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DEVELOPMENT OF NEW COMPUTATIONAL IMAGE ANALYSIS TECHNIQUE FOR MEASURING THE CIRCULARITY AND STRAIGHTNESS OF SEAMLESS PIPE

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ABSTRACT: Circularity and straightness of a pipe is a very important factor in determining the pipe quality which is absolutely necessary in applied field. Frequent failures and quality of screw threads machined at the ends of steel pipe are undermined if these properties are not correctly maintained within the required limit. Hence, in production line the measurement and maintenance of roundness factor and straightness of a pipe accurately is of utmost importance. For meeting the quality demand, different techniques have been employed but these are not cost effective all the time. Many factory employed online measurement technique by using some sensors and sophisticated setup. However the manual process by using some precision device is time consuming and chance of human error is also considerable which are not suitable at all for high quantity production line. The machine vision technique employed earlier in this regard has used some online setup which is not convenient enough for satisfying the purpose smoothly. The authors of this paper took this problem into account and thereby present a new machine vision technique by image analysis which has proven to be very effective in measuring the circularity and straightness of a seamless pipe. The authors used the digital image processing technique so that the user can dynamically interact to get the result very quickly and easily. Later on, the response, precision and stability of the technique are verified by physical measurement, which show good agreement.
KEYWORDS: Pipe Circularity, Pipe Straightness, circularity, Machine Vision, Measurement

INTRODUCTION

Circularity and straightness of a pipe is of crucial importance in determining pipe quality for various industrial and offshore applications. To avoid different mechanical failures like buckling it is necessary to know the degree of pipe straightness. The roundness factor and straightness have certain tolerance limit according to the application for which it is used and they also vary according to the manufacturers and their quality management. The existing processes for measuring the pipe roundness and straightness, are time consuming process, costly and not that much efficient. On-line inspection method has been adopted by many factories which are very expensive. In some cases the use of machine vision has improved the situation cost effectively and reduced the required time. Different measurement method for different related applications has been explored which include the use of alignment telescope, jig transits, optical levels etc. [1-2]. Junichi et al [3] used laser beams to obtain the straightness along a measured line or measured central axis by moving the target. However, the technique had a few drawbacks. R.S. Lu et al. [4] studied the online and real time laser visual alignment measurement technique to measure the spatial straightness of large objects. They developed an experiment system based on this technique. Lu Xiaobo et. al [5] used an optoelectronic measuring method based on the principle and technology of laser and optoelectronic inspection to measure straightness of the deep pipe by using the quadrant detection, precision machine, image processing and computer technology for reference. Sasaki et. al [6] used laser beam as straightness reference. The authors of this paper considered to check the circularity and straightness of a seamless pipe and thereby present a new machine vision technique which has proven to be very effective. The authors used the digital image processing technique to develop a GUI so that the user can dynamically interact to get the result very quickly and easily. The predictions made by the software are validated by physical measurements.

ALGORITHM USED FOR PIPE CIRCULARITY

For performing the circularity check and straightness test of a pipe using digital image processing technique involves the application of the computer logic and algorithm to analyze the images. A graphical user interface environment was developed using digital image processing technique to dynamically assessed the pipe picture to get the result very quickly and easily. GUI presentation of the developed algorithm for pipe quality measurement are shown in Figure 1.

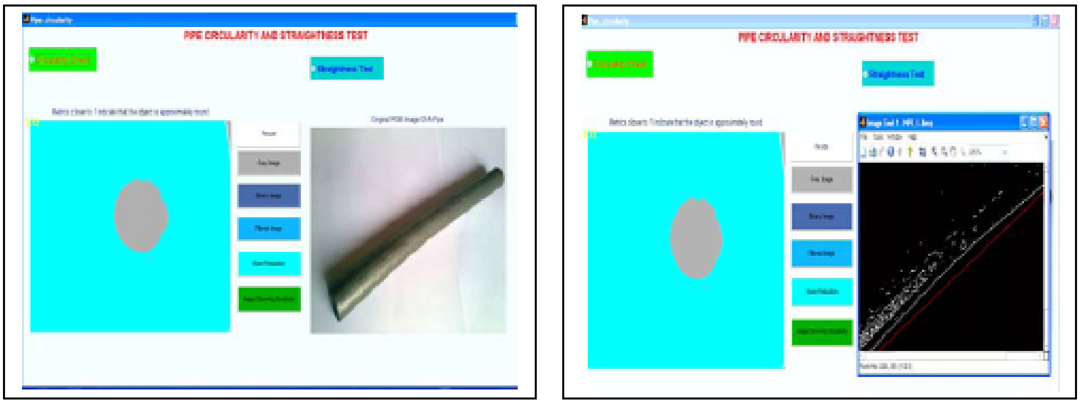

Figure 1: GUI presentation of the developed Algorithm

For this purpose, MATLAB R2008a image processing toolbox was used which can efficiently analysis the acquired images represented by n by m 2-D matrix form. The flow chart of the process sequence for circularity measurement is depicted in figure 2.

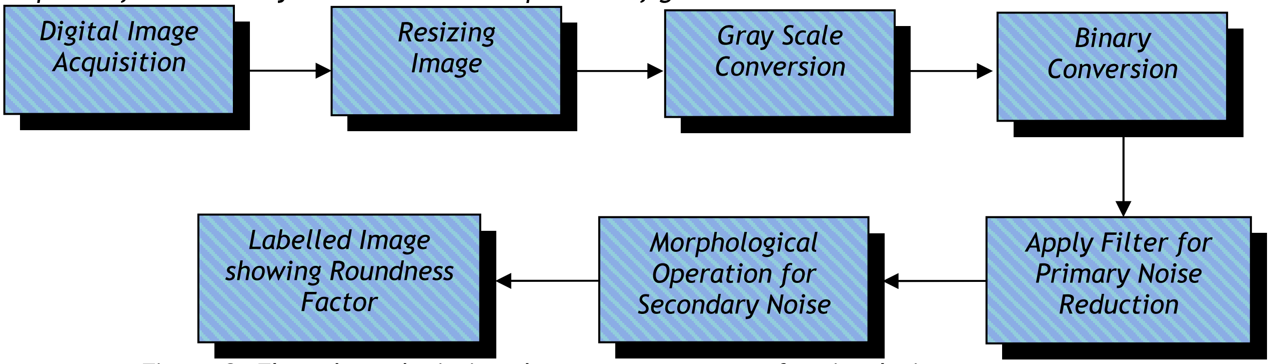

Figure 2. Flow chart depicting the process sequence for circularity measurement

Figure 3 shows the conversion and analysis sequence of the image. The acquired RGB image is resized keeping its aspect ratios intact to standardize the comparison and then grey scale and binary conversions are performed as the pre-processing steps. Binary conversions are performed on the image so as to detect the edge of the pipe which is to be analyzed for determining the CM factor.

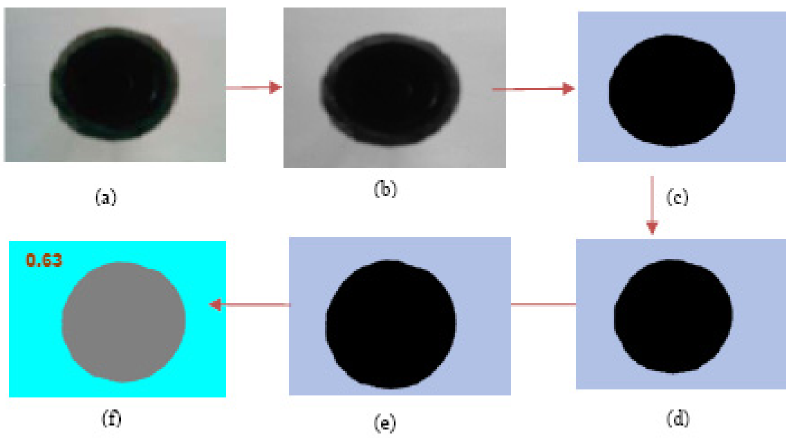

Figure 3: Steps for determining circularity: (a) Front view of pipe in RGB matrix (b) Gray-scale and resized image of pipe (c) Black and white image of the pipe (d) Black and white image of the pipe with primary noise reduction (e) Black and white image of the pipe with secondary noise reduction (f) image showing predicted CM Factor

A linear filter is applied to omit pixels within certain range. Then morphological operation is performed in order to reduce the noise and unnecessary pixels and thus acquire a uniform valued set of pixels which is necessary for proper labeling of the image. The software then calculated the circularity factor (CM factor) using the following equation:

$$CM = 4*pi*area/perimeter^2 \qquad (1)$$

The circularity factor is 1 for a perfect circular shape and it is always less than 1 for non circular shape

ALGORITHM USED FOR PIPE STRAIGHTNESS

The digital image processing technique for measurement of straightness of the pipe followed the following process sequence as shown in figure 4.

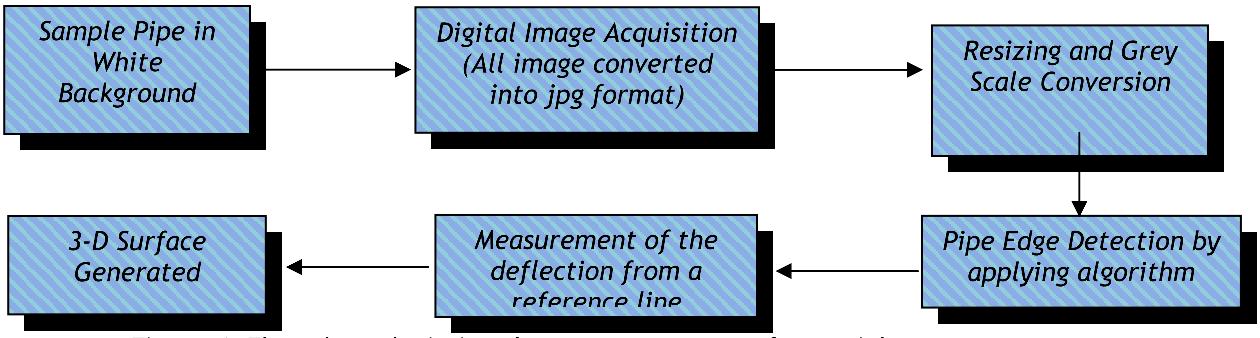

Figure 4. Flow chart depicting the process sequence for straightness measurement

Figure 5 shows the conversion and analysis sequence of the image for straightness measurement. After reading the acquired image in MATLAB environment some pre-processing operations (like resizing the image and grey scale conversion) are done. Then Sobel method is applied to the gray-scale image for edge detection. The Sobel method finds edges using the Sobel approximation to the derivative. It returns edges at those points where the gradient of the image maximum.

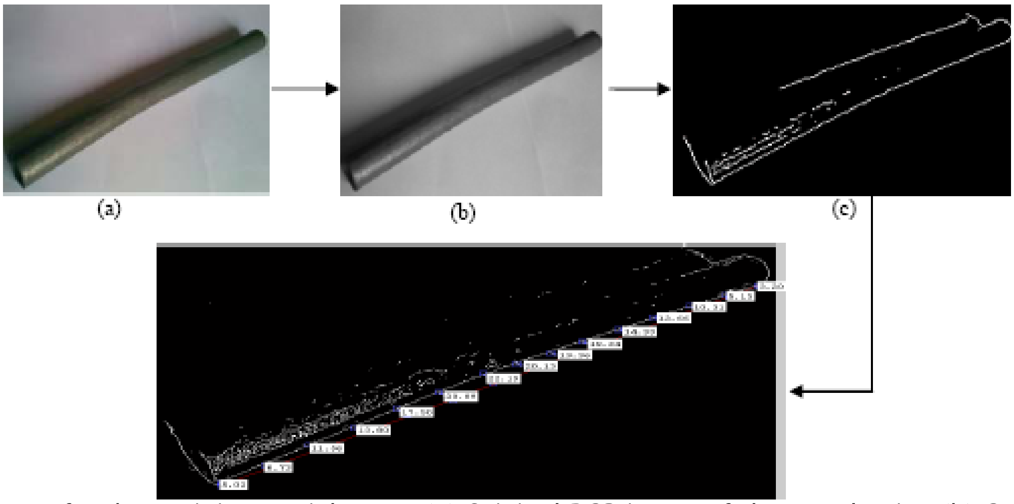

Figure 5: Steps for determining straightness: (a) Original RGB image of the sample pipe (b) Gray-scale image of the pipe (c) Pipe Edge detected by applying algorithm (d) Reference line drawn to measure the deflection from the reference line with scaling factor

A reference line is then drawn and the deflections of the pipe edge from that reference line is measured by the MATLAB. The distance values are calculated based on pixel information of the image at different point considering the image magnifications factors. The scaling factor considering the magnifications parameters need to be considered for comparison with the experimental results. For this particular analysis problem, the scaling factor is calculated as 2.45. For the comparison of the straightness factor the calculated value of the analyzed pipe must be reduced to the scaling factor values.

EXPERIMENTAL MEASUREMENT

For determination of accuracy and the repeatability of the developed technique, experiments are performed and accuracies are compared. For circularity measurements, two pipes are taken and their diameters measured with the help of slide callipers. The areas are then calculated. The perimeters of the pipes are also measured to calculate the roundness factor. For straightness measurement, a pipe of 20cm length was taken. Figure 6 shows the experimental set-up for the measurement of the deflections of the pipe. The deflections at different points on the pipe from its idealized central axis are measured with the help of the dial gauge.

COMPARISON OF RESULTS

The circularity of two sample pipes is measured both experimentally and by the developed image processing technique. The results are compared and an average error of 8.14% was obtained. Table 1 shows the results and comparisons of both experimental and software predicted data.

Figure 6: Measuring the deflections of the pipe by a dial gauge

Table 1: Comparison of results of experimental and software predicted CM Factors

Sample	CM Factor (Experimental)	CM Factor (Image processing)	Error (%)
1	0.58	0.63	8.60
2	0.78	0.72	7.69
Average			8.14

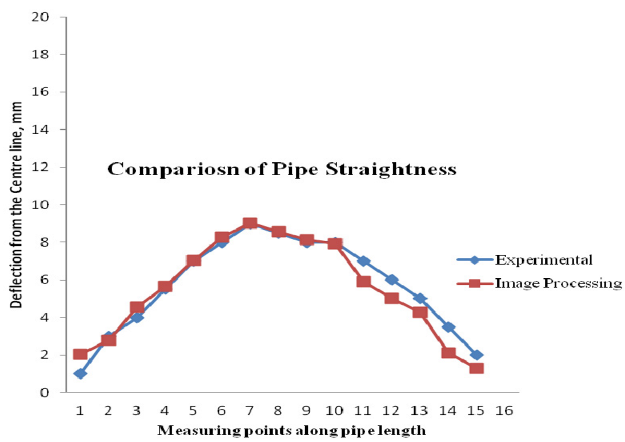

Figure 7: Graphical representation of experimental and predicted deflections from the reference line of the pipe

The differences in CM factors resulted due to the boundary padding effect of the morphological operations performed on the image but are still within reasonable accuracy. Figure 7 shows a graphical analysis of the experimental and predicted deflections from the reference line of the pipe. As the graph suggests, the experimental and predicted values are very close within experimental accuracy. From the experiment it is found that the eccentricity, which is the maximum deflection of the pipe, is 9 mm whereas the software predicted the eccentricity to be almost 9.05 mm.

CONCLUSIONS

The algorithm developed in this paper was verified and the experimental results showed good agreement with the results obtained from image processing. The developed algorithm is very much effective for tracking the straightness data of a long pipe which is very much cost effective if employed in the pipe manufacturing industry.

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