

QUALITY CONTROL OF PARTS IN INDUSTRIAL PRODUCTION WITH IMAGE PROCESSING METHODS

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Abstract

Mass production is done with industrial machines. During manufacturing, the parts undergo various processes to give them their final shape. In machining, the processing of the part is inspected at the final stage. In this study, a visual inspection system has been designed to determine the quality of the part at the final stage of processing. The semi-finished cylindrical parts are processed on the rotating round magazine in the current production system. The six-step round magazine has four processing stops which are take-in, centering, drilling, and take-out the parts consecutively. The developed visual inspection system in this study is designed for the last stop of this round magazine. The part images are captured by the camera and the color and diameter of the part and areas of holes on the part are determined. The developed inspection system makes pass or failed decisions for each part by comparing measurements with the specifications of the part. Measurements of all parts are saved to the process database for further analysis. As a result of this study, the developed inspection system is considered suitable and integratable for round magazine process quality control.

Keywords: Image Processing, Industrial Production, Quality Control

INTRODUCTION

Demands arise with increasing needs. When the demands are not met in sufficient quantities, product prices increase. To meet the demands economically, fast and mass production is required [1-3]. For this purpose, technological advances have been applied to the manufacturing industry. Serial and fast production is done with machines, reducing human intervention. This also ensures the production of the same quality [4]. In production, machines are expected not to make mistakes compared to humans [5]. Machines without human emotions can perform the same job repeatedly. In this way, faster, economical, and safer manufacturing can be achieved [6]. However, it is known that machines make mistakes in some cases. Machines that have no thoughts and a limited perception of their surroundings do the job they were pre-coded for [7, 8]. They execute the instructions given by the programmer. Some situations are difficult to

predict. The information they receive from the environment is limited and they work by interpreting this information [9].

For a semi-finished product to turn into a product, it must go through various processes. Injection, casting, pressing, and machining are some production methods. Machining is based on processing the part on suitable machine tools. Manufacturing is done by reducing material from the part. A cutting tool is used for material reduction. This cutting tool takes chips from predetermined points [10]. In some cases, the cutting edges may not fulfill its function. Or the resulting chips may prevent proper processing. In these cases, it causes faulty parts to be produced [11]. For this reason, quality control is carried out after production. For quality control, parts are inspected visually and with a measuring instrument. If there is an error in manufacturing, manufacturing must be terminated to understand this situation [12].

In this study, a visual quality control system was developed by adding a camera to the part processing station. In the second part, the features of the processing machine will be discussed. Afterwards, the image processing methods will be explained. Finally, the results and conclusions will be given.

EXPOSITION

The study will be explained in two main parts. The first of these is part production, machining, and processing of parts in mass production. Secondly, the results obtained with the camera to be added to the mass production bench will be discussed. The images taken with the camera will be processed on the computer and the quality control of the parts will be carried out. The camera will work integrated with the computer and report the status of the parts to the operator automatically. In addition, all measurements of parts are saved to the database and can be examined later if there are any manufacturing-related errors. Examining these production data by statistical meanings, the most frequently occurring errors can be determined and process flow can be fixed to improve productivity.

Part Processing Station

The machining station is shown in Figure 1. The numbered parts in the Figure 1. are;

- 1- Magazine (Round table)
- 2- Part entry stop and part detection sensor
- 3- Centering stop
- 4- Drilling stop
- 5- Part exit stop

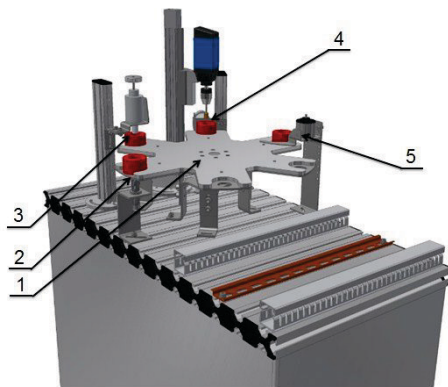


Fig. 1. Part Processing Station [13]

The parts fed to this station are positioned on a magazine. The magazine is a round, rotating table. There are six chambers in which the incoming parts will be positioned. The parts in these chambers are subjected to various processes at various stops. The turntable moves and rotates when appropriate signals arrive. Parts are entered and exited at this station. After the part entry, the table rotates one turn and moves to the centering station. The part is centered at this station and prepared for the drilling process. Part entry can also be done while this process is being performed. After the centering is completed, it turns one more stop and comes to the processing station. In this case, the part is drilled. The part entry and centering process continues simultaneously at the previous two stops. After the drilling process, the part is transferred from the exit stop to the next station. Production continues in series. Part entry, centering drilling, and part exit are performed simultaneously. In this study, it was aimed to perform part quality control by adding a camera to this station. For this purpose, the detection of the parts with the camera and the preliminary work were completed in a separate area. In the next stage, it is aimed to take images with the camera before the part comes out. In the next section, image processing and quality control results will be discussed.

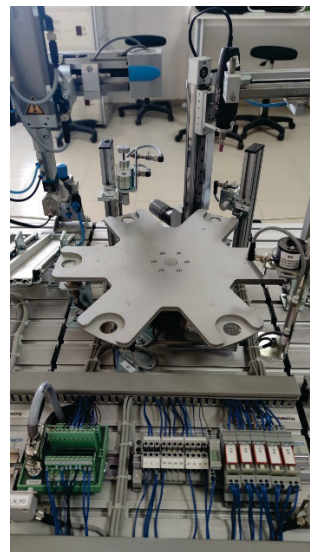


Fig. 2. Part Processing Station used in The Study

Figure 2 shows the parts processing station used in the study. Control of this station is provided by the S7 1214 DC/DC/DC programmable controller. The parts on the rotating table are placed by a Cartesian robot arm. For machining, the drill is controlled by a linear slide. The single-axis drill automatically drills holes when the part arrives. It is checked with sensors whether there are parts or not. Rotary table movement is done by a DC motor. There are six parts chambers. One revolution of the turntable is completed in six steps. Every step movement is detected by the sensor. When the step is completed, parallel part feeding, part removal, centering, and hole drilling operations are performed simultaneously. The turntable will not move until any of these operations are completed. The completion status of critical operations is detected by limit switches. In this way, safe operation is ensured. The processed parts can be inspected while a camera added to the last stop of this processing station. The camera is not physically included in the system. However, it is planned to be included after various physical adjustments. The image processing software is developed in a separate experimental setup out of a round table system.

The Parts In Processing and Inspecting

The processed and inspected parts are plastic cover parts with a specific diameter and height. Parts are in three different colors black, red, and metallic plated. Some samples of parts in different colors are shown in Figure 3.

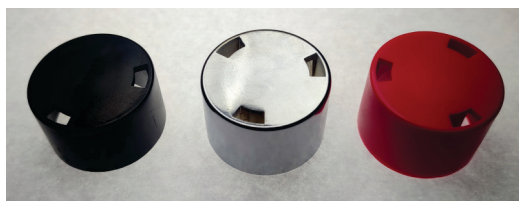


Fig 3. The parts that are processed and inspected.

All processed parts must have three holes on top. Holes are punched as an arc shape. The quality control of parts is only on the diameter and the status of punched holes. In

this situation, only the top view of parts is adequate for inspection.

The Image Processing Environment

In industrial image processing, environmental conditions can be arranged to facilitate image processing. In this study, both background lighting and foreground lighting are used to illuminate the part under inspection. Foreground lighting illuminates the surface of the part while background lighting exposes the holes throughout the part and makes them visible to the camera. Diffusors are used to prevent reflections from the metallic finished part. The light sources are white-colored LED strips. The lighting setup arrangement is shown in image Figure 4.

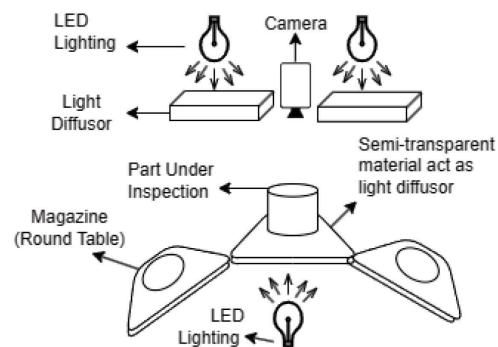


Fig 4. Camera and lighting arrangement of the inspection system

When camera mounting and working distance have been fixed, the calibration process must be done. The calibration process consists of lens calibration and determining the pixel scaling coefficient. The lens calibration is made to determine radial and tangential image deformation correction coefficients. The radial coefficients are defined as in Eq. 1.

$$\begin{aligned} x_c &= x \cdot (1 + k_1 r^2 + k_2 r^4 \\ &\quad + k_3 r^6) \\ y_c &= y \cdot (1 + k_1 r^2 + k_2 r^4 \\ &\quad + k_3 r^6) \end{aligned} \quad (1)$$

In equation Eq.1., x and y represent a point on the captured image, and x_c and y_c represent the corrected position of x and y on the undistorted image. Similarly, the tangential coefficients are defined as in Eq. 2.

$$\begin{aligned} x_c &= x + [2p_1 xy + p_2 (r^2 + 2x^2)] \\ y_c &= y + [p_1 (r^2 + 2y^2) \\ &\quad + 2p_2 xy] \end{aligned} \quad (2)$$

In equation Eq.2., x and y represent a point on the captured image, and x_c and y_c represent the corrected position of x and y on the undistorted image.

For correction of the distorted image, k_1, k_2, k_3, p_1, p_2 coefficients from the Eq. 1. and Eq. 2. need to be determined. A chessboard-patterned sheet is used to obtain these calibration coefficients. The OpenCV image processing library has a dedicated function to calculate coefficients from the various chessboard-patterned sheet images. The obtained calibration coefficients are saved to a calibration data file for use in the correction of captured images in the processing stage.

A pixel scaling coefficient is needed to calculate part dimensions in known metrics like millimeters or centimeters. This coefficient indicates how many pixels are present per millimeter length distance. To obtain the pixel scaling coefficient, a shape that has known dimensions is used. All calibration coefficients have been saved to the configuration file for use processing in the future.

Processing the part image from capturing to the final decision has several stages. A brief flow diagram of these stages is shown in Figure 5.

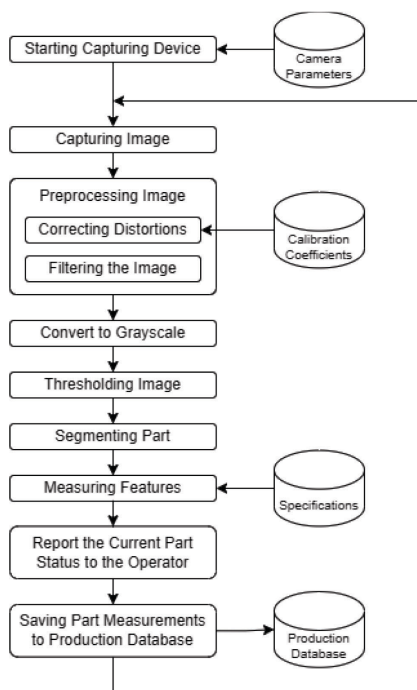


Fig 5. Stages of Quality Control Process by Image Processing

The first step is preprocessing the captured image. This stage consists of image undistortion and filtering processes. Correction of image radial and tangential distortions has been done in this stage. Previously saved calibration coefficients are used for these corrections. The OpenCV library has a dedicated function for these corrections. After correction of the shape of the captured image, image pixels are filtered by using blur functions. Blur functions suppress the pixels that have outlier intensity values. Filtering functions are also known as smoothing functions due to smoothing the pixel values.

A grayscale image has only light intensities independent of the color of pixels. For analyzing the intensities and determining the proper thresholding value, smoothed images are converted to grayscale images. The OTSU thresholding algorithm is used for obtaining binary images. The OTSU algorithm calculates the threshold value from the distribution of intensities in the grayscale image [14]. An example of the inspected part and its thresholded binary image is shown in Figure 6.

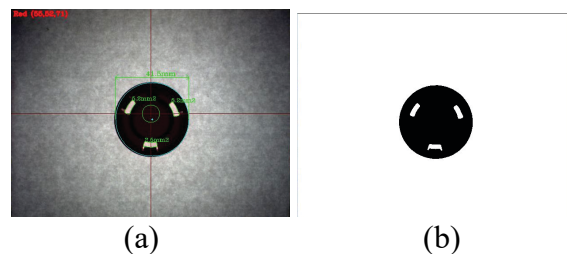


Fig 6. a) A captured and b) thresholded binary images of part

Hough Circle Transform is applied to the binary image to find the fittest circle on the part image. The Hough Circle Transform algorithm determines a center point if there are some pixels probably on a circle [15]. The binary image has a part silhouette that has a nearly perfect-shaped circle. The Hough Circle Transform algorithm returns the center point and radius of the detected circle. The returned radius indicates the part diameter in pixels. It is converted to millimeters by the pixel scale coefficient calculated in the calibration process

previously. The diameter of the part is calculated from the number of pixels using Eq. 3.

$$\phi_{mm} = \frac{\phi_{pixel}}{ppm} \quad (3)$$

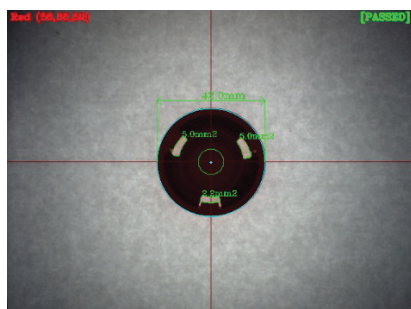
The ϕ_{mm} and ϕ_{pixel} are diameters in millimeters and pixels respectively. The ppm is the pixel-per-millimeter scaling coefficient obtained from the calibration process.

After determining the part boundary, the inner contours are calculated as subprocesses. The part specification defines the number of holes and the lower and upper limits of hole areas. Each inner contour represents the inner holes. Contour areas are used to determine the area of holes because holes are not round nor in a proper shape. A binary image of an example part with holes is shown in Figure 7. The sample parts have exactly three holes in them.

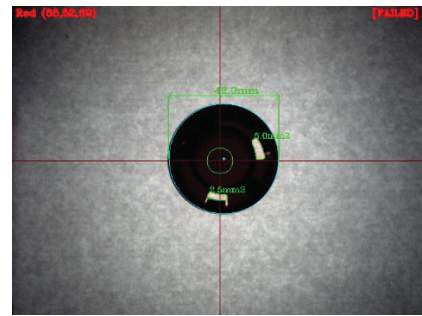


Fig 7. Holes on the part in the binary image

The number of holes and areas of all holes are compared to the specification limits. If any of the measurement does not meet the specification limits, the part is marked as failed on screen. If a part meets all specification limits, the part is marked as passes on the screen. All color, measurement values, and final status of parts are added to the production database for further analysis. An example of a passed and a failed part is shown in Figure 8.



(a)



(b)

Fig 8. a) a passed and b) a failed part due to absence of a hole

CONCLUSION

Human intervention is minimized in the mass production of parts. Parts produced through certain processes are checked at the end of the process. In this study, a visual inspection system has been developed to check the quality of processed parts. Image processing techniques were used to determine the quality of the parts. Parts are marked as passed or failed by checking the visual measurements with the specification limits. The marked parts are informed to the operator on the live capture screen and all measurement data of all parts are saved to the production database. The production database can be analyzed for frequently occurring errors and processes can be improved to eliminate most occurred errors.

As a result of this study, the developed inspection system has determined the parts successfully as expected.

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