Technology Introduction

Technology for Detecting the Orientation of Oil Seal

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1 Introduction

Recent production sites are required to automate their inspection process due to higher product quality requirements and reduced work force. In KYB, the Production Technology R&D Center and Production Engineering Department are jointly promoting the development of inspection technologies to automate the inspection process. Among those is the development of an automatic inspection technology to replace human inspectors allocated to the manufacturing process of oil seals (hereinafter "seals") that are one of the components of shock absorbers (hereinafter "SA"). The technology has been introduced in mass production. This paper describes the overview.

2 Purpose of Development

The purpose of the technical development is to automate the inspection process for inspector labor saving. A technology for detecting the orientation of the insertmetal (hereinafter the "metal"), which is one of the seal components, has been developed.

Human inspectors are allocated to the process of checking finished seals. The inspection technology we have developed is introduced into the process that may be the source of reversed metals, not the process of checking finished seals, with the aim of reducing the loss caused by non-conformities.

3 Target Parameters of Development

The target parameters for inspection capability and time were set as shown in Table 1. Evaluation error means recognizing a non-conforming item as a conforming one by mistake. In case of an evaluation error, non-conforming items will be released to the subsequent process, which may lead to claims in the market. Contrary to evaluation error, over-inspection refers to recognizing a conforming item as a non-conforming one. Over-inspection prevents work from being released to the subsequent process, resulting in a halt in the production. This eventually leads to lower productivity. The target inspection time was set based on the current visual inspection time of human inspectors to prevent worsening of the cycle time.

Table1 Target parameters of development

	Evaluation error [%]	Over-inspection [%]	Inspection time [sec.]
Target	0.000	Not more than 0.3	Not more than 2.1

4 Outline of Target Part

Photo 1 shows an enlarged view of the SA and seal assembly, the seal to be inspected, and the front and reverse sides of the metal.

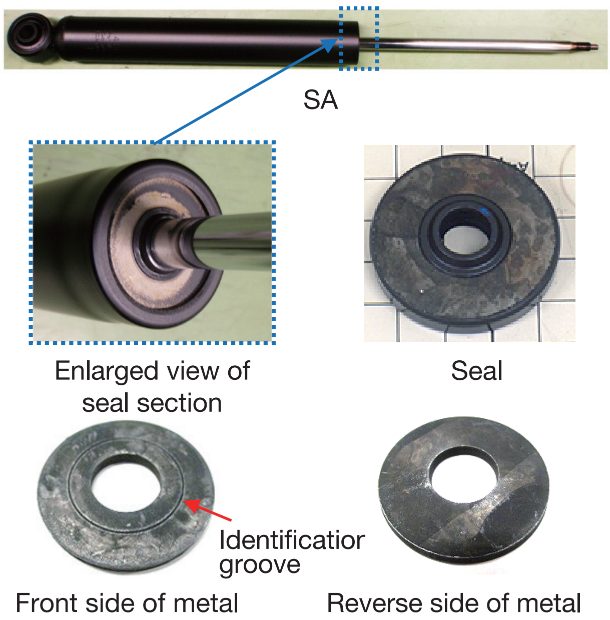


Photo 1 SA, seal, and metal

The seal is a part for preventing oil leakage through the sliding part of the piston rod of SA. The metal, which is one of the seal components, is molded integrally with rubber material to form the seal. The metal has front and reverse sides that can be differentiated from each other. Molding the metal into the seal with its wrong side up will result in a higher risk of oil leakage. To prevent this, the metal has an identification groove on one side. In this document, the side of the metal with the identification groove is called the front side.

5 Overview of Process with Inspection Technology Introduced

The inspection technology was introduced into the process in which human operators manually set metals and rubber pieces on the jig [Note 1)] before molding. Photo 2 shows the work bench and jig in the target process. The work bench had to be replaced by a device for automated inspection.

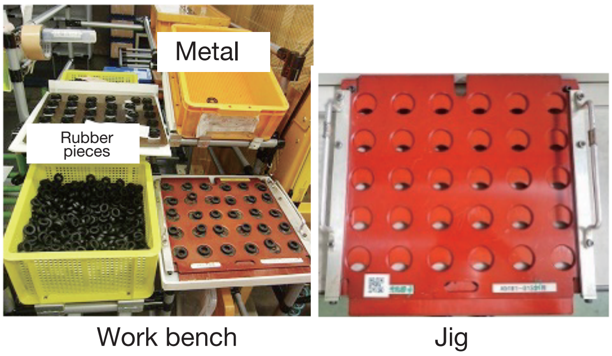


Photo 2 Work bench and jig

The operator puts the jig on the work bench and sets metals with the side with the identification groove facing up in the circular pockets one by one. Then, the operator places rubber pieces on each metal and sets the jig in the molding machine.

Note 1) The jig is used to set metals and rubber pieces in the molding machine.

6 Details of development

6. 1 Inspection Method

The inspection used an image processing system that can not only capture images from a position where the system cannot obstruct the operator but also examines all metals on the jig at a time. It was decided to determine whether the metals are front or reverse facing through image processing, superficially by detecting the presence of the identification groove, which is the most distinctive feature among the differences between the front and reverse sides.

6. 2 Inspection System

Fig. 1 shows an example of the configuration of the inspection system. Internally built communication software was used to transmit signals from the image processing and inspection software to the digital I/O board within the inspection PC. The digital I/O board and PLC [Note 2)] were interlocked so that metals could not be released to the subsequent process unless they passed the inspection.

The image processing and inspection software has inspection, calibration, and set-up modes as described later. The software was designed so that the calibration and set-up modes can be switched over with a push-button switch.

This loop-running inspection is automatically started when the operator's hand leaves the imaging area.

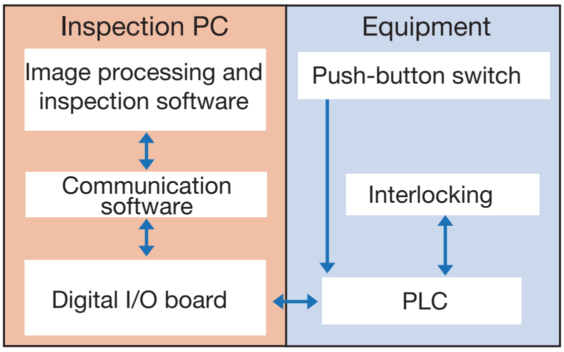


Fig. 1 Configuration of inspection system

Fig. 2 shows the flow chart of operation of the inspection software that was introduced in mass production:

Note 2) Acronym for Programmable Logic Controller.

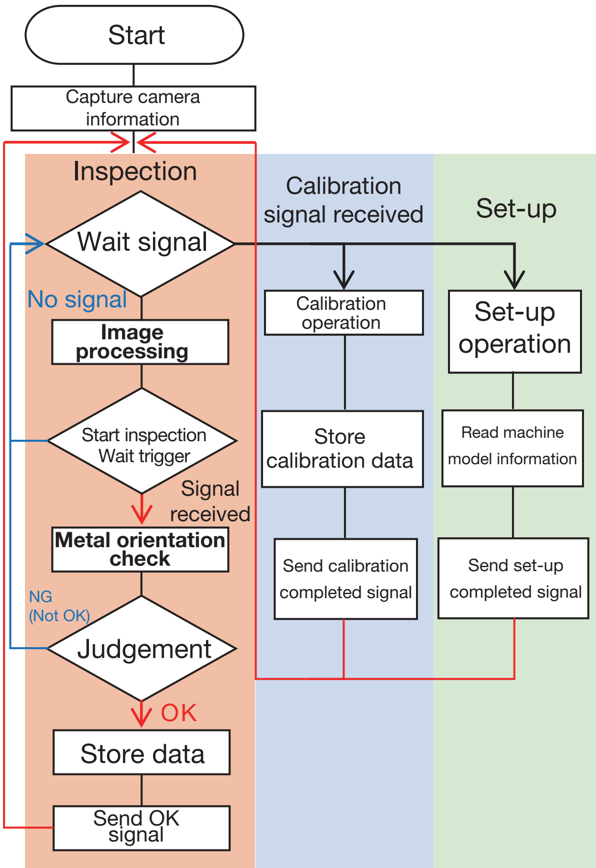


Fig. 2 Flow chart of software operation

In mass production, the push-button switch can be used to switch the operation mode from inspection to calibration or set-up. Inspection mode is run in loop and does not need to be started up with the switch. The system is configured to trigger the inspection when the operator's hand leaves the imaging area, and the molding machine has work in position. The image processing technology is used to locate the operator's hand and determine whether work is set in the machine or not.

This paper focuses on introducing the metal check (front/reverse side) in the flow chart.

6. 3 Optical Equipment

Photo 3 shows the actual inspection machine. Fig. 3 shows the general layout of the optical system. This optical system consisted of a camera and two lighting units. The camera was installed directly above the jig at a height where the camera could not interfere with the operators. The resolution of the camera and its lens were selected to enable the detection and imaging of the identification groove of the metals set in the jig. The lighting units were located in such a manner that allowed irradiation of the whole area of the jig from the right and left sides.

Photo 3 Actual inspection machine

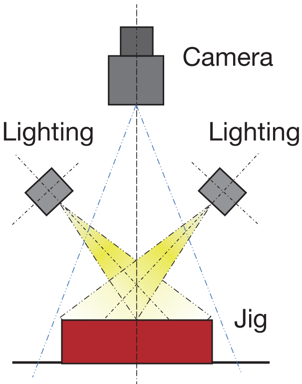
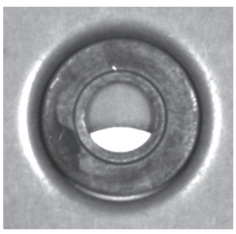


Fig. 3 General layout of optical system

Photo 4 shows images captured by the system on the actual inspection machine. Conditions for the inspection were set under the constraint that the layout of the lighting and camera system was limited by the equipment layout of the production line.

The inspection machine is likely to be affected by disturbance light because the machine cannot be covered with blackout curtain as this may lead to workability deterioration and the ingress of contaminants during molding. Then, an inspection algorithm has been developed that is unlikely to be affected by these factors.

Entire image



Enlarged view of image

Photo 4 Images

6. 4 Inspection Algorithm

6. 4. 1 Flow of Image Processing and Inspection

Fig. 4 shows the general flow of the processes from image capturing to inspection.

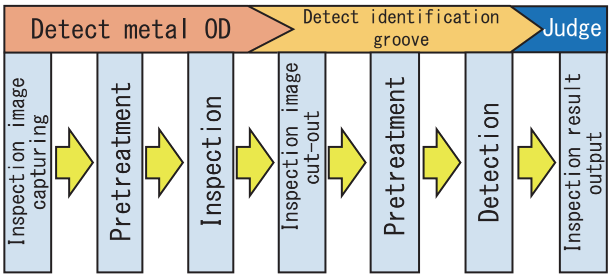


Fig. 4 General inspection flow

After an inspection image is captured, the outside diameter of the metals is detected to determine the position and number of metals. Then, only the area around the circular identification groove of each metal is cut out to allow detection of the groove. The number of grooves is compared with the number of metals to make a judgement. When these numbers match, "OK" is displayed. When they do not match, "NG" (Not OK) is displayed along with the location of the NG metal(s). For NG, the operator flips the reversed metal(s), automatically turning NG into OK.

6. 4. 2 Pretreatment

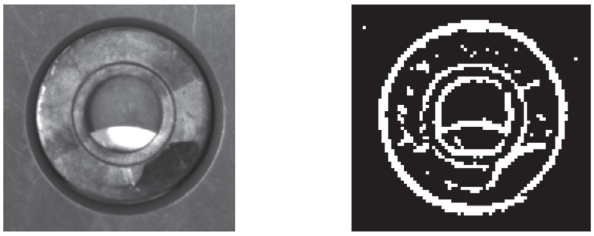
In practice it is difficult to directly detect the identification groove on the captured image. So, the image must be processed to highlight the features to be detected. In this project, a band-pass filter was introduced. The band-pass filter passes frequencies within a certain range and is used to extract the outside diameter and identification groove. As shown in Photo 4, the contour of the metals on the jig and their identification groove appears darker than the surroundings. The contour (outside diameter) and identification groove of metals can be extracted using the band-pass filter.

There is a difference in gray value [Note 3)] between the contour of the metals on the jig and their identification groove and the surroundings. This difference is considered unlikely to greatly diminish even if the metals are affected by disturbance light. So, the use of the band-pass filter allows the detection of elements of the outside diameter and identification groove of metals without being substantially affected by disturbance light.

The band-pass filter was applied with commands that had been prepared in the image processing software.

Note 3) The level of brightness. The white-to-black level is given by a number between 0 and 255.

Photo 5 shows an example of an image captured before treatment and another subjected to processing with the filter and automatic binary processing that allocates black or white to individual pixels according to their brightness. In the image after treatment, the areas in white indicate the parts that were extracted by the processing. Hereinafter the band-pass filter processing and the automatic binary processing are collectively called the pretreatment.



Before treatment　　After pretreatment

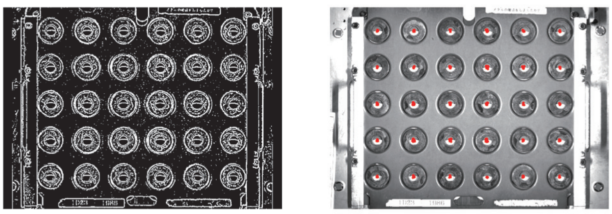
Photo 5 Images before and after image processing

6. 4. 3 Detection Method

Feature extraction from images subjected to pretreatment was done with the Hough transform technique. The Hough transform is a feature extraction technique used in image processing and can be used to detect lines and circles in the image. Circle detection finds any circles within the target image that match the diameter information that has been given in advance. If an applicable circle is found, the coordinate of the center of the circle is detected. In this project, the outside diameter of the metal and the diameter of the identification groove indicated in the drawing are used as the diameter information to be given to the system.

6. 4. 4 Detection of the Outside Diameter of Metals

The outside diameter of the metals is detected in the captured images that have been subjected to pretreatment and the Hough transform in terms of the outside diameter. Photo 6 shows an image after the band-pass filter processing and another image after the Hough transform in terms of the outside diameter. The dots in red appearing in the image subjected to the Hough transform are the dilated center points of the metals. The automatic inspection system determines the number of metals by counting the number of these red dots.

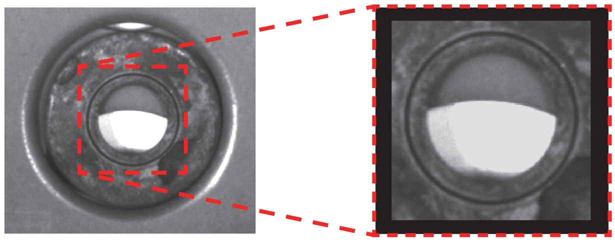


After pretreatment　　After Hough transform

Photo 6 Metal outside diameter detection process

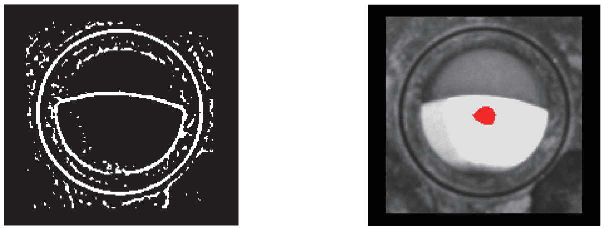
6. 4. 5 Detection of Identification Grooves

Photo 7 shows inspection images of the identification groove. This inspection uses the center of the circle detected by the Hough transform of the metal outside diameter. From the image, a rectangular section is cut out in dimensions larger than the diameter of the circular identification groove indicated in each drawing. Then, the images shown in right of Photo 7 are obtained as many as metals are captured in Photo 4. Each of the cut-out images is subjected to pretreatment and then the Hough transform in terms of the diameter of the circular identification groove. This will detect the identification grooves. Photo 8 shows an image after the pretreatment and another image after the Hough transform in which the center of the circle has been detected and dilated. The number of identification grooves can be determined by counting these center points.



Before cut-out　　After cut-out

Photo 7 Cut-out inspection images



After pretreatment　　After Hough transform

Photo 8 Detected identification groove

6. 4. 6 Evaluation

After detection of the identification grooves has been completed, the inspection results should be evaluated. Evaluation criteria have been established so that the jig passes the inspection (OK) when the number of metal outside diameters detected matches the number of identification grooves while the jig fails the inspection (NG) when it does not. For mass production machines, the jig is locked and cannot be taken out of the work bench as long as the result is NG. The jig cannot be released from the work bench until the result is turned to be OK.

7 Results of Development

The results of the evaluation of the inspection capability are shown in Table 2. 62,000 parts currently in production were used in the evaluation of the inspection capability during the period between January 8 and February 1, 2022.

Table 2 Results of evaluation

	Evaluation error [%]	Over-inspection [%]	Inspection time [sec.]
Target	0.000	Not more than 0.3	Not more than 2.1
Result	0.000	0.005	2.0
Evaluation	○	○	○

The targets for all the items were achieved.

The automatic inspection system was introduced in April 2022. Inspection labor saving, which was established as the purpose of this development project, was achieved.

8 In Closing

This project successfully developed technology for detecting the orientation of oil seal metals. The following summarizes the project:

(1) The inspection was made during the process for setting metals in the jig.

(2) The presence/absence of the identification groove was identified by image processing for inspection.

(3) The inspection algorithm included edge detection with the band-pass filter and circle detection with the Hough transform.

(4) The inspection capability was proven for mass production with an evaluation error rate of 0% and an over-inspection rate of 0.005%.

(5) he inspection time was maximum 2.0 seconds, which is equivalent to the visual inspection time for human operators.

(6) The technology was introduced in mass production and inspector labor saving was achieved.

The inspection technology described in this paper can be applied not only to the detection of the identification groove of the metals but also to other inspection processes with circle detection such as for assembly error of circular parts.

Finally, I would like to take this opportunity to sincerely thank all those concerned who extended cooperation to this development project.

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