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# Error Control of Cylindrical Objects with Image Processing

Kürşad UÇAR[1*], Hasan Erdinç KOÇER[2]

[1]*Department of Electric- Electronic Engineering /Selçuk University, Turkey*
[2]*Department of Electric- Electronic Engineering /Selçuk University, Turkey*
[*]*(kucar@selcuk.edu.tr)*

***Abstract –***Image processing methods have been widely used for detection of product faults in recent years. Images of industrial products that made of various materials are taken with different types of cameras and by using different lenses. Working on images of metallic products is difficult because of reflections, stains and halation on the object. Telecentric lens and telecentric illumination are used to come up with this problem. In this study, the axis shift due to the welding of a sphere and a cylindrical body was detected using image processing methods. An image was taken every 60 degrees when the object was rotated. The error of the product was detected on 6 images of each product. Firstly, the images that are colored are converted to black and white. Then the gaps in the image were destroyed by morphologic methods. Then positions of the two joined parts relative to each other are used. The position information of six views of an object is compared. According to the differences in relative location information, it is decided that object is produced with faulty or not. At the same time measurements of the size of the body were also made.

*Keywords – Cylindrical objects, Image processing, Telecentric, Shape measurement, Metal objects.*

## I. Introduction

In recent years, with the increase in the number of production companies, there has been a competition between producers. With the competition, each manufacturer tries to produce as much and as high quality products as possible. Therefore, the control of the products produced and the removal of them if they are faulty is a very important stage during the production phase. People and machines can be used for error detection. The machines are preferred because of the advantages such as fatigue, continuous operation, low cost, stable operation. Controls can be made using different methods depending on the structure, type or shape of the products produced. A kind of these methods is the controls which are made by imaging and using image processing methods. The control of various products such as marble, fabric is done by using image processing methods and different methods [1], [2], [3], [4].

Cylindrical metal bodies can be produced in one piece or can be produced by joining more than one piece. Cylindrical products in one piece can be produced by processes such as chipping, processing on an object. For the products formed by joining more than one part, the biggest problem is the necessity of the parts being the same axis. The fact that the axes of the joined parts are not the same is called axis shift. Products with axis shift are structurally distorted and unwanted. Figure 1 shows two parts with axis shift. Axis shifts can be determined visually by the size of the object or the amount of the slip. The human eye cannot do so in highly sensitive perceptions. Automatic systems with high accuracy are preferred because they have stable working level.

Controls for the production errors of metal products using the camera are usually carried out in one direction [5], [6]. Measurements made on a surface can only give fault information about a surface. However, many of the products produced in the industry are produced in 3D. For this reason, it is an important problem to determine which part of the fault is in the part of the object. The method of detecting errors on object with a stick used for error detection becomes more difficult as object volume increases. In this work, every aspect of the object is dealt with in order to find the production errors of the cylindrical bodies. Though images are two-dimensional, three-dimensional object errors are detected. In this context, objects were rotated 360 ° around their axis and images were taken. It has been determined that the mistakes are detected by the images obtained by rotating the object every 60 °. For this reason, an object has been done with six images.

Fig. 1 Two parts with axis shift

Especially products which have been processed or have a certain shape can be formally mistaken in the production stage of the desired products. The measurements of the dimensions of the products produced in the production line, are a time consuming and laborious process which can be done by hand. It is especially difficult to measure the curvatures on the object, the angles. It will also cause inefficient use of human power. The required measurements are provided automatically or automatically by the person over the images. For this reason, in this study, the dimensions, curvature and angular measurements of the objects were taken.

## II. Materials and Method

In this study, the system of detection and formal measurement of production errors of cylindrical products by image processing methods was realized. In this context, a measurement system was designed and constructed to take images of cylindrical objects. Two servo motors, programmable logic controllers (PLC), telecentric lens and telecentric lighting are used for effective operation of the system. Images were captured with a camera with a resolution of 2048x1088 pixels and a sensor size of 2/3. Image processing and error detection after image acquisition were performed on the computer using Matlab program.

*A. Servo Motors and Drives*

The motor is an industrial device that generates force by moving circularly. Generally, the motors are classified into four different types as DC motor, AC motor, Servo motor and Step motor. Although the logic of the work is different, the structures of the different types of engines are similar. Since the internal structure of servo and stepper motors is not only stator and rotor, they are classified as more advanced engine types. The servos are separated from the AC motors when there is a potentiometer or a control circuit that measures the position of the encoder and motor shaft.

The motors form an angle of 360° as they move in the circular area. One of the important features of servomotors is sensitivity. The accuracy of servo motors is specified by the number of steps. The shorter the angle, the greater the precision of the Servo motor. For example, a Servo motor that completes a full turn in 400 steps has a single turn rating of 360/400 = 0.9 °. This step is a sign of sensitivity. So this servo motor can rotate with 0.9 ° accuracy. The number of steps of the servo motor must be increased to obtain a precise servo motor. Thus, precise positioning and rotation motion can be achieved at the required level. But with the number of steps it increases in cost.

*B. Programmable Logic Controller (PLC)*

Programmable Logic Controller (PLC) is an electronic device for realizing the control and control circuits of industrial automation systems [7]. These devices, which have input / output units as well as communication interfaces, are industrial computers operating under a system program suitable for the control structure [8]. The control circuits of industrial automation systems are the most widely used areas of PLCs. Relay, contactor, time relay, counter, such as the control circuit realized by the elements of the place using the PLC leaves the system [9]. This is because PLCs must be suitable for direct use in industrial automation systems. Unlike normal computers, the PLC has many inputs and outputs. Their greatest advantages are their electrical noise, temperature differences and resistance to mechanical impacts, which are effective on circuits. Each PLC manufacturer installs its own software system in the PLC. This supervisory system scans the input information at incomprehensible speeds and responds accordingly to the real time output information. PLC plays a big role in the foreground of elements such as producing more and better quality products in a short time and producing with very low error rates.

*C. Telecentric Lens and Illumination*

The telecentric lens is a compound lens with infinite output or input focus. That is, the multi-element lens design in which the main rays are parallel to the optical axis in the image or object space. Figure 2 shows how to receive beams for a conventional lens and a telecentric lens. Therefore, telecentric lenses have constant magnification regardless of image or object position. An example of how images are viewed using conventional lenses and telecentric lenses is shown in Figure 3.

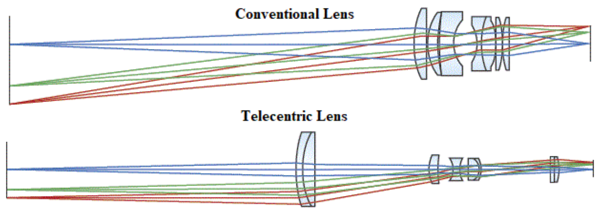


Fig. 2. Receive beams for a conventional lens and a telecentric lens[10]

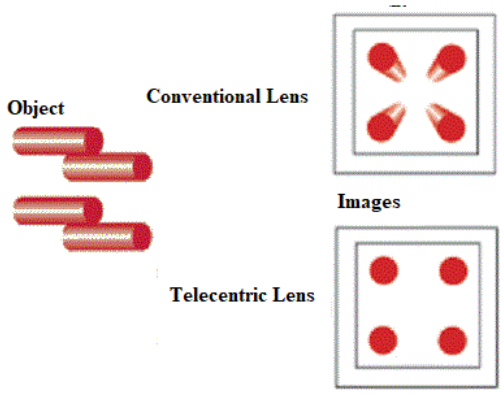


Fig. 3. An example of how images are viewed using conventional lenses and telecentric lenses[10]

Telecetric lighting is also the concept in which the main rays are aligned to the optical axis and processed in parallel. In other words, telecentric lighting is aligned backlight. The telecentric illuminator increases edge sharpness and measurement accuracy by reducing reflections from objects. For this reason it is very practical to avoid the reflective properties of metal surfaces in particular. The collected light rays come out of the illuminator and remain gathered as they strike the surface of an object. Conversely, light rays from a conventional backlight expand and interfere with each other, producing diffuse reflections.

*D. Image Pre-processing*

When images are taken, they are taken together with a number of surpluses that are not relevant or difficult to handle in different types. These surpluses can be environmental impacts such as noise, lighting differences, or they may be a part of the unconscious that is not really relevant. Removing these redundancies is an important step as it facilitates the work on the image. In addition to this, edge detection, finding corner points, and filtering are also performed as pre-processing to facilitate image processing.

1. Morphological Operations

Morphological image processing allows the objects to be distinguished and grouped by dealing with the formal structure of the forms [11]. These methods are usually used on black-and-white images, but also on gray-level images. Morphological filters are generally derived from two basic processes, namely etching and expansion. In addition to a structural element for operations, two functions are used, called fit and hit, to express mathematically. From these functions, the fit function overlaps with the element of the structural element and the pixel on which the structural element is located. It is sufficient for at least one of the pixels of the structural element to overlap with the elements of the structural element at the moment. Structural elements can be in different sizes and shapes. Different structural elements can be used depending on the probing or image being worked on. Figure 4 presents four different structural element examples. The dark section and the dark section of the image on this side are checked for the correspondence of the region and the resultant value of the circle on the structural element is printed.

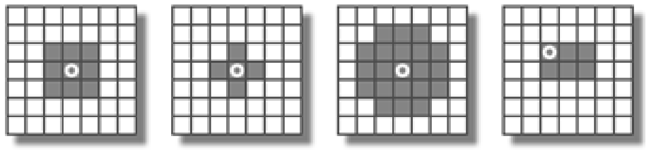

Fig. 4. Some structural element

2. Edge Detection

Objects involved in image work are associated with unrelated surpluses in the image. For this reason the relevant object must be detected in the image. Thus, unnecessary information that is not relevant can be extracted. The most common and easiest method for detection is to obtain edges with edge detection methods.

Along with the development of image processing methods, many edge detection methods have emerged. There is a difference in colour tone between objects and the background. The areas where the colour tone difference is the edges of the regions are. For this reason, edge detection is performed by looking at the neighbouring pixels.

Sobel, *Gx*

| | | |
|---|---|---|
| -1 | -2 | -1 |
| 0 | 0 | 0 |
| 1 | 2 | 1 |

Prewitt, *Gx*

| | | |
|---|---|---|
| -1 | -1 | -1 |
| 0 | 0 | 0 |
| 1 | 1 | 1 |

Roberts, *Gx*

| | |
|---|---|
| 1 | 0 |
| 0 | -1 |

Sobel, *Gy*

| | | |
|---|---|---|
| 1 | 0 | 1 |
| -2 | 0 | -2 |
| -1 | 0 | -1 |

Prewitt, *Gy*

| | | |
|---|---|---|
| -1 | 0 | 1 |
| -1 | 0 | -1 |
| -1 | 0 | -1 |

Roberts, Gy

| | |
|---|---|
| 0 | 1 |
| -1 | 0 |

Fig. 5. Some structural element

Sobel [12], Canny [13], Prewitt [14] and fuzzy logic [15] Laplace are only a few of the methods of edge detection. Figure 5 contains Sobel, Prewitt and Roberts filters. The filters denoted by Gx represent the filters used to find the edges in the x-axis direction relative to the coordinate plane, and the filters denoted by Gy in the y-axis direction in the coordinate plane. By taking the square of the sum of the squares of the pixel values in the same coordinate of these two new images obtained, the pixel value in that coordinate of the common view to be formed is found [16]. The edges of the objects on the image are uncovered in the resulting image.

3. Corner Detection

He and Yung [17] use the global and local curvature properties in the corner finding algorithm method they proposed and balance the effects of these curvature properties when extracting the corners. In order to do this operation, first of all an edge detection algorithm is used to obtain the black and white image of the edges. The edges are extracted by a multi-scale algorithm based on the curvature scale space, which can perceive the edges of the planar curves on the resulting image. After contour removal, a constant low scale curvature is calculated to maintain the true corners of each contour, and the local maximum of the absolute curvature is retained as corner candidates. An adaptive threshold is calculated according to the mean slope within a support zone. The curvature of the angular candidates is removed from the rounded corners by comparing with the adaptive threshold. Based on a dynamically recalculated support zone, the corners of the remaining corner candidates are evaluated to remove any incorrect corner from the center. Finally, the last points of the open contours are handled and marked as corners unless they are very close to another corner. Thus, only the necessary corners can be determined on shapes with many corners resulting from the imaging features as in Figure 6. Measurements made using the edge properties would have to be measured with all the pixel points around the shape.

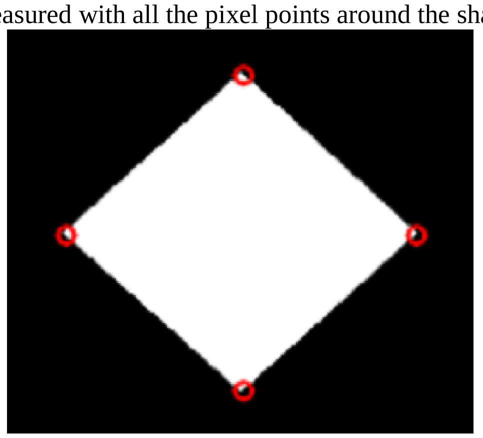

Fig. 4. Some structural element

## III. Results

. As a result of this work, software that can take images of cylindrical objects and software that can measure the axis shift, size measurement, curvature of the cylindrical bodies and angle measurement on the images by using image processing applications using Matlab program. The functions of the functions used in the software created in this section have been tried to be explained in detail with the example application. An interface has been developed for using the workspace. The developed interface is shown in Figure 5.

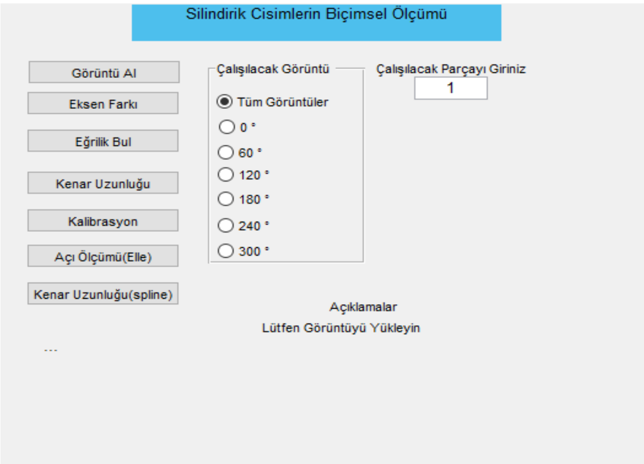


Fig. 5. Developed interface

It is possible that the objects involved are due to the welding of two parts and that the axes are shifted from their origin. The main focus of this study is axial drift. It is demanded by the manufacturer that the axis of the particle, which is a part of the object, and the axes of the part to which it is welded are as close to each other as possible. In order to find the axis difference, the axes of two parts are removed. The axial part of the spherical part can be easily found by circular Hough transformation. The axis of the part where the spheroidal part is welded is obtained by using the middle points. That is, 20 columns are selected from the starting point of the piece to the shovel. In these columns are the midpoints of the part. In order to find the middle point, the average of the starting and ending points of the piece in the column is taken. It draws a line with twenty points obtained. Another straight line with the same slope as the slope that has the drawn straight line is drawn from the first selected column of the segment to the vertical position of the spheroidal segment. The difference between the end point of the second line drawn and the centres of the spheroidal part indicates the amount of axial shift. Figure 6 shows the work done on an image with axis shift.

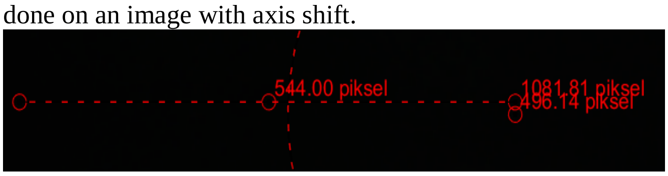


Fig. 6. An image that has axis shift

There are curvatures in the nature of the pieces studied. These curvatures can be found differently in production due to the object structure. These curvatures can provide information about how the object is produced correctly, as well as provide convenience for the user. Each curvature can be represented as a circle with a certain radius. In this context, the curves in which the radius is part of the circle are shown using the circular Hough transformation. The curves shown in Figure 7 are shown on a visual segment. Figure 7 shows four circular structures on the upper side of the object and three curvatures on the lower side. The fact that the curvatures are in different numbers indicates a mistake in object production.

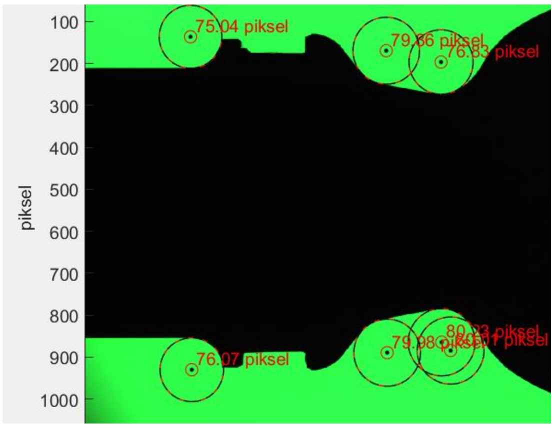


Fig. 7. The curves that found the object

In the process of finding the edge length, all the corners of the object are found, and the size of the object is measured. Since the part being worked has curvatures, instead of drawing a straight line between the corner points, a curve is plotted. The point to note here is the number of corner points. Because when the number of corners is large, the process will take time. If the number of corner points is small, the curve drawn on the circumference may be different from the object shape. Figure 8 shows the presence of an object edge length. Each small circle on the image indicates the location of the located corner points.

Angle measurement allows the user to measure the angle between the desired points on the image. Angle measurement is made by selecting three points on the image. Two lines are formed from the three selected points. The three points form the common point of the two lines. In other words, the first point selected is the intersection of the two lines that form. Since the angle will also occur at the intersection point, the angle formed at this point is calculated.

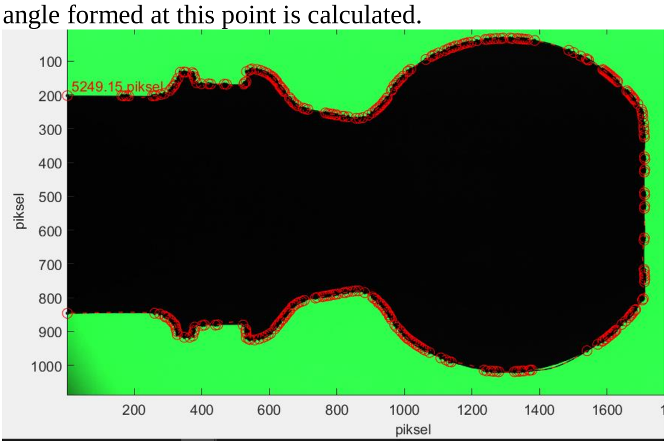


Fig. 8. The object edge length

## IV. CONCLUSION

As a result, error detection is performed by image processing of cylindrical metal objects. For this, a mechanism is established to get the image of the cylindrical object. Telecentric lenses and telecentric lighting equipment have been used for effective imaging. The amount of axis shifts detected is shown in Table 1.

The measurements described above have been successfully performed with a sensitivity of one per cent of the millimetre.

Table 1. Amount of axis shifts

| Object | 0° | 60° | 120° | 180° | 240° | 300° |
|---|---|---|---|---|---|---|
| 1 | -9,14 | -2,15 | 8,66 | 12,61 | 5,98 | -4,79 |
| 2 | 1,38 | 19,71 | 18,19 | 2,72 | -16,18 | -16,17 |
| 3 | 11,99 | 4,65 | -3,03 | -9,53 | 0,06 | 8,49 |
| 4 | 4,60 | -8,97 | -11,70 | 1,44 | 16,12 | 17,92 |
| 5 | -10,85 | 3,90 | 16,96 | 14,03 | -1,05 | -13,01 |
| 6 | 8,07 | 10,80 | 5,60 | -2,34 | -3,26 | 0,54 |
| 7 | -8,61 | -1,80 | 11,63 | 15,73 | 6,70 | -4,23 |
| 8 | -29,60 | -27,16 | 6,20 | 38,56 | 35,21 | 2,75 |
| 9 | 9,98 | 9,02 | 2,44 | -3,02 | -3,83 | 4,25 |
| 10 | -17,72 | 18,47 | 38,54 | 22,79 | -13,16 | -33,29 |
| 11 | 29,41 | 39,88 | 14,11 | -22,08 | -32,90 | -7,75 |
| 12 | -9,46 | -13,91 | -1,79 | 13,28 | 17,08 | 6,16 |
| 13 | 30,48 | 31,53 | 4,46 | -23,05 | -22,94 | 1,21 |
| 14 | -11,08 | -29,21 | -16,82 | 14,57 | 33,17 | 21,02 |
| 15 | 10,60 | 9,67 | 3,25 | -2,22 | -2,35 | 2,53 |
| 16 | 14,74 | -1,82 | -14,26 | -7,78 | 8,81 | 20,77 |
| 17 | -9,74 | -3,40 | 7,16 | 17,73 | 16,08 | 1,85 |
| 18 | 12,24 | 0,18 | -8,71 | -5,60 | 6,89 | 14,75 |
| 19 | -3,03 | 28,52 | 33,07 | 9,32 | -23,54 | -26,55 |
| 20 | -9,04 | -3,66 | 8,04 | 14,21 | 8,39 | -2,69 |
| 21 | -7,94 | -10,52 | 1,34 | 11,47 | 14,17 | 3,49 |
| 22 | 6,04 | -12,73 | -15,81 | -0,62 | 19,82 | 22,40 |
| 23 | -16,56 | 3,49 | 18,55 | 22,69 | 3,59 | -12,88 |
| 24 | 7,83 | 11,00 | 5,68 | -2,51 | -6,49 | -0,75 |
| 25 | -1,95 | 24,39 | 30,12 | 7,33 | -16,94 | -22,36 |
| 26 | -3,15 | 5,02 | 10,85 | 8,51 | 0,41 | -5,97 |

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