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Selection of Optimum Illumination Mechanism Using DWT Synthetic Image and Discriminant Measure[Poster referred]

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Abstract

In this paper, surface defects and typical illumination mechanisms for steel plates are analyzed, and then optimum illumination mechanism is selected using discrete wavelet transform(DWT) synthetic images and discriminant measure(DM). The DWT synthetic images are generated using component images decomposed by Haar wavelet transform filter. The best synthetic image according to surface defects is determinded using signal to noise ratio(SNR). The optimum illumination mechanism is selected by applying discriminant measure(DM) to the best synthetic images. The DM is applied using the tenengrad-euclidian function. The DM is evaluated the degree of contrast using the defect boundary information. The performance of the optimum illumination mechanism is verified by quantitative data and intuitive image looks. It is judged that the selected illumination mechanism could apply effectively to surface inspection system.

Discriminant measure, Optimum illumination mechanism, Steel plate, Surface inspection, Discrete wavelet transform

1. Introduction

Steel plate is most widely used in a variety of industries including automotive and shipbuilding steels. Currently, vision-based automated inspection systems used in steelmaking processes are unlikely to be accurate. There are many problems such as hazardous places, operating speed and low contrast, non-uniform, featureless steel surface image characteristics[1].

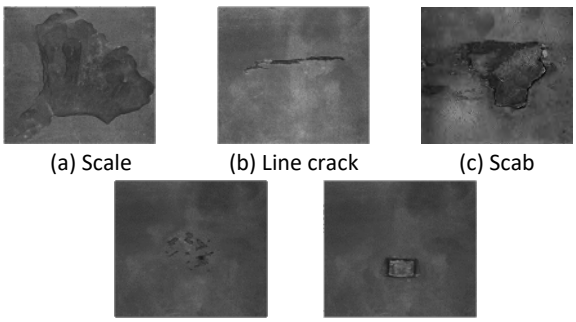
In this paper, the DWT is applied for treating with these three properties in steel plate surface images. The synthetic images are generated by applying the DWT. They are evaluated using SNR, and the best synthetic image is selected. In order to the optimum illumination mechanism is selectied using the tenengrad-euclidian based DM in the best synthetic image.

2. Steel plate surface defects and illumination mechanisms

Typical surface defects of steel plates are consist of scale, scab, crack, foreign object, etc. They are described in Figure 1. They are uneven shape surface defects. The defect regions of these surface images are darker than the defect-free regions due to incomplete diffuse reflection components.

Typical illumination mechanisms include directional illumination (DI), bi-directional illumination (BI), coaxial illumination (CI), and dome illumination (DOI). The fused illumination mechanism was constructed considering the characteristics of the typical illumination mechanisms[2]. BI & CI in Figure 2 (a) can make the reduction of shadow effect due to BI. DOI & CI in Figure 2 (b) can acquire even and bright image, regardless of irregular surface shapes.

In this paper, the parameterization of illumination mechanisms is made according to the angle and height of illumination. The effect of illumination angle for DI and BI has been investigated. The angle is changed from 30°to 70° with interval 10˚. Here, 5 images can be obtained in DI and BI. DOI has 3 channels(high, middle, low) according to illumination structure height, which can be controlled respectively. Then 7 images are obtained in the DOI. In the same manner of BI, BI & CI have 5 images according to illumination angle change. Also, DOI & CI 7 images according to channel.We make use of totally 145 images, which include 25 images for DI , BI , BI&CI and 35 images for DOI , DOI & CI, respectively.



(a) Scale (b) Line crack (c) Scab
(d) Star crack (e) Foreign object

Figure 1. Steel plate defects

(a) (b)

Figure 2. Illumination mechanisms

3. DWT synthetic images and discriminant measure

The DWT is applied for improving to low contrast, non-uniform and featureless properties in steel plate surface images. The

DWT filter[3] is applied using the haar wavelet transform filter. The synthetic images are synthesized using the decomposed component images by DWT. The DWT synthetic images are modelled as Eq (1).

$$S_i^{123} = E_i^1 + C_i^{1,2}E_i^2 + C_i^{2,3}E_i^3 \quad (1)$$

Where E is the normalized energy image of the decomposed component image, and C is the weight between the resolution component images.

The DWT synthetic images are evaluated by SNR. The SNR is means the intensity of the signal with information divided by the intensity of the noise, and is defined as Eq (2).

$$SNR = \frac{\widehat{I_d} - \widehat{I_{df}}}{\sigma_{df}} \quad (2)$$

Where $\widehat{I_d}$ and $\widehat{I_{df}}$ are the average of the defect and defect-free region, and σ_{df} is the standard deviation of the defect-free region.

Table 1 shows four normalized data of applying the SNR to DWT synthetic image. As a result of comparing the normalized data, S_{hv}^3 images showed the highest ones in the four defects except line crack. However, there is also relatively high value in line cracks. Therefore, the best synthetic image is determined as S_{hv}^3.

The DM is a measure used to determine which group belongs to when a certain pattern or feature is divided into several groups. The DM is based on the tenengrad-euclidian function. It is defined as Eq (3), The DM is modelled using the quantitative substract of boundary information between defect-free region and defect region[4].

$$\mathrm{DM} = \left(F_{TE-d} - F_{TE-df}\right) \quad (3)$$

$$F_{TE} = \sum_x \sum_y I(x,y)^2, \qquad I(x,y)^2 > T$$

Where F_{TE-d}, F_{TE-df} mean pixel value of image in the defect and defect-free region. I(x,y) is boundary information. T is an arbitrary threshold for limiting boundary information and then makes some noise be reduced a little.

The results of the DM are in Table 2 so that they can be compared with normalized values according to illumination mechanism. As a result of comparing the normalized data in Table 2, BI&CI showed the highest ones in the four defects except scab. However, there is also relatively high value in scab. Therefore, optimum illumination mechanism was selected as BI&CI. In addition, Table 3 shows the parameters indicating the maximum DM values in each defect. The optimum illumination parameter of BI&CI is selected as 70 degrees which has the most numerous accumulation of the maximum value. The DWT synthetic images by the optimum illumination mechanism are shown in Figure 3. It is showed that they have high contrast and discriminating features.

4. Conclusions

In this paper, the optimum illumination mechanism for the surface inspection of steel plates was selected. The DWT synthetic images were modeled for improving low-contrast, nonuniform and featureless steel plate image, and then the best sy synthetic image among them were deteremined using SNR. The tenengrad-euclidian based DM was applied to the best synthetic image in each illumination mechanism. As a result of applying DM, the optimum illumination mechanism was selected as BI&CI and its optimum parameter is 70 degreee. It is judged that the selected illumination mechanism could apply effectively to surface inspection system.

Table 1 SNR comparisons for synthetic images

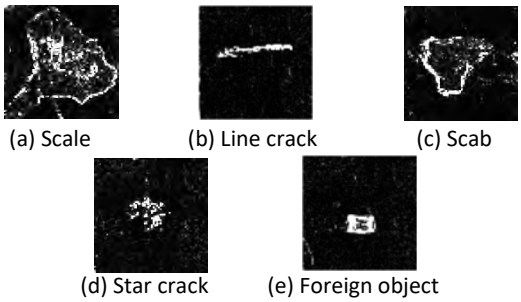
Defect / S_i^n	Scale	Line crack	Scab	Star crack	Foreign object
S_{hv}^3	**1.00**	0.94	**1.00**	**1.00**	**1.00**
S_{hd}^3	0.63	0.65	0.94	0.34	0.67
S_h^3	0.22	0.62	0.85	0.80	0.75
S_h^{23}	0.29	**1.00**	0.93	0.78	0.84

Table 2 DM value comparisions for illumination mechanisms

Defect / Illumination	Scale	Line crack	Scab	Star crack	Foreign object
DI	0.90	0.97	0.80	0.89	0.91
BI	0.98	0.95	**1.00**	0.89	0.96
BI&CI	**1.00**	**1.00**	0.98	**1.00**	**1.00**
DOI	0.15	0.76	0.87	0.88	0.85
DOI&CI	0.15	0.75	0.94	0.87	0.74

Table 3 Parameters of optimum illumination mechanism

Surface defect	Illumination for a defect (Parameter)	Optimum illumination
Scale	BI&CI(70˚)	BI&CI (70˚)
Scab	BI&CI(60˚)	
Line crack	BI&CI(70˚)	
Star crack	BI&CI(70˚)	
Foreign object	BI&CI(70˚)	



(a) Scale (b) Line crack (c) Scab (d) Star crack (e) Foreign object

Figure 3. DWT synthetic images by optimum illumination mechanism

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