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Inspection of Structural Adhesive Using Line-Laser Based Vision System

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Abstract

The paper studies about a line-laser based vision system to measure structural adhesive as a non-invasive inspection. It proposes a novel vision system to measure height and width of adhesive (or object) by optical triangulation using line-laser, and analyzes for resolution, gaze angle, focal length and baseline of vision camera, proper to measurement. The validity of the proposed method was verified through actual measurement of structural adhesive.

Keywords*: line laser, vision system, structural adhesive, optical triangulation, non-invasive inspection*

1. Introduction

Lately, in order to enhance hardness, collision performance, and durability of automotive frame, conjugation technique based on structural adhesive, instead of mechanical fastening technique, is widely utilized, for resisting complex production situations; light weight of product, factory dust, and product waterproof *etc*.[1]

A camera based vision system integrated with inspection equipment using laser is widely used to inspect ointment of automotive structural adhesive. Laser based inspection equipment may be possible to check whether or not adhesive was applied, but has a disadvantage to examine quality of product. On the other hand, vision based inspection equipment is widely used, as it is low cost and can be applicable to adhesive ointment success or failure, and quality examination of product. Thickness inspection, as well as adhesive ointment success or failure and width inspection, is also required to recently enhance reliability of product. Although stereo vision system can be applied for inspecting width of adhesive, it has a difficulty in acquiring disparity of maximum height, since width of adhesive is narrow and its surface is flat.[2, 3]

The 3D object scanner is used to rapidly capture shapes of objects. Optical triangulation is a typical technique which achieves high-range accuracy with simple calculation and can be applied to objects which are located within a range of up to a few meters from 3D scanner. The inspection by optical, non-invasive methods for analyzing surface objects or those surfaces, is also introduced. Optical triangulation allows establishment of metrological systems, due to its inherent relative simplicity, robustness and reliability which can cope with most modern requirements of non-invasive inspection for objects and those surfaces [4-9].

In this paper, line laser based vision system was studied to measure height and width of structural adhesive, as a non-invasive inspection. It introduces a novel measurement system to inspect height and width of adhesive (or object) through optical triangulation using line laser, and analyzes resolution, gaze angle, focal length and baseline of camera,

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proper to measurement. The validity of proposed line laser based vision system was verified through experiments for linear object, similar with structural adhesive.

2. Line Laser Based Vision System for Structural Adhesive Inspection

A construction drawing of a line laser based vision system for structural adhesive inspection is shown in Figure 1. It basically consists of a structural adhesive dispenser, a line laser pointer and a camera. The line laser beam is perpendicularly shined to the structural adhesive, and its scene is captured by the camera. The height and the width of adhesive can be calculated through optical triangulation.

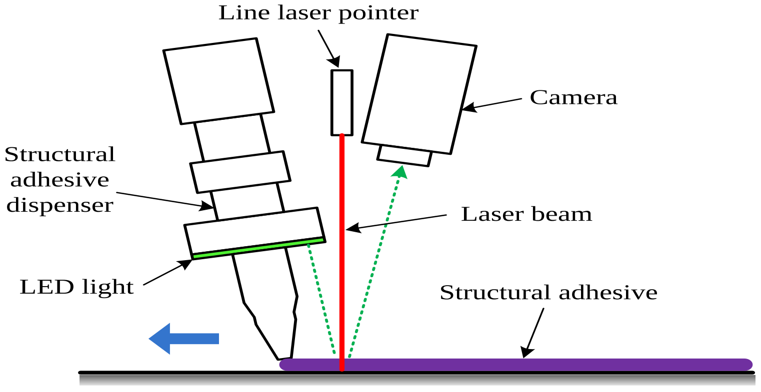


Figure 1. Schematic of a Vision System for Structural Adhesive Inspection

A concept of optical triangulation geometry is shown in Figure 2. Line laser is vertically installed to reference plane and camera is leaned with gaze angle θ. The image of laser beam mirrored to reference plane falls at zero central coordinates. For distance B between camera and laser, vertical distance D_0 between camera and reference plane is given by

$$D_o = B / \tan \theta . \quad (1)$$

When laser beam is shined to an object located at height H from reference plane, the image is mirrored on image plane falls on a location away with h from central coordinates. In other words, as height of object H get higher, position of laser beam mirrored on image plane is dislocated with h, the related formula is as follows;

$$\phi = \tan^{-1} \frac{h}{f} \quad (2)$$

$$D_h = \frac{B}{\tan(\theta + \phi)} \quad (3)$$

$$H = D_o - D_h \quad (4)$$

where f is the focal length of the lens.

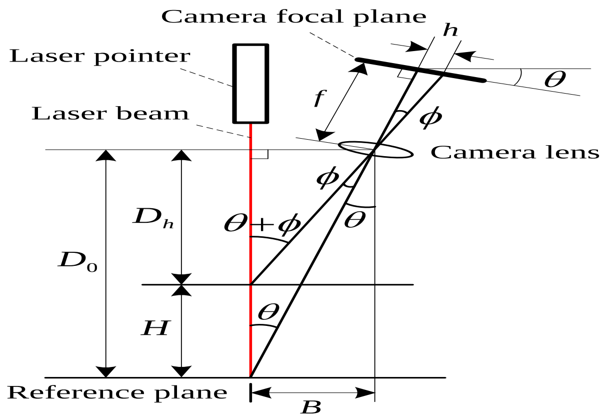


Figure 2. Concept of Optical Triangulation Geometry

Fig. 3 shows laser profiles for direction between laser and adhesive. In case ointment direction of adhesive is perpendicular to line laser direction, height *H* and width *W* are easily obtained as shown in Figure 3(a). However, for skew angle α between structural adhesive and line laser as shown in Figure 3(b), *W'* is calculated from *W'*/2 (distance between of *B* and *C* in Figure 3(b)), after obtaining tangential intersection point *A* of parallel line with line laser and perpendicular point *B* with line laser. Figure 3(c) presents a case of that ointment plane of adhesive is inclined. In this case, height and width can be calculated from point *B* and *C* after obtaining tangential intersection point *A* of parallel line with line laser.

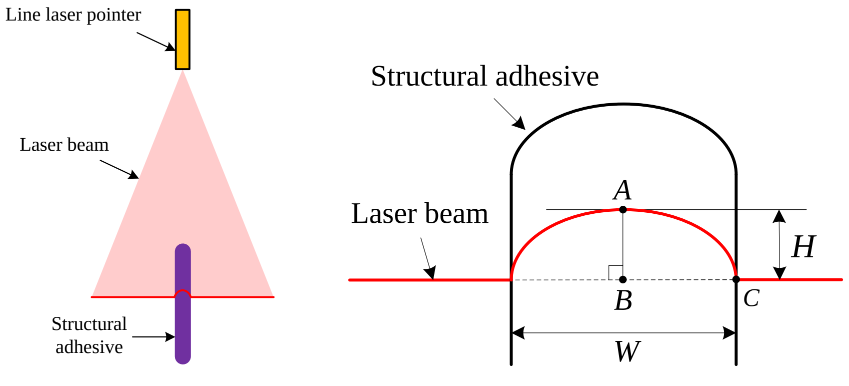
The width of object can be obtained using triangle similarity condition, and it is given by

$$W = \frac{D_o h_h}{f \cos \theta} \tag{5}$$

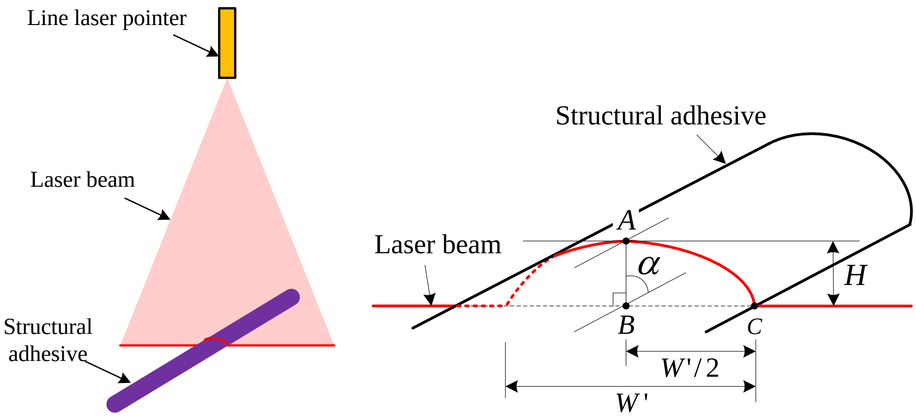
where h_h is horizontal displacement on image plane. As shown in Figure 4, in case direction of adhesive is not perpendicular to line laser direction, actual width *W* is given by

$$W = W' \cos \alpha \tag{6}$$

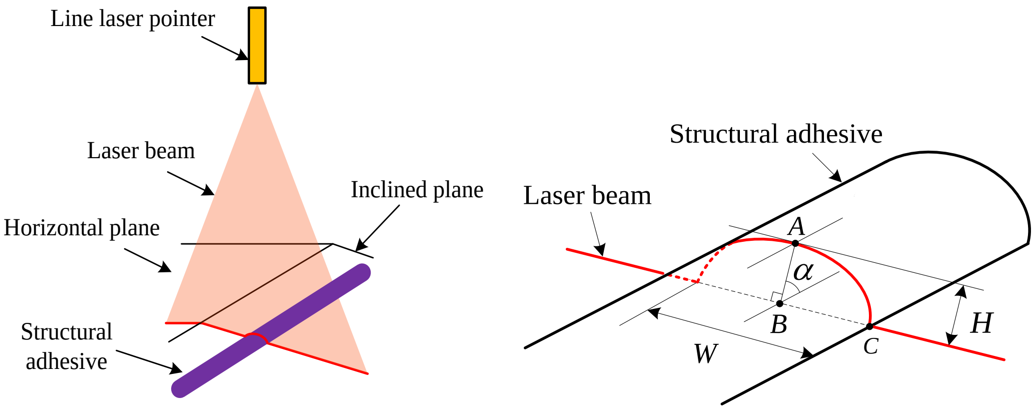
where *W'* is measured width and α is skew angle.



(a)



(b)



(c)

Figure 3. Laser Profiles: Directions between Laser and Adhesive are (a) Perpendicular and (b) Not Perpendicular, and (c) Ointment Plane is Inclined

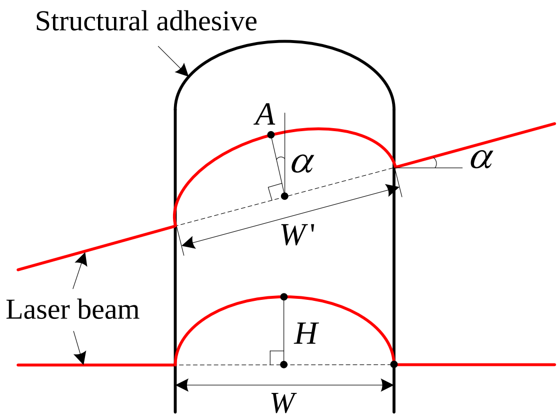


Figure 4. Laser Profiles Corresponding to Direction of Laser and Adhesive

The important parameters related to laser based optical inspection system include a focal length *f*, a baseline *B* and a gaze angle θ of camera. D_0 is depends on θ and *B*, as shown in eq. (1). Figure 5 shows the proportion relation between object height *H* and displacement *h* on image sensor plane corresponding to gaze angle θ. We can see that the curve is plotted with a nonlinear characteristics for small θ. Figure 6 shows the relation between object height *H* and image displacement pixel corresponding to focal length *f*. The image displacement pixel is proportional to *h*, and we assumed that one pixel size is 7.6μm. The higher focal length is (similarly, zoom-in effect), the smaller object can be measured.

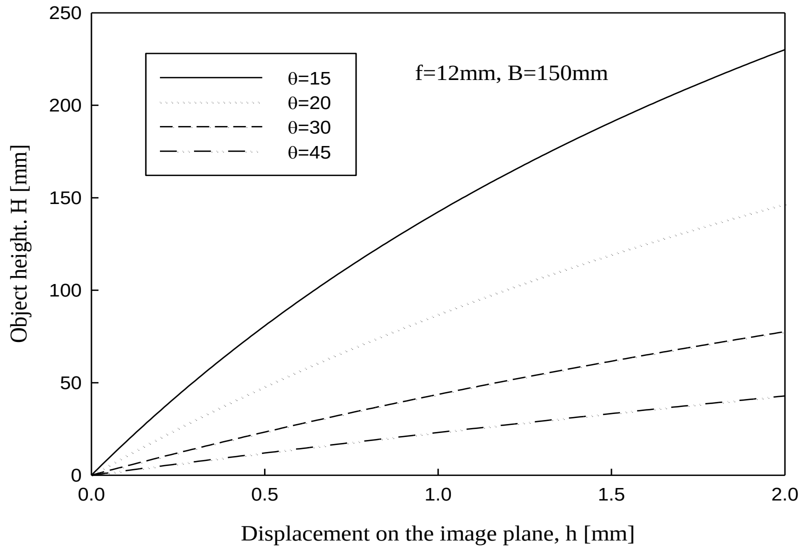


Figure 5. Object height *H* vs. Displacement *h* Corresponding to Gaze Angle θ

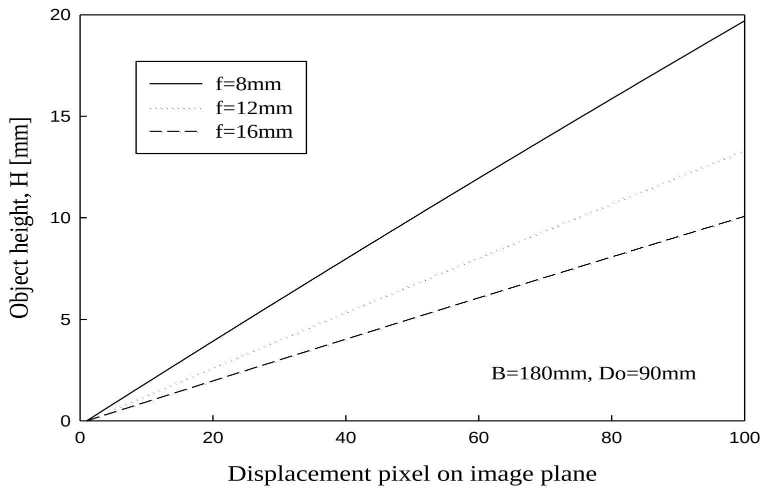


Figure 6. Object height *H* vs. Displacement Pixel Corresponding to Focal Length *f*

4. Experiment Results

Experiments for measuring height of structural adhesive were conducted through the proposed line laser based vision system. The camera specification used in the experiment is shown in Table 1. The images were captured to 640×640 resolution, so this has an effect on a pixel size on image sensor(actually, 7.6μm×7.6μm/pixel).

Table 1. Specifications of the Camera used in Experimentation

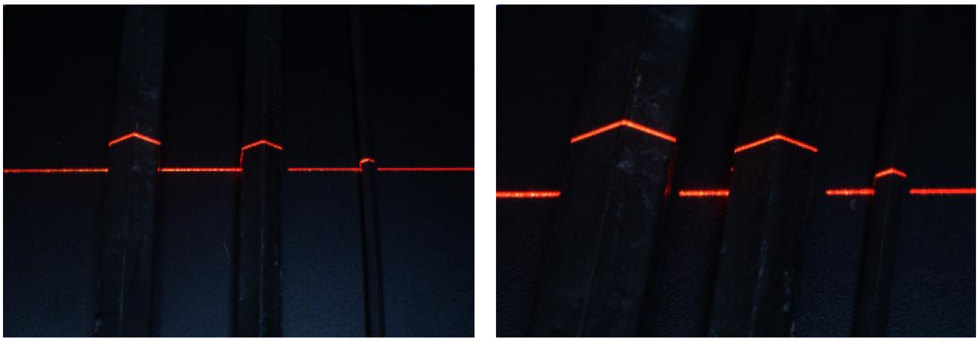
Sensor size	Resolution	Focal length	Pixel size	Image area
1/3 inch	976(*H*)×496(*V*)	8 & 16mm	5.00μm×7.40μm	4.88mm×3.67mm

Figure 7 shows an example of experiment for measuring width of 3 type (10mm, 8mm, 3mm) hexagon wrenches and mock adhesive. Then, the measured height and actual one were compared from the result image. At focal length of 8mm, as shown in Figure 7(a), wrenches of 10mm and 8mm are seen with high visibility, on the other hand, one of 3mm is not seen with good resolution. Figure 7(b) shows images acquired at focal length of 16mm. We can know that wrench image of 3mm has high resolution compared to the wrench image in Figure 7(a), due to zoom-in effect by high focal length.

Figure 8 shows images for mock adhesive and wrench of 3mm, acquired at focal length of 8mm and 16mm. In case of long shutter speed as shown in Figure 9(a), laser beam is spread due to beam saturation. On the other hand, the beam is thin on the image captured by short shutter speed, as shown in Figure 9(b).

Table 2 represents the calculated height and width for 3 type hexagon wrenches and mock, active adhesive. From captured images, we searched image displacement pixels associated with object height and width, and calculated vertical and horizontal displacements, h_v and h_h, through producting of a pixel size 7.6μm. Then height H and width W are calculated through eq. (1) to eq. (6).

The difference error between actual value and measured one is caused by inaccuracy of parameters included at optical system modeling. Therefore, compensation process through precise experiment is needed to reduce the measured errors, as future work.



(a) (b)

Figure 7. Captured Images of the 3 Type (10, 8, and 3mm) Hexagon Wrenches: (a) *f*=8mm and (b) *f*=16mm

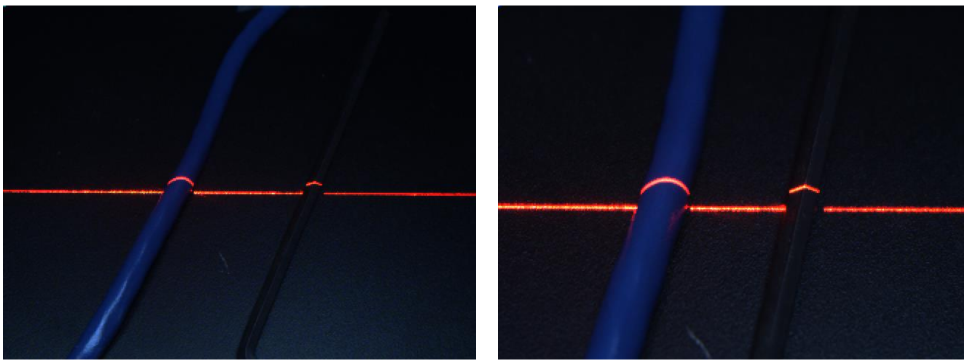


Figure 8. Captured Images of an Mock Adhesive and a 3mm Hexagon Wrench: (a) *f*=8mm and (b) *f*=16mm

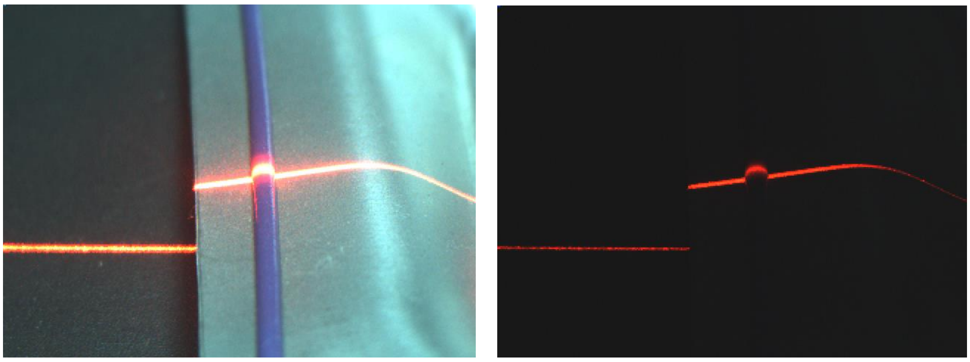


Figure 9. Captured Images of Actual Adhesive: Shutter Speed is (a) Long and (b) Short

Table 2. Results of Experiment (*B*= D_0=110mm)

Test object	Hexagon wrenches			Adhesive	
	10mm	8mm	3mm	Mock	Active
Focal length, *f* [mm]	8	8	16	16	16
Vert. displacement, h_v [mm]	0.39	0.30	0.23	0.29	0.11
Calculated *H* [mm]	10.22	7.95	3.12	3.92	1.50
Hori. displacement, h_h [mm]	0.54	0.41	0.30	0.50	0.24
Calculated *W* [mm]	10.50	7.97	2.92	4.86	2.33

4. Conclusions

In this research, a line laser based vision system to inspect status of structural adhesive was proposed. Based on triangulation using line laser, height and width measurement method of objects was introduced. The validity was confirmed through experiments. Because height and width of actual structural adhesive are small, width of laser beam should be slender and imaging sensor with high resolution is required.

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