Technology Introduction

Development of 3D Dimension Inspection Device by Image Processing

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1 Introduction

KYB's automobile shock absorber (hereinafter "SA") consists of multiple parts welded together. SAs are to be installed on vehicles by fastening with bolts (Fig. 1). Prior to shipment, SAs are subjected to dimensional inspection by manual measurement to verify the position of the mounting holes to be used for installation on vehicles and the outside dimensions. However, this way of inspection involves human error and would impose a higher burden on measurement personnel as the lot size is becoming smaller. To solve these problems, a 3-dimensional (3D) dimension inspection device using image processing has been developed. This article introduces the device.

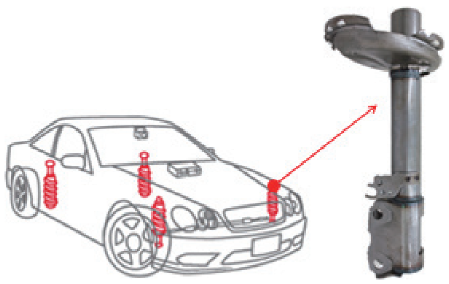

Fig. 1 Shock absorber

2 Purpose

To develop an automatic inspection device capable of measuring 3D dimensions (hereinafter the "inspection device") and introduce the inspection device to improve the quality assurance level.

3 Required Functions of Inspection Device

The inspection device is required to have the following three functions. We have developed an inspection device equipped with all these functions:

①Capable of 3-dimensionally (X, Y, Z) measuring the position and angle of target parts

②Capable of freely selecting the measuring position to support measurement of various models (Required measuring positions vary by target vehicle model).

③Automatic measurement and pass/fail evaluation

4 Measuring Objects and Measurement Items

Fig. 2 shows the measuring objects and names. Table 1 shows the measurement items for the target parts. The parts are welded onto an outer casing. Installation position and angle vary by model, and the measurement position varies by model accordingly. Therefore, measurement must be carried out in many directions. Furthermore, in addition to hole measurement, in-plane points measurement is also required.

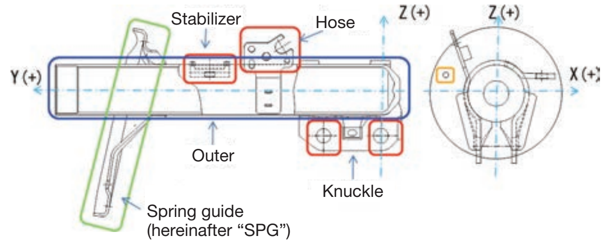

Fig. 2 Measuring objects and names

Table 1 Measurement items

Measuring object	Measurement item
Knuckle, hose, stabilizer (bracket)	Hole position and angle
SPG rotating direction	Hole position
Inclination of SPG	Position of 3 points on a plane
Outer casing	Position of cylindrical shaft

5 Overview of Inspection Device

5.1 Measurement methods used

The measurement device uses non-contact measurement techniques to enhance the degree of freedom. Among the three measurement methods listed in Table 2, the optimal one is selected for each measuring object.

Table 2 Measurement methods

Measuring object	Measurement method
Knuckle, hose, stabilizer (bracket)	Optical cutting (image processing)
SPG rotating direction	Stereo measurement (image processing)
Inclination of SPG	Measurement using laser displacement sensors
Outer casing	Measurement using laser displacement sensors

5.2 System configuration

Fig. 3 shows the system configuration of the inspection device and Photo 1 shows a fabricated device. The features of the inspection device are described below. The functions will be explained in detail in a separate section.

①The introduced measurement system is designed to measure a rotating product. This allows the device to have a lower number of cameras, leading to a lower increase in cost and easier maintenance.

②An algorism to enable high-precision measurement of the position of holes made by pressing has been developed and implemented (with the optical cutting method applied).

③A measure to reduce the possible effects of ambient temperature variations on measurement accuracy has been taken so that in-plant measurement can be conducted.

④Inspection result visualization and data analysis functions have been implemented to allow early detection/analysis of failures.

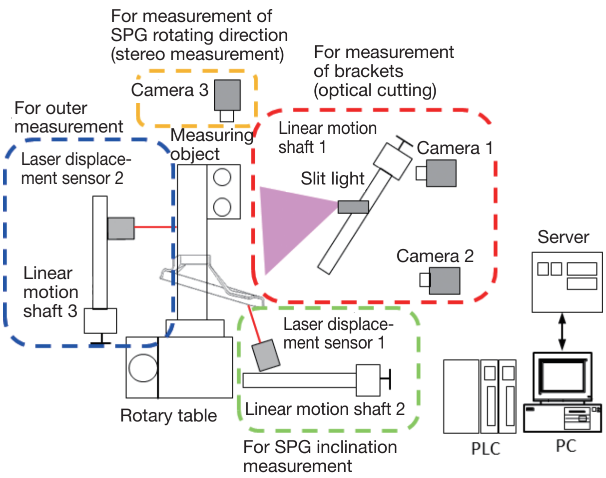

Fig. 3 System configuration

Photo 1 Appearance of inspection device

5.3 Operation flow

Fig. 4 shows the operation flow of the inspection device.

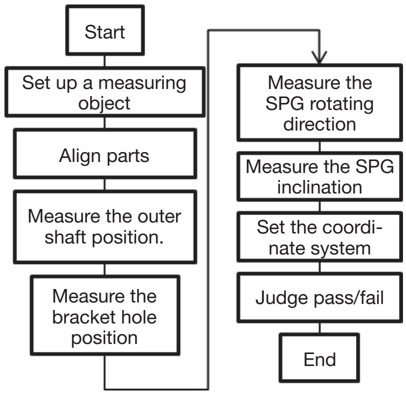

Fig. 4 Operation flow

6 Principles of Measurement of Optical Cutting Method

This section explains the principles of measurement of the optical cutting method, which is the main technique used in the inspection device. [1)]

There are three minimum elements for the device to implement optimal cutting: a camera, slit light projector and measuring object (Fig. 5). Measurement should take place in steps; ① Irradiate the measuring object with the linear slit light, ② Shoot the slit light projected on the inspection work from another direction; and ③ Acquire the 3D positional information about the target from the captured images and the relationship between the slit light irradiated position and camera position using the principles of the triangulation technique.

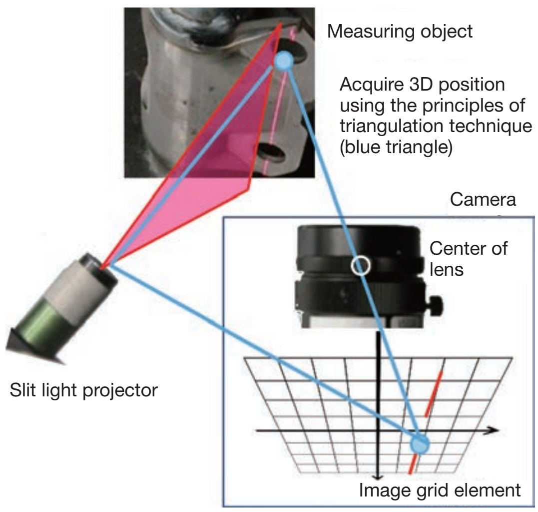

Fig. 5 Principles of measurement of optical cutting method

7 Features of Inspection Device

7.1 Measuring the turning product

For measurement with the minimum device elements described in section 6 using the optical cutting method, the measurement range is only limited to the plane where the slit light is projected. However, this inspection requires measurement in a 3D space. That is, the measurement range must be expanded. Then, the inspection device uses a drive to move the slit light projector along a single axis and a rotating mechanism to turn the measuring object. This combination achieves the required measurement range.

The use of this configuration makes it possible for the inspection device to have the minimum number of components including cameras and slit light projectors, leading to a lower increase in cost and easier maintenance.

7.2 High-precision measurement algorism for pressed holes by optical cutting method

In the optical cutting method, the 3D position data acquisition range for a single beam of slit light is limited to along the slit light, as explained in section 6. For general hole position calculation using the optical cutting method, thus, multiple slit light beams are used to detect the endpoint where the slit light beams disappear in the hole by image processing and calculate the hole position as shown in Fig. 6.

In this method, however, the calculation of the center of the slit light always involves an error attributable to the irregular reflection of the light at the hole edge and the width of the slit light. These problems made it difficult to accurately detect the endpoint of the slit light (Fig. 6) , which resulted in the hole position measurement error.

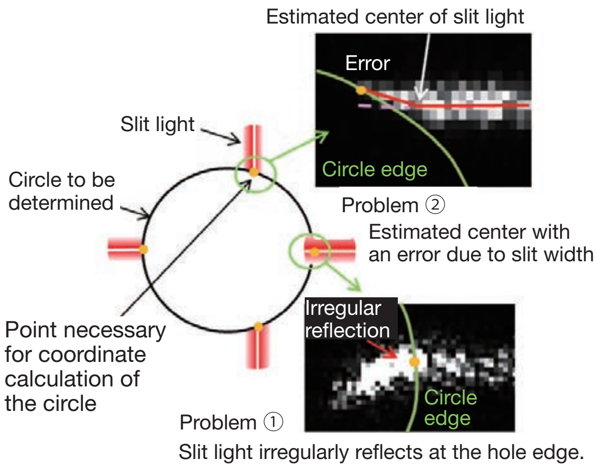

Fig. 6 Error factors for hole position measurement using optical cutting method

In this development project, these problems were solved by developing a positon calculation algorism (Fig. 7) based on the fact that the holes are made on a plane. This algorism allows that, once the 3D information of the plane of the target object is acquired, the characteristics of the images of the target object captured by monocular cameras can be used to obtain all the 3D positional information. The algorism can be applied not only to the optical cutting method, but also to other widely-expanding technology that allows 3D measurement of planes, including the stereo and optical radar methods.

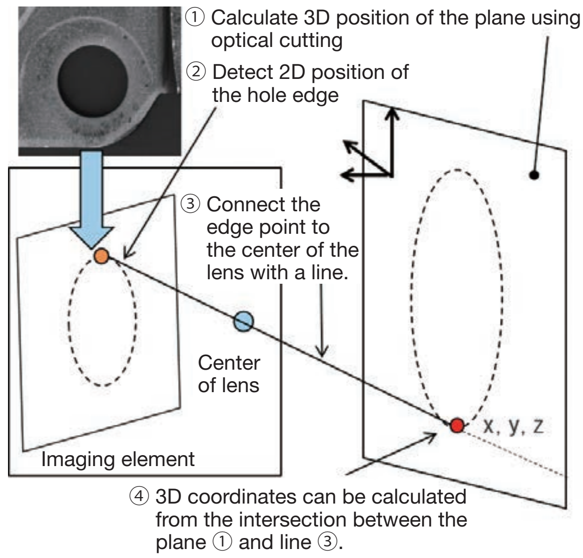

Fig. 7 Developed hole position calculation algorism using optical cutting method

7.3 Measures against effects of ambient temperature variations on measurement accuracy

Commercially available contact 3D measurement equipment is recommended to be used in spaces where the ambient temperature is controlled, in order to maintain measurement accuracy. However, it is unavoidable for this new inspection device, which is for in-plant use, to be exposed to a temperature variation of several tens of degrees Celsius throughout the year. The exposure would affect measurement accuracy. As an example, Table 3 shows the result of a simple trial calculation of the effect on accuracy:

Table 3 Simplified evaluation of effect of temperature variations on accuracy

Trial calculation condition	Distance between camera and measuring object	450 mm
	Fixed frame material	Steel
	Coefficient of linear expansion of steel	12×10^{-6}/K
	Temperature variation	10°C
Deviation from the distance between camera and measuring object due to temperature rise		0.054 mm

According to the table, a temperature variation of 10°C causes a deviation from the original position of the measurement equipment as large as 0.054 mm. Since the optical cutting method used in this inspection device is based on the principles of the triangulation technique that determines the position of an object from the positional relation with the camera, slit light projector and object, the effect of the positional deviation on measurement accuracy would be a problem. In addition, the inspection device carries out measurement while rotating the product, so the effect of temperature variations would be increasingly more severe. Measures to prevent the temperature variation are needed. The following describes the two measures against temperature effect we have actually taken.

① Using a low-expansion frame material

The amount of expansion of the frame due to temperature variation is proportional to the coefficient of linear expansion of the material. Then, we use a low-expansion material whose coefficient of linear expansion is 3 x 10^{-6}/K (1/4 of that of steel) in the frame of the inspection device.

② Measures to reduce frame temperature variations

The low-expansion material used in the frame is certainly unlikely to elongate, but the amount of elongation is not 0 (zero). To reduce the temperature variation of the inspection device frame, the frame is surrounded by a fence within which a compact air conditioner is installed. This provides an environment where the frame is unlikely to encounter temperature variation (Fig. 8).

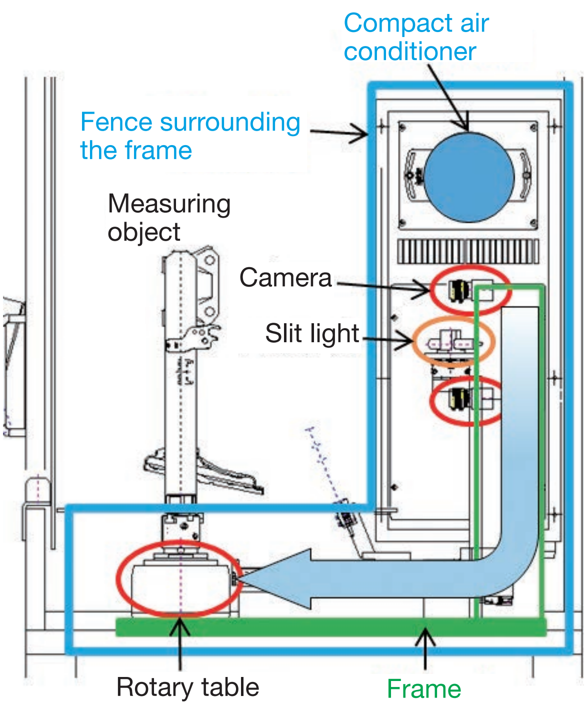

Fig. 8 Measures to reduce frame expansion due to ambient temperature variation

7.4 Inspection result visualization and data analysis

The inspection device monitor displays measurement results in the form of measurement and specification values for each measurement item and the results of pass/fail evaluation. The background color will change when NG or Action Note 1) results are given, allowing the operator to identify the faulty part at a glance. The history can also be viewed on another screen (Fig. 9). The measurement results can be centrally controlled by a control terminal software program[2]. Collected data can be displayed using the software in the form of trend data graph, histogram, standard deviation, Cp and Cpk. The software can also be used to identify data variations or as material for improvement.

Note 1) "Action" is given to a conforming product with a deviation from the design value by a certain amount. This evaluation result is intended to grasp the trend before nonconformity occurs.

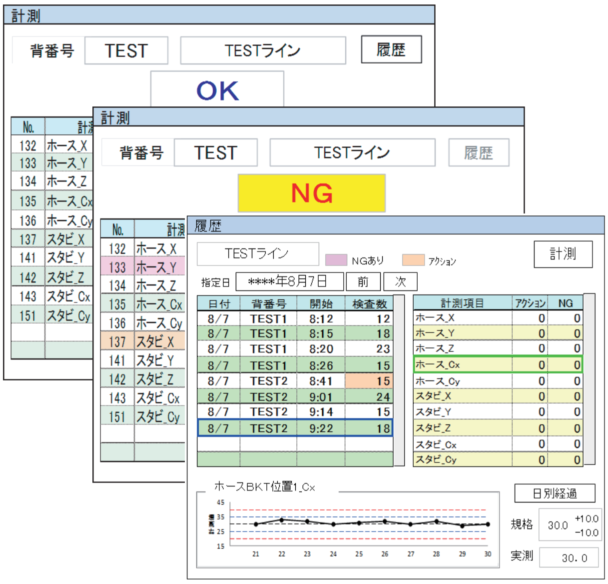

Fig. 9 Measurement result screen

8 In Closing

The 3D dimension inspection device capable of automatically measuring many different models of SAs has been developed and introduced, contributing to improved quality assurance.

In addition, the device is provided with inspection result visualization, data collection and data analysis functions. It is desirable to effectively use the data for early detection of failure and improvement activity for higher quality and higher productivity.

Finally, on this occasion I would like to deeply thank assistant professor Kunihito Kato of Gifu University, who was involved in the joint research[3], and the members in his office who extended great support and cooperation to this development project, as well all others who were involved.

References

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2) Akihiko Nishio, Kenichi Tanabe: Development of Inspection Support System, KYB Technical Review No.42, (April 2011).

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