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DEFECT DETECTION FOR FORGED METAL PARTS BY IMAGE PROCESSING

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Abstract—Forging is the process of making and shaping metals by use of hammering or pressing. Forging is one of the main processes in metal production. To keep the quality of forged parts high is very important from the viewpoint of performance or safety of the products. Hence forged part quality is checked by visual inspection whether there is any defect, it imposes a lot of loads to the workers. Same way the defect detection is expected to be substituted by laser measurement or image processing instead of human eyes, comparison of both methods has hardly been carried out. In this , experimental results to detect defects by both methods are described for one forged part. Mainly, comparison between frequency analysis by Fourier or wavelet transform and image processing is reported.
Index Terms—Image processing, defect detection, forged metal.

I. INTRODUCTION

Forging is a manufacturing way to shape metal by using compressive forces. Advantages of forging contains significant savings in materials, higher production rate, and better grain structure [1]. To keep product quality extreme, inspection of surface defects is a necessary process. The surface defects include cracks, smearing, corrosion, scaling, flaking and so on [2]. The human visual cortex is a widely advanced [3], so that human defect detection speed and accuracy defy the imagination. Problems are, however, mental pressure applied to the human and inevitable human errors after inspection for a long time. Since processes that before had to be done manually can now be automated using computers [3], one solution against these problems is applications of computer vision systems. El-Agamy et al. [2] have created an automated system for detection and classification of surface defects in metal parts. The system contains of two main modules: image enhancement module and defect detection module. It can detect and classify common surface defects including cracks, dents, fretting, flaking, scaling and smearing. It, so, simply uses a pattern matching technique with stored defects templates in the program database. On the other side, Lundh [3] used a magnetic particle testing method in combination with an image analysis tool. The outputs showed great promise for the detection of cracks in forged metal parts. so the magnetic particle testing is a kind of special methods that uses properties of magnetic fields. Maillard et al. [4] used active thermography for defect inspection and found that active thermography using laser-flash or method of excitation worked effectively under certain conditions. Then, an ultrasonic crack detection method is used to explore the depth of cracks as a potentiometric method [1].

In this paper, we compare two computer vision techniques of laser and visual-spectrum images to detect defect in forged metal parts. Now a days, a laser can be used as excitation source and photothermal hardness profiles could be estimated [5]. It is believed that the cracks might be detected as its variation difference from the normal patterns even though the profile was observed as one-dimension because of the line laser. The technology is generally expensive. On the other side, image analysis techniques can be applied to the 2-dimensional images captured by CCD (Charge- Coupled Device) cameras, which are more easily available.

The remaining of the paper is organized as follows. In Section II, a defect detection algorithm is introduced for one- dimensional laser measurement data, where Fourier transform is used as frequency analysis. Section III tells the another algorithm for the laser measurement data in which Fourier transform is just replaced by wavelet transform. In Section IV, we distributed a series of image processing algorithm for a CCD camera image to detect defects. Section V describes the conclusions.

II. PRBLEM DETECTION FROM LASER MEASUREMENT DATA BY FOURIER TRANSFORM

The orientation of forged metal surface is measured by a line laser. Hence the measured data are acquired in one- dimensional, they can be treated as pixel values in an image. Assuming that an picture from a defect-free metal surface, which is called a master image, is available, a combination of several image processing techniques is applied to detect defects. The series of operations are shown in Fig. 1.

As the pre-operations in Fig. 1, edges are varied for both an inspected and the master images. Edge extension is to extend the edge place horizontally by using the same value as the edge points presented as in Fig. 2. Edge extension is the original method in this study, and it is necessary to remove the subtle difference of the edge position between the inspected and the master pictures. Then the pictures are compared, and the differential image is obtained by subtraction of the edge images. An example of the differential picture is shown in Fig. 3. The residuals of the subtraction may be problematic. Hence, the low and high frequency elements hinder detection of the defects, so that 2-dimentional Fourier transform is used to extract frequency elements from the subtracted image and the low and high frequency elements are removed by using a band-pass filter. At the end, the output image from the band-pass filter is

changed again by inverse Fourier transform, then a threshold processing is needed to suppress some noise. The band-pass filter is designed heuristically in this paper.

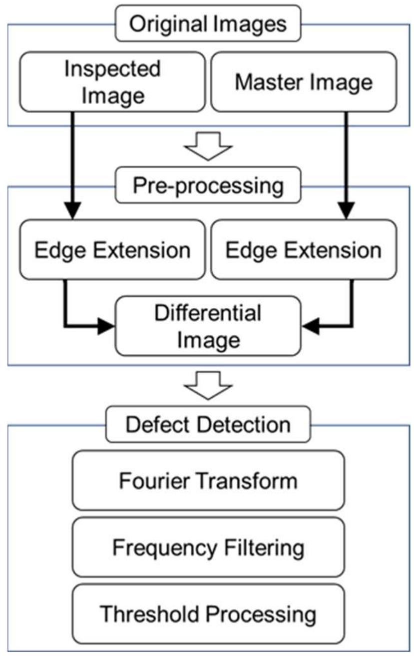

Fig. 1. Defect detection algorithm using Fourier transform for laser data.

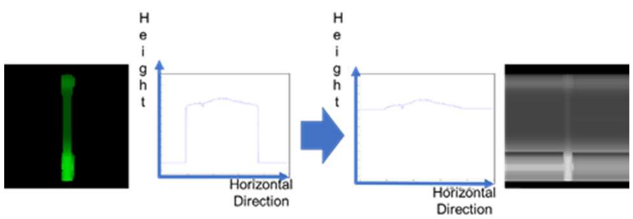

Fig. 2. An example of edge extension.

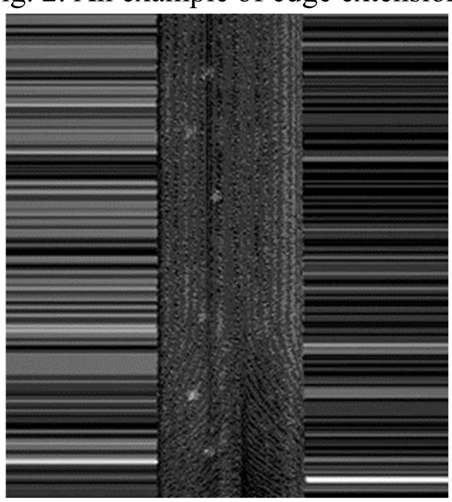

Fig. 3. An example of the edge differential image between inspected and master images.

Fig. 4 shows the picture after inverse Fourier transform and the final resultant image is shown in Fig. 5. In Fig. 5, the white dots showing the defects detected by this method and the positions of the real defects are shown by the squares with red edges. The red and blue dots are also added so that it would be easy to study resultant consistency. The red dots shows that the real defects could be detected by this method, while blue dots mean that this method defected

Wrong defects in the place where the real defects do not exist. The wrong detection comes from the laser measurement data difference between the inspected and master images.

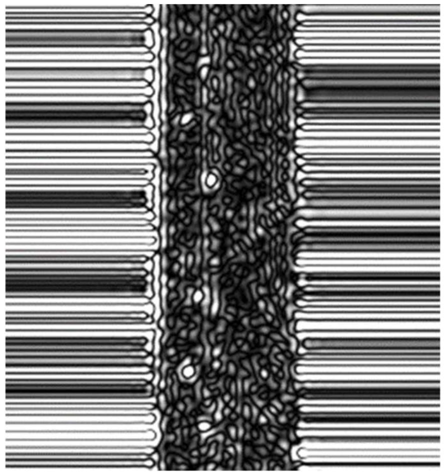

Fig. 4. An output image after inverse Fourier transform.

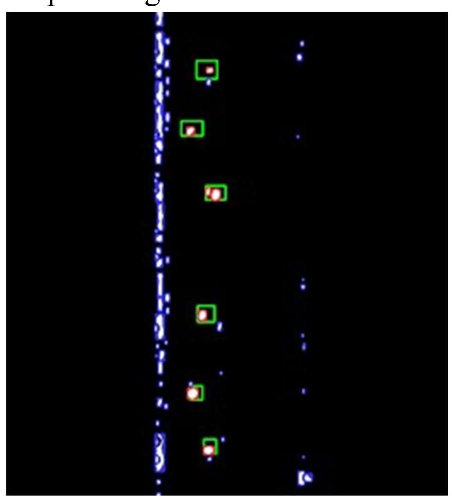

Fig. 5. The resultant image by thresholding.

III. DEFECT DETECTION FROM LASER MEASUREMENT DATA BY WAVELET TRANSFORM

In general, since Fourier transform is only localized in frequency, it has problems to grab local variation in an image. On the other side, wavelets are localized in both frequency and position in the image. To show the wavelet analysis, only thing to do is replacing Fourier transform with wavelet transform. In this paper, multi-scale wavelet transform is applied to the differential image in which wavelet transform is applied 6 times. At the end, inverse wavelet transform is applied to obtain the resultant image. Fig. 6 and Fig. 7 present the image obtained by the inverse wavelet transform processing and the final result. The colours in Fig. 7 have the type of meaning as in Fig. 5. Compared with Fig. 5, fewer real problems are detected as well as the fake detection located in the edges is suppressed in Fig. 7.

IV. PROBLEM DETECTION BY IMAGE PROCESSING

In this Study, a less expensive CCD camera is used instead of an expensive laser. In addition, we propose a
series of picture processing without using any master image to detect defects. The picture processing algorithms can be applied more easily, since a CCD camera image is obtained in two-dimensional.

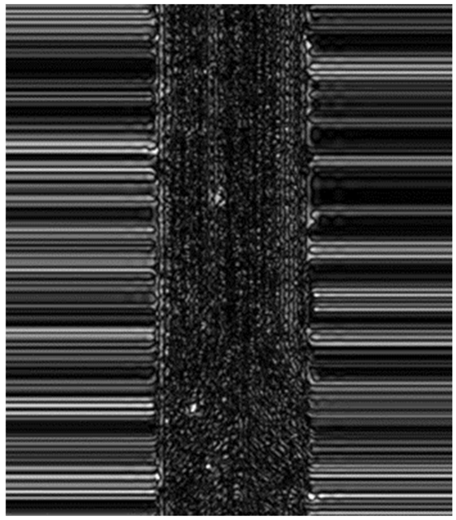

Fig. 6. An output image after inverse wavelet transform.

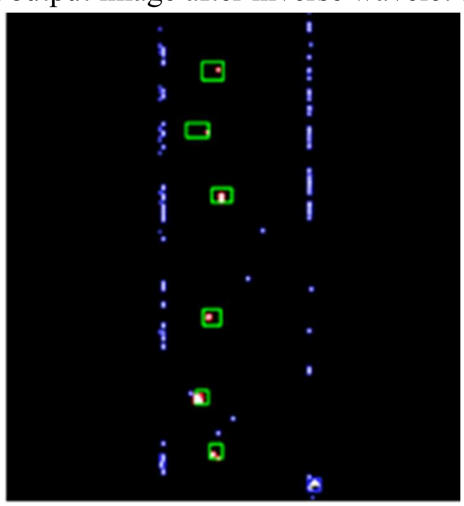

Fig. 7. The resultant image by thresholding.

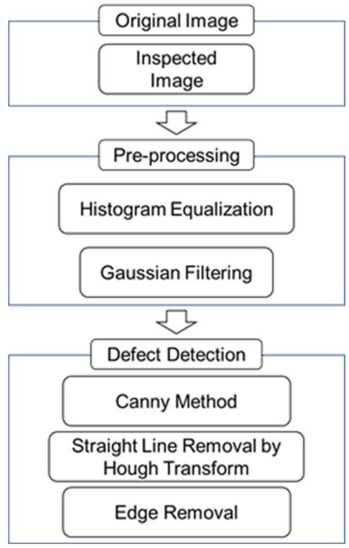

Fig. 8. An original CCD.

The series of picture processing steps are shown in Fig. 8. As the pre-processing in Fig. 8, the histogram equalization is applied to the CCD camera picture. As the histogram equalization has a role of extending difference in brightness in the picture, defect features are emphasized. Subsequently, Gaussian filtering you can applied to blur the edge features and to depress textural noise. The features of Gaussian filtering are determined heuristically. Hence, Canny edge detector, that is one of the common edge detection methods, is utilized to identify large differences among adjacent pixels. So, not only the edges by defects but also the original metal shape edges and the boundary edges of the metal may be detected by this method. The other edges are relatively longer than the former, namely the edges by problems, because they come from the geometrical shape of the metal. So, longer straight lines are removed by Hough transform detection to acquire the last result. The original CCD camera image, the resultant image after Canny edge detector, the straight lines found by Hough transform, and the final result are shown in Fig. 9, Fig. 10, Fig. 11, and Fig. 12, respectively. The colours in Fig. 12 have the same meaning as in Fig. 5.

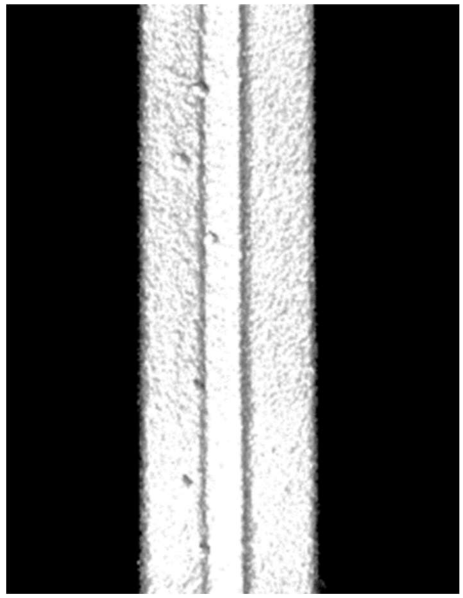

Fig. 9. Defect detection algorithm using image processing for CCD camera images.

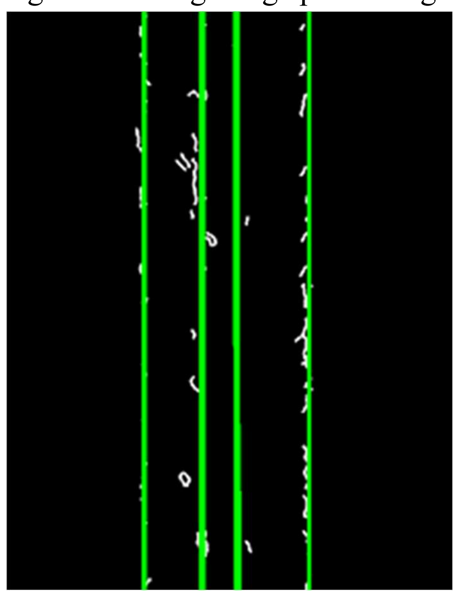

Fig. 10. An output image after Canny edge detector.

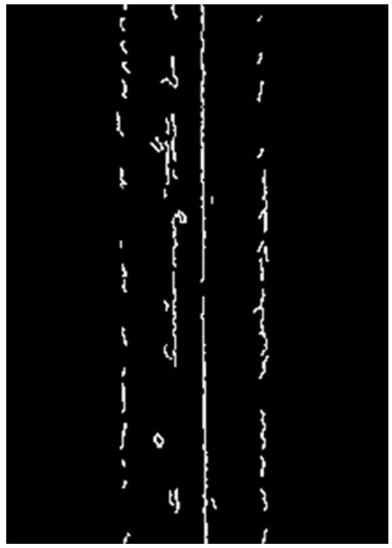

Fig. 11. Straight lines detected by Hough transform.

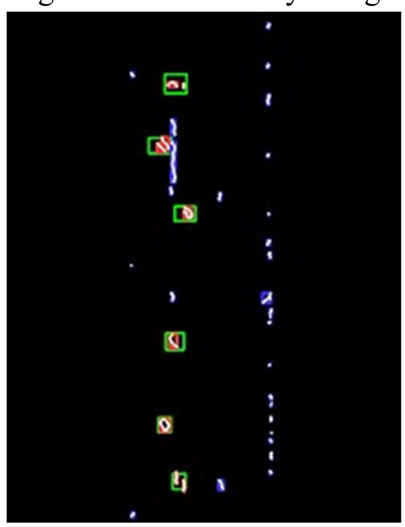

Fig. 12. The resultant image by thresholding.

V. CONCLUSIONS

In this study, problem detection methods for forged metal parts are reported. Development of these idea is useful to alleviate human inspection stress and pressure. So the sensing part if defects, one-dimensional laser and a CCD camera are also be used; the former is more expensive than the latter. For the laser measurement informations, we proposed a defect identification method based on frequency analysis: Fourier or wavelet transform. On the other side, for the CCD camera picture, we proposed a series of image processing to detect problems. The outputs obtained by these methods were comparable. But the master picture was needed for the case of laser data processing, so it was not needed for the case of CCD image processing. As the output of comparison between Fourier and wavelet transform, real problems are detected better for Fourier transform, while fake detection located in the edges is suppressed for wavelet transformation.

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