特集 7　　UDC 620,179.118

A Study on Two Dimensional Measurement of Surface Roughness

2次元表面粗さ測定に関する研究

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1. Introduction

Surface roughness is one of the important parameters specifying the quality of machined parts. Necessity of the measurement in machining process with higher accuracy and property than that by the conventional tracing method by contacting needle is increased as the recent development in manufacturing technology. Two dimensional measurement of surface roughness makes it possible to observe the surface matrix by three dimensional view. It was proposed to measure the statistical quantity of two dimensional surface roughness in times of the diffraction pattern to projected laser beam [1]. However, the cross section line of the surface roughness can not be obtained by such method. In this paper it is aimed to know the two dimensional roughness in terms of the cross section line, in other words the surface shape of plane. The method adopted in this paper is based on that the deformation of the image of the slit beam is due to the cross section on the surface. The image is recognized through industrial television connected with mini computer. The successive image processing by the system makes it possible to compose the two dimensional surface roughness.

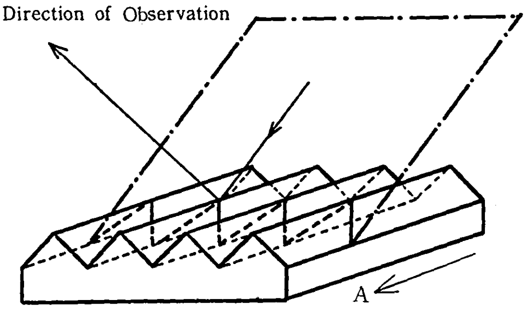

Fig. 1 The principle of cross section by slit beam

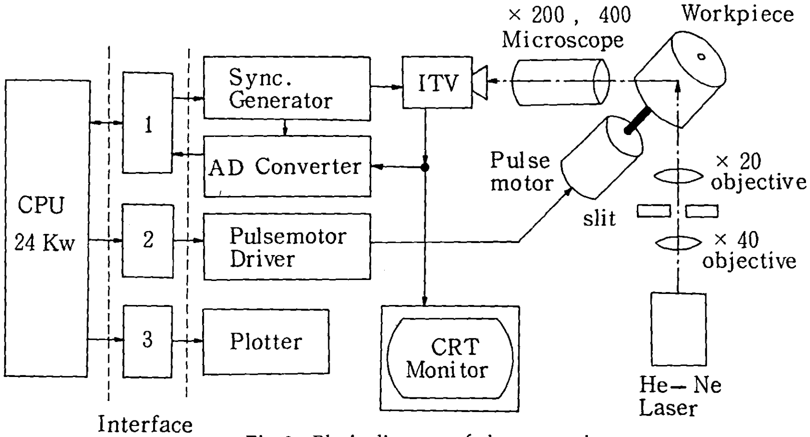

Fig. 2 Block diagram of the measuring system

2. Principle of the Measurement

The method adopted in this paper has been essentially known as an optical method to measure the surface roughness. The principle of this method is shown in Fig. 1. A slit beam which is projected to the objective surface makes a deforemed image due to the shape of surface [2].

This can be observed from any other direction than the incident angle. Usually the image is

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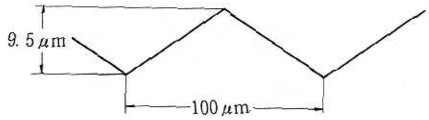
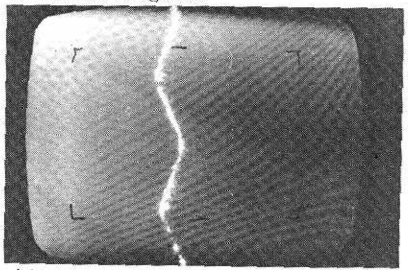
observed through microscope. If the test piece is sent stepwisely towards the direction A in the figure two dimensional measurement of the surface roughness is accomplished.

Test apparatus system which is set up for the measurement of the turned parts is shown in Fig.2. He-Ne laser is used as the light source. The slit beam the width of which is less than 10μm is projected to the part so that the direction of the slit is parallel to the axis of the work piece. The image of the slit beam on the machined surface is magnified through the microscope and is sent into



(a) Cross section of a standard test piece for surface roughness



(b) Image of the cross section by the slit beam on the CRT monitor

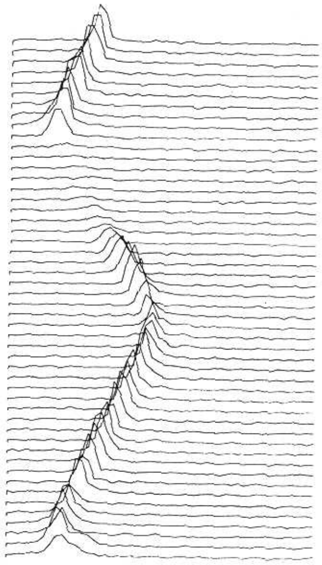
Fig. 3

the industrial television (ITV) camera. The image can be observed on the screen of monitering cathode ray tube (CRT) as a bright line. The signal of this image is digitized through AD converter along every scanning line and taken into CPU of YHP 21MX mini computer with 24K words core memory.

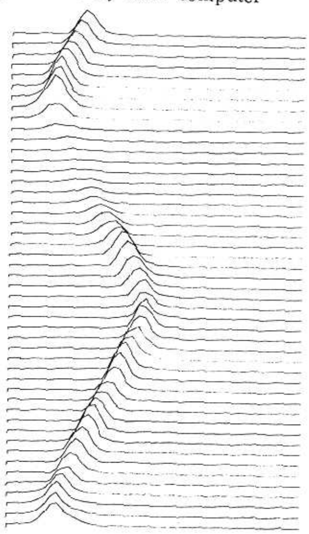
Bright point is recognized as that of high voltage in the computer. After this processing CPU drives pulse motor with rotating angle of 1.8 degrees for every step on which the test piece is set. The resolution of the image can be made up to 245 lines in the vertical direction and 265 lines in the horizontal direction.

3. Recognizing Process of the Image

Fig. 3 (a) shows a shape of standard test piece of surface roughness. Fig. 3 (b) depicts its image on the CRT screen. If the bright line is traced as a line, the cross section line of the roughness can be identified. Fig. 4(a) is drawn by x-y plotter



(a) Description of intensity of the image processed by mini computer



(b) Smoothed description of Fig. 4 (a)

Fig. 4

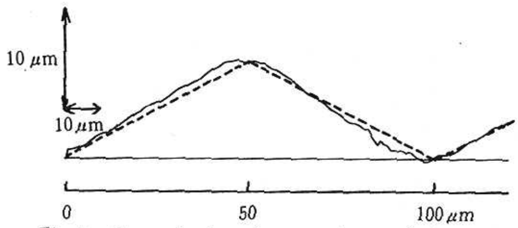


Fig. 5 Recognized surface roughness of the standard test piece

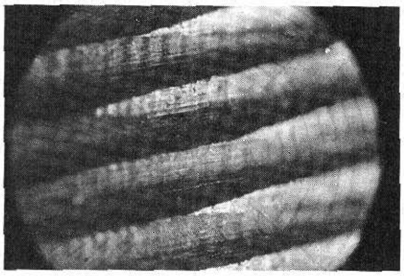
due to the digitized signal of Fig. 3 (b). Every scanning line of the CRT monitor corresponds to the line. It shows that the bright part on the scanning line stands as that of higher voltage.

However there are several problems to be solved before the cross section line of the surface is drived. Since the brightness of the image is not homogeneous and varies along the image due to the property of the surface matrix, and it is also affected by the diffraction of the projected beam on the surface, it is required to process the signal to recognize the image as the surface roughness. The smoothing of the data for Fig. 4 (a) is made by taking average as for the objective point and its surrounding four points. The result is shown in Fig. 4 (b). This makes it possible to trace the cross section line of the surface roughness by connecting the maximum of the every scanning line in the figure. Fig. 5 shows the result and it can be said that it is good expression for the test piece.

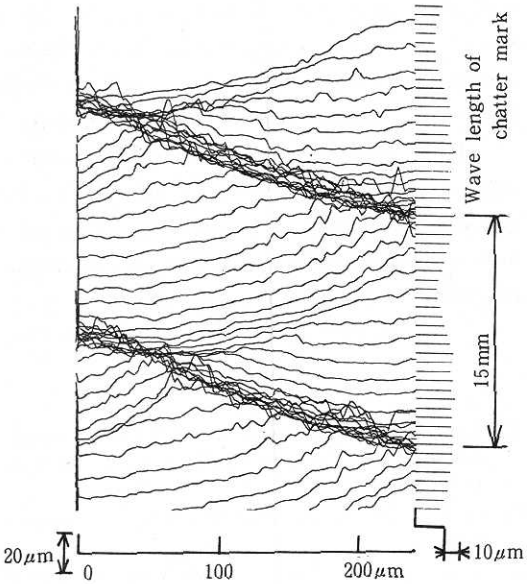
4. Example of the Measurement

The measuring procedure above mentioned is applied to a turned part of brass which have self-excited chatter mark. Fig. 6(a) shows a photo of the surface observed by a microscope. Fig. 6 (b) is the result in which every line describes the surface roughness along the line parallel to the axis for every 1.8 degrees. The sharp edge of the chatter mark is recognized as twisted thick lines. The concaved surface is seen as wide and narrow interval of every line of the cross section. This means that such two dimensional measurement of surface roughness makes it possible to visualize three dimensional texture of the surface.

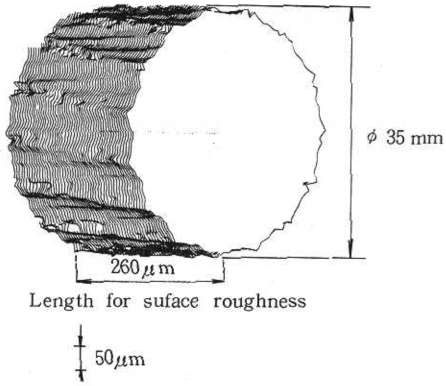
Fig. 6 (c) shows that the results in Fig. 6 (b) is superposed on the base circle. In addition to



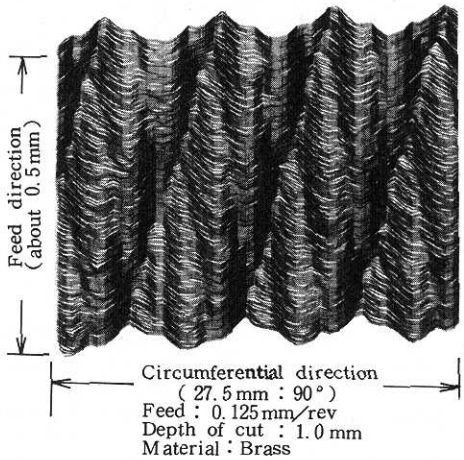
(a) Microscopic photo of self-excited vibration for turning



(b) Two dimensional surface roughness measured in circumferential direction for Fig. 5(a)



(c) Surface texture for Fig. 5(a) superposed on the base circle



(d) Developed expression of the surface for Fig. 5(a)

Fig. 6

conspicuous chatter mark slantwise ovserved small marks running parallel to the axis of the work are found. These are the trace of the multiple regenerative effect which works to keep the amplitude finite after the chatter occurs [3]. Fig. 6 (d) shows a developed part of the surface of Fig. 6 (a). This explains detail of the surface texture more precisely. These results help us to understand what is occuring during chatter.

5. Connection of the Image in the Feed Direction

It is required to measure the surface roughness in the feed direction, which corresponds to the conventional measurement. If the work is sent in the feed direction, some part of image before the feed is necessary to be connected with that after the feed. Fig. 7 (a) explains the procedure.

In this figure image of the part B is stored as the reference, and the image of the part A is that to be connected. As the evaluation function for the connection 1) the minimization of the difference area of the both image pattern and 2) the maximization of the correlation of the both pattern are studied. This is carried out for the standard test piece of the surface roughness. These evaluation functions are described as follows,

1) Expressing the area of differnce as $s(R, Y)$

$$s(R, Y) = \sum_{i=1}^{N} |d_{AV} - (R_i - Y_i)| \quad \rightarrow \text{MIN}$$

where

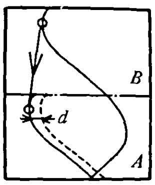
$$d_{AV} = [\sum_{i=1}^{N} (R_i - Y_i)]/N$$

2) Denoting the correlation as $s(R, Y)$

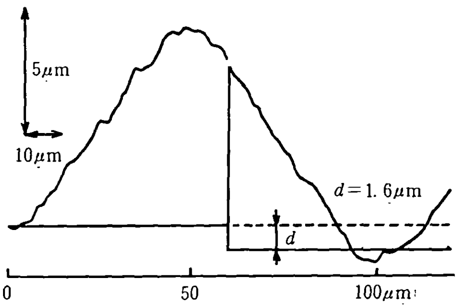
$$s(R, Y) = (R, Y)/\|R\|\,\|Y\| \quad \rightarrow \text{MAX}$$

In these descriptions R and Y mean the image pattern of reference and that to be measured respectively.

At the moment better results are obtained by the first criterion. Fig. 7 (b) shows the image can be connected smoothly by this procedure.



(a) Explanation for connecting the cross section line of the surface in the longitudinal direction



(b) Example of the connection based on the procedure shown in Fig. 6 (a)

Fig. 7

6. Conclusion

It was proposed to measure the surface roughness by processing the image of the cross section due to slit beam through ITV which was connected with a mini computer. The following conclusions were obtained by the investigation. 1) The procedure and the algorithm to recognize the image of the cross section of the slit beam on the surface was developed. Automatic image processing for this sort of surface roughness measurement was made possible. 2) It was shown that the surface roughness of the circumferential direction with width of slit beam could be instrumented. Three dimensional view of the surface texture could be well observed by this method. 3) A principle to extend the measurement shown in 2) to the longitudinal direction which might cover the wide range of the surface characteristic was studied.

It is expected that this approach would be applied to the investigation of the self-excited vibration of cutting, the accuracy due to the stiffness of the machine tool structure, the lubrication effected by the surface roughess and so on.

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7. References

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2) G. Schmaltz: Techniche Oberflachenkunde, Springer, 1936

3)* Y. Kondo and H. Sato: A Study on Self-Excited Vibration in Turning, Preprint of JSME Annual Meeting, 760-14, 1976-10, 21

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