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Measuring discontinuity shape using laser displacement sensor

~Influence of measuring edge shape~

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Abstract

On-machine measurements using laser displacement sensors are paid attention to improve reliability and productivity at the manufacturing site of industrial products. However, the shape of a measuring object presents several issues when undertaking practical dimensional measurements using laser displacement sensors. Several issues occurring during measurement can lead to error. Many attempts have been taken to identify the causes of error, but they have not been confirmed. If we can identify the causes of error, laser displacement sensors can be applied to on-machine measurement. Therefore, we tried to identify them as described herein.

Keywords—Laser displacement sensor, Precision measurement, Spacial filtering, Profile projection, On-machine measurement

1. Introduction

Laser displacement sensors are paid attention to measure the complex shape in the precision field, partly because they can take measurements faster than contact type displacement sensors can. Nevertheless, some problems occur because of measured object shapes. Shapes are roughly classifiable as having a continuous surface or a discontinuous surface. The dimensional measurement field particularly requires attention to discontinuous surfaces and demands accurate measurement of edges. The edge position, sensor spot position and sensor output must be grasped simultaneously to detect the edge. Nevertheless, it is impossible to detect an edge position using only sensor. Based on these, we tried to clarify an edge using a combination of a laser displaced sensor and Anti-Pinhole (A.P.) method. A.P. method is a new system for profile projection using a spatial filtering system.

2. Measurement principle

2.1. Anti-Pinhole method

We developed high-accuracy systems to detect edge positions using spatial frequency filters. Figure 1 shows that rays of two types arise when a laser irradiates a measuring object. Today however, it has been difficult to discern edge positions because of light interference, as shown on the left side of Table 1. Therefore, we proposed through-only diffracting rays using a pin-gauge as a spatial frequency filter. This process detects the edge position with sub-micrometer accuracy, as shown on the right side of Table 1.

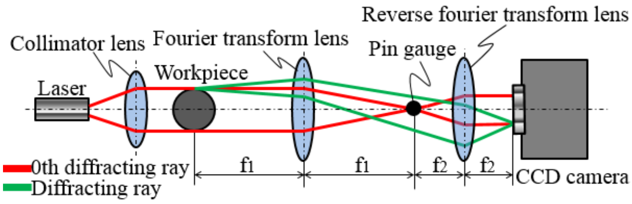
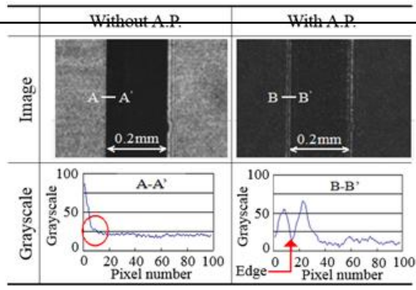


Figure 1. Principle of A.P. method.

Table 1 Comparison with images and grayscales.



2.2. Optical system to detect and measure an edge shape

The optical system depicted in Figure 2. Its conditions are presented in Table 2. After projecting an edge first using A.P. method, the irradiating sensor's laser is like Figure 2. In doing so, we can project both the edge and sensor spot in a CCD camera. Sensor's laser brings about a strong scattering ray at the edge point, as shown by the dashed arrow in Table 3. Therefore, we proposed sensor placements of three types shown in Table 3.

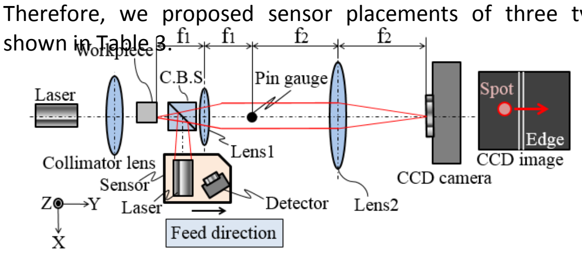
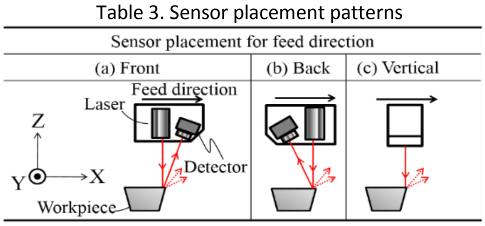


Figure 2. Optical system for detect edge position and measurement.

Table 2. Experimental conditions

Sensor		KEYENCE LK-G30
Workpiece		Work material : Cemented carbide, □15 × 15,Sub mirror finish
Lens 1 focusing length [mm]		50
Lens 2 focusing length [mm]		550
CCD camera	Pixel number	1600(H) × 1200(V)
	Pixel size[μm]	4.6(H) × 6.2(V)

Table 3. Sensor placement patterns



3. Experimental results of detect edge and measurement

Figure 3 presents results. In both of the graphs, the red line is the edge position detected using A.P. method. The abscissa shows the distance between the sensor spot centre and the edge position: δx. In the graph, (a), (b), and (c) respectively signify the placement for the feed direction, as shown in Table 3. Both graphs present relevant data.

1) Even though the measurement surface is perfectly flat, displacement changed from δx = -50 μm to δx = 50 μm at (a) and (b) types of sensor placement.
2) Laser displacement sensor spot is in the crossed edge position, nevertheless sensor still outputs information.

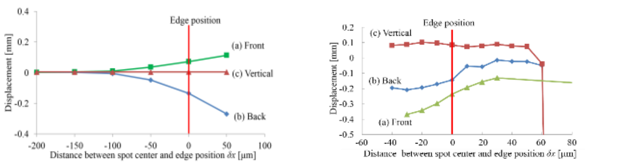


Figure 3. Experimental results (PSD/CCD).

4. Experimental considerations

Regarding 2) in III, we clarified ISOT2013 [1]. Therefore, we now explain 1) in III. First, a sensor's detector ordinarily only detects rightward and leftward movement as displacement, as shown in Figure 4. Table 4 shows our assessment of the top view and side view of the workpiece. As shown in the left side of Table 4, the sensor's spot is located in the middle of the workpiece. The spot in the detector and light distribution are shown on the left side of Table 4. Then, the sensor spot moved to the nearby edge. In this case, the spot in the detector and light distribution are shown on the right side of Table 4. Therefore, only a partial spot come into the detector. In comparison with these, one can realize a difference in the spot in the detector. Accordingly, the light distribution will change. The peak position also changes. In contrast, no change of displacement was observed at the sensor placement of the vertical type. The sensor placement was changed. The detector placement also changed along with it. As described above, the sensor's detector ordinarily only detects movement rightward and leftward as displacement: upward and downward movement is not detected as displacement. This can be regarded as the cause of 1) in III. It is necessary to ascertain whether the peak position is changed or not by differences of sensor placement.

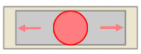
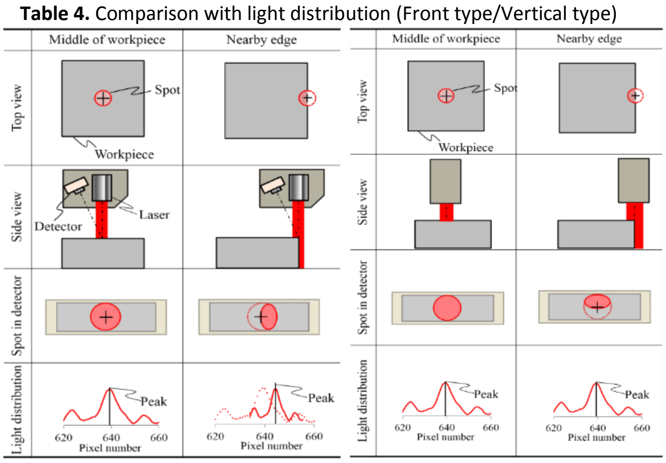


Figure 4. Displacement direction of detector.

Table 4. Comparison with light distribution (Front type/Vertical type)



5. Spot observation experiment

5.1 Experimental setup

We attempted spot observation on the detector. The optical system used for spot observation is shown in Figure 5. We used a camera instead of detector and observed a spot on the detector to ascertain whether the suppositions described in IV are correct or not. Specifications are presented in Table 6.

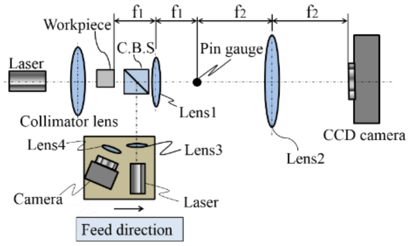


Figure 5. Optical systems for spot observation.

Table 6. Specifications of spot observe sensor

Lens 3 focusing length [mm]		50
Lens 4 focusing length [mm]		200
CCD camera	Pixel number	1600(H)×1200(V)
	Pixel size[μm]	4.6(H)×6.2(V)

5.2 Experimental results

In these graphs, the vertical axis shows the X-direction peak position of the camera, which is the same as the detector's detect direction. The abscissa shows δx, the distance between the sensor spot centre and edge position. For this experiment, the sensor spot size is 100 μm. Therefore, δx of 50 μm is the moment sensor spot hits the edge. As might be readily apparent, results match our suppositions. The peak position changed at a moment sensor's spot hit to edge and peak position changed gradually. In contrast, right side of Figure 6, the peak position did not change even if a sensor's spot hit to edge.

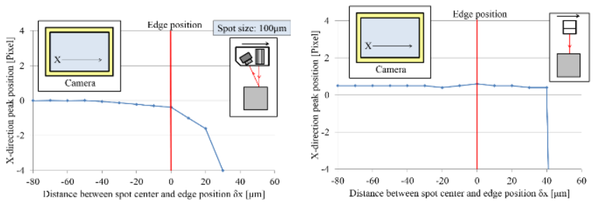


Figure 6. Transition of peak position.

6. Conclusions

(1) We proposed optical systems with a combined laser displacement sensor and A.P. method.
(2) Using (1), we estimated the output of the laser displacement sensor at the edge position.
(3) Sensor outputs were completely altered by different sensor placement.
(4) Sensor output's edge position was off to the side from actually edge position.
(5) The cause of (3) was identified as a change of the peak position.
(6) The cause of (4) was identified as sensor keeps output until laser spot slip off the measurement surface.

Accordingly, we should measure the edge shape with vertical sensor placement for the feed direction and consider error of radius of laser spot. By doing so, we can use laser displacement sensors to on-machine measurement. We will strive to measure chamfered workpieces in future studies.

References

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