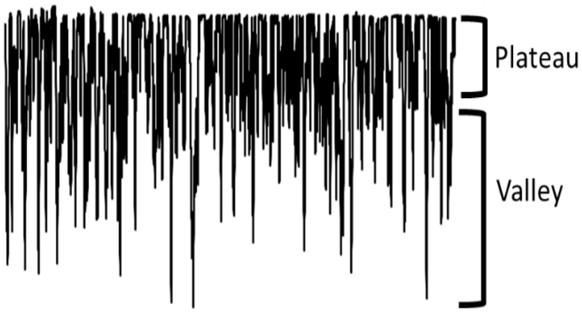


Figure 1. Plateau surface structure.

2. RGRF

Currently, ISO 21920-1 [1] specifies that the plateau surface should be filtered with GRF of ISO 16610-31 [2]. In addition, a previous study proposed the FMGF [6–8] as a filter that overcomes the shortcomings of the GRF. The GRF is a robust regression filter that uses the M-estimation method [2]. For each repetition, the GRF is corrected according to threshold and the magnitude of the difference between the primary profile and mean line. When the median value of the difference between the primary profile and the mean line is less than the set threshold, the calculation is repeated. Therefore, the output depends on the setting of the threshold. The FMGF is a robust filter that combines fast M-estimation and Gaussian filter (GF) [10]. The fast M-estimation method uses a second-order B-spline basis function as a loss function to determine the evaluation value that maximizes the sum of the loss function [6–8]. The second-order B-spline basis function has the characteristic that the weights within the basic width coincide with the quadratic function and the weights outside the basic width converge to 0. With this characteristic, the output of the FMGF coincides with the output of the GF for the profile data without spikes.

3. Experiments and Results

This study investigates the behaviors of the output of the GRF and FMGF for a plateau surface. Figure 2 shows the output results when thresholds of the GRF is set to 1, 0.1, 0.01, and 0.001 μm. Figure 3 shows the output results at a resolution of FMGF of 50 and basic widths of 10, 20, and 30. Figures 4 and 5 show the results of removing the mean lines by the GRF and FMGF, respectively, for each parameter setting. The outputs of the GRF in Figures 2 and 4 confirm that the mean lines are distorted by the deep valleys of the plateau surface with increasing threshold. The outputs of the FMGF in Figures 3 and 5 are poorly valid because the outputs are affected by shallow valleys when the resolution of the FMGF is set to 50 and basic widths are set to 20 and 30. On the other hand, when the basic width is set to 10, the mean line is highly valid because the effect of shallow valleys is less. These results show that the output of the RGRF for the plateau surface is significantly different depending on the parameter setting. This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation, as well as the experimental conclusions that can be drawn.

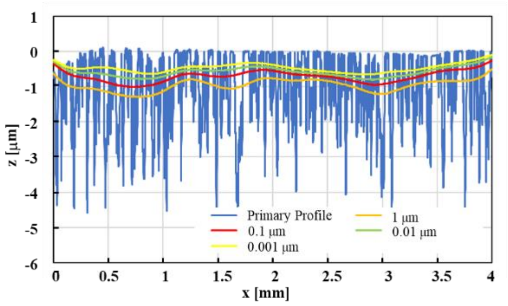


Figure 2. Output of GRF at each threshold.

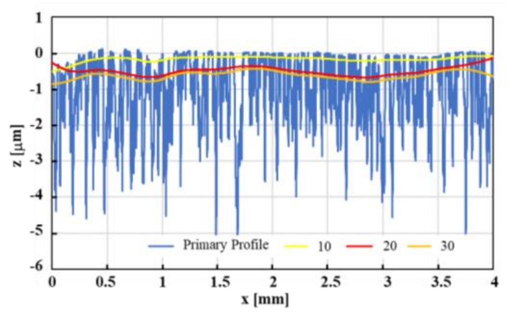
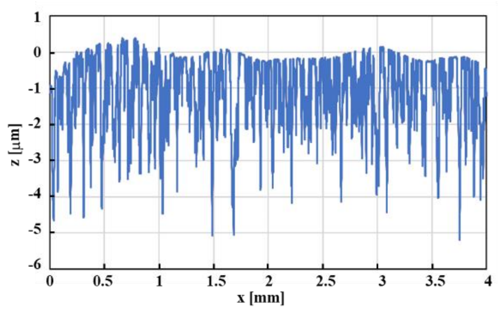
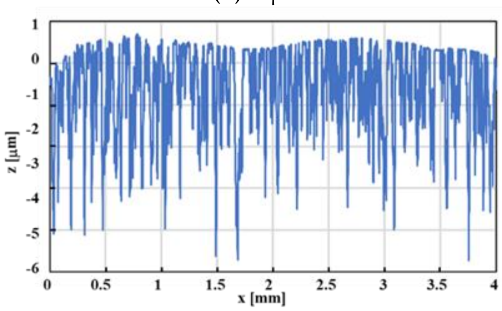


Figure 3. Output of FMGF at each basic width.

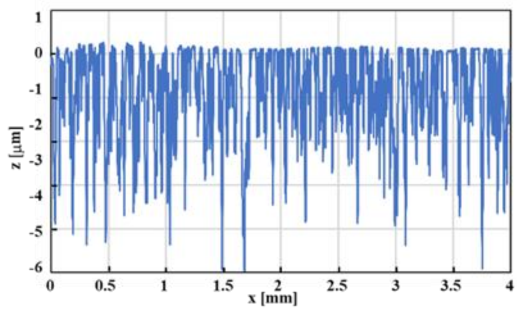


(**a**) 1 μm

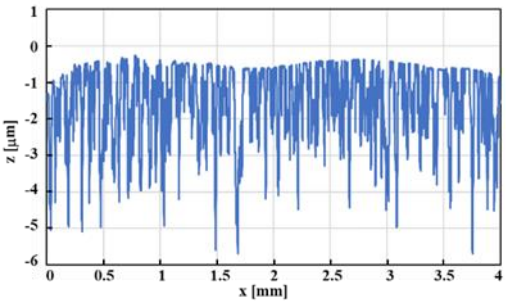


(**b**) 0.001 μm

Figure 4. Roughness profile of the GRF at each threshold (primary profile–mean line).



(**a**) 10



(**b**) 20

Figure 5. Roughness profile of the FMGF at each basic width (primary profile–mean line).

4. Conclusions

In this study, we investigated the behavior of the RGRF for the plateau surface. The results of this study and the future plan are summarized as follows. The output of RGRF for the plateau surface was significantly different depending on the parameter setting. In addition, the RGRF confirmed that an optimum parameter setting is important for high validity output. In future, we will further clarify the behavior of the RGRF on a plateau surface to investigate the optimum parameter setting of the RGRF.

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Conflicts of Interest:

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