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VISUAL AND INTELLIGENT RECOGNITION OF DEFECTS IN UNDERWATER STRUCTURES USING ACFM TECHNIQUE

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ABSTRACT
The traditional alternating current field measurement (ACFM) technique identifies the defect by the butterfly plot, which is easily disturbed by the lift-off variations of the probe. This paper presents a novel intelligent recognition method for the inspection of defects using the ACFM technique. Firstly, the magnetic field in Z direction (Bz) is discovered as the insensitive signal to the lift-off. Secondly, the image gradient field inversion algorithm is presented to reconstruct the surface profile of the defect. Thirdly, the convolutional neural networks (CNN) deep learning algorithm is proposed to achieve intelligent recognition and classification of defects. The results show that the crack, irregular crack and corrosion defect can be recognized and classified accurately..

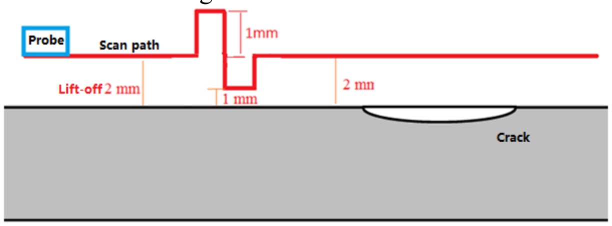
Keywords: Visual and intelligent, ACFM, classification and recognition

1. INTRODUCTION
The ACFM technique has been widely used in offshore structures, due to the advantages of less clearing, noncontact measurement and quantitative evaluation[1]. In the underwater environment, there are many attachments on the surface of the structure, as shown in Fig. 1. The rugged surface makes the probe lift-off variation seriously, which brings many interference signals[2]. The traditional ACFM technique identifies the defect by the characteristic signal and butterfly plot. It is hard to identify the defect by the butterfly plot and the characteristic signal in the underwater environment by the operator. What's more, the type of defects cannot be recognized by the traditional characteristic signals. It is meaningful to develop an intelligent method to recognize the defects, which can reduce the dependencies on the operator and the misjudgment ratio.

Fig. 1. Attachments on underwater structure

In this paper, the intelligent recognition method is presented to recognize and classify the defect intelligently. Firstly, the *Bz* is set as the insensitive signal to the lift-off. Secondly, the *Bz* image gradient field inversion algorithm is presented to reconstruct the surface profile image of the defect. Thirdly, the convolutional neural networks (CNN) deep learning algorithm is proposed to achieve intelligent recognition and classification of different kinds of defects.

2. INSENSITIVE SIGNAL TO LIFT-OFF
The lift-off variation experiments are carried out to study the distorted signal caused by the probe lift-off. The probe is driven up and down to simulate the lift-off variations. The interference signals caused by the lift-off and characteristic signals of the defect are shown in Fig. 2.



(a)

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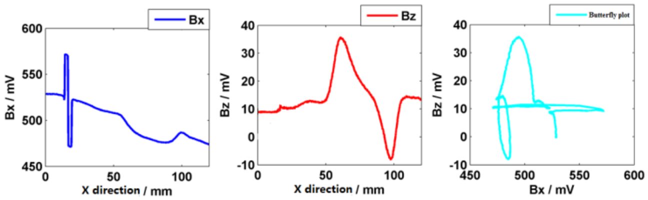


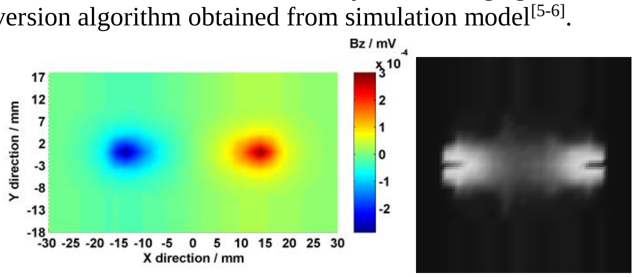
(b)

Fig. 2. Lift-off variations of probe. (a) Scan path of probe. (b) Characteristic signal *Bx*, *Bz* and butterfly plot .

The probe is driven by a scanner to detect the crack with the speed of 2 mm/s and keep the lift-off of 2 mm. The probe is driven up 1 mm and then down 2 mm before across the crack. The results show that the magnetic field in X direction *(Bx)* is disturbed by the lift-off variations seriously. The peak of the interference signal caused by the lift-off variations is much greater than the characteristic signal of the crack. However, the *Bz* almost keeps smooth and steady when the lift-off varies. The *Bx* shows a trough, when the crack is present. Meanwhile, the *Bz* shows opposite peaks at the ends of the crack. The peaks of the characteristic signal are much greater than that of the interference signal caused by the lift-off variations. Besides, the defects cannot be identified effectively by the butterfly plot because of the interference signal caused by the lift-off variations. The results show that the *Bz* is insensitive to the lift-off variations. Thus the *Bz* can be set as the characteristic signal to recognize and classify the defects.

3. VISUAL IMAGA OF DEFECT SURFACE PROFILE

According to the principle of ACFM technique, the *Bz* is mainly produced by the gathered current field at the tips of the defect. Thus the *Bz* reflects the distribution of gathered current field around the defects in the specimen, which reflects the surface profile of the defect. The gradient of scalar field can calculate the maximum value and direction of scalar field[3-4]. The *Bz* image gradient field inversion algorithm is presented to reconstruct the surface profile image of the defect. As shown in Fig. 3, the surface profile images of the crack, irregular crack and corrosion defect are reconstructed by the *Bz* image gradient field inversion algorithm obtained from simulation model[5-6].



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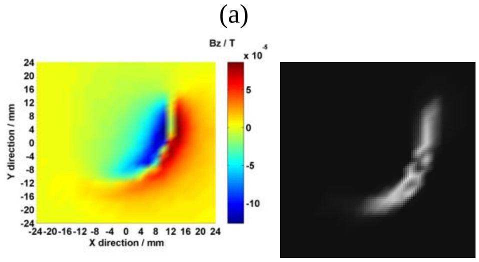

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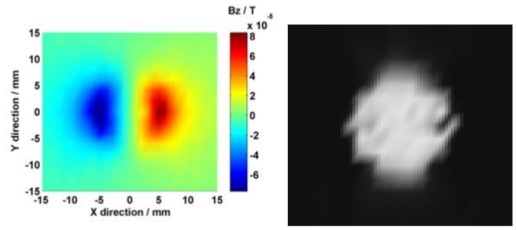
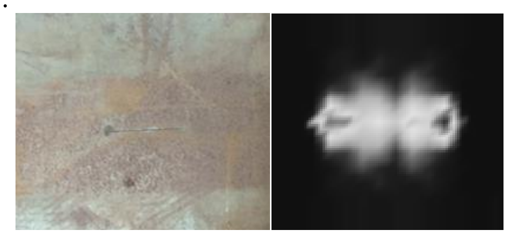


(c)

Fig. 3. Surface profile images of defects in simulation model. (a) *Bz* and surface profile of the crack. (b) *Bz* and surface profile of irregular crack. (c) *Bz* and surface profile of corrosion.

The results show that the surface profile image is consistent with the true outline of the defect in the simulation model. To verify the efficiency of the gradient field inversion algorithm, the *Bz* image is plotted by raster scan using ACFM probe. The surface profile images of the defect in the specimen are shown in Fig. 4. The surface profiles of defects are reconstructed visually.



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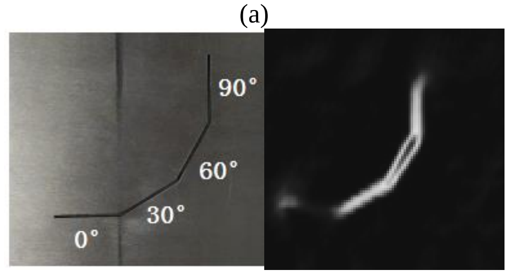

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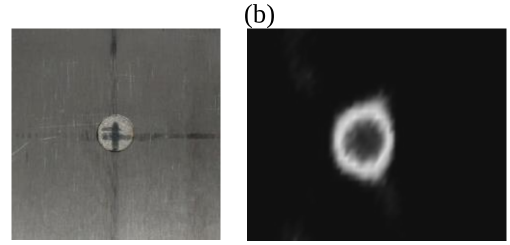

(c)

Fig. 4. Surface profile images of defects in specimen. (a) Surface profile of crack. (b) Surface profile of irregular crack. (c) Surface profile of corrosion.

4. Intelligent classification and recognition of defects

The defect surface profile image database is developed by simulations and experiments. The convolutional neural networks (CNN) deep learning algorithm is proposed to achieve intelligent classification recognition of different kinds of defects[7-8]. There are 80% random samples in the database for training. The remaining 20% samples are for testing. The training and recognition results of the samples are shown in Fig. 5. The results show that all the image samples can be recognized and classified accurately. The identification accuracy of testing samples is 100 %.

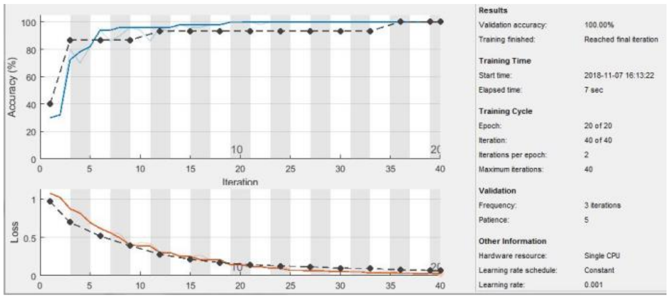

Fig. 5. Intelligent recognition and classification results of defects by CNN deep learning algorithm.

5. CONCLUSION

In this work, the novel intelligent recognition method is presented to achieve recognition and classification of defects. Firstly, the *Bz* is discovered as the insensitive signal to the lift-off variations. Then the gradient field inversion algorithm is presented to reconstruct the surface profiles of defects. In the end, the surface profile image database is set up by simulations and experiments. The defects are classified by the CNN deep learning algorithm. As a result, the defects can be recognized and classified intelligently by the intelligent recognition method using the ACFM technique.

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