Research on Detection Methods of Steel Defects Based on Modal Analysis

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***Abstracts*—Steel is used in construction, Bridges, ships, boilers and other projects on the metal structure, or is used in the manufacture of machinery and equipment parts, which can produce defects such as corrosion and crack due to the effect of load and environment. In order to ensure the healthy use of steel, it is necessary to carry out defect detection. Therefore, a method to detect steel defects based on modal analysis is proposed in this paper. Theoretical model of square steel, which both ends are fixed, was studied. By theoretical simulation, the influence of defects shape and size on modal parameters was studied. The results showed that some order modes change significantly in the modal analysis with the increase of the radius of corrosion defects, and some order modes change significantly in the modal analysis with the increase of the width of crack defect. So, the size of defects can be characterized by the frequency variation of some orders.**

Keywords—steel; defect; modal analysis; detection

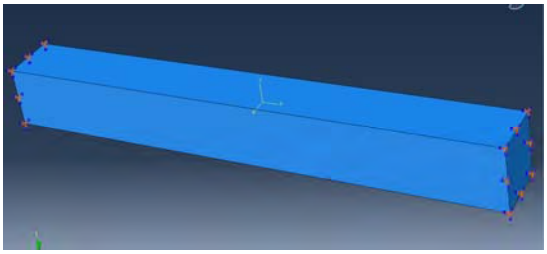
I. INTRODUCTION

Steel has been widely used for easy processing and forming. It is used in construction, bridges, ships, boilers and other projects on the metal structure, or is used in the manufacture of machinery and equipment parts, which can produce defects such as corrosion and crack due to the effect of load and environment. In order to ensure the healthy use of steel, it is necessary to carry out defect detection. It has been studied to detect component defect using modal analysis by scholars and experts. Zhang Zerong et al.[1] used strain mode to detect the crack of the shaker beam. The results show that the strain mode will change suddenly in the crack location. Therefore, the strain modal change rate can be used as the diagnostic index of beam crack. Li Lingjie et al.[2] studied that the strain modal difference was used to characterize the crack of the cantilever beam. The results show that the strain modal difference can identify the single crack of the cantilever beam, and can identify the multiple crack too. In addition to, the strain modal difference can detect the position of the crack, and can detect the degree of crack damage. Ma Yijiang et al.[3] conducted modal analysis on the cracks of the simply supported beam using the transfer matrix method. It is found that the natural frequencies of the simple supported steel beams can be used to detect the crack depth. Khalkar. V et al. [4] have studied the effect of V shape and rectangular shape cracks on the natural frequency by analyzing the free vibration of the cracked cantilever beam. The results showed that the presence of small size rectangular shape crack in the beam can be effectively detected by vibration measurement methods than small size 'V' shape crack. Moezi S A et al.[5] estimated the number, location and depth of cracks created in several Euler-Bernoulli beams using the hybrid Cuckoo Nelder Mead Optimization Algorithm (COA-NM) Amount of calculations performed by COA-NM to achieve this accuracy is much less compared to other methods. Khalkar. V et al[6] presented numerical and experimental studies on modal behavior of cylindrical, lightly damped beam structures containing a notch-like crack with variable position and geometry. The deviations between real and determined crack positions range between 0.05 and 0.28 percent for crack depth/diameter ratios of less than 7 percent. The above results provide theoretical basis and technical support for this study.

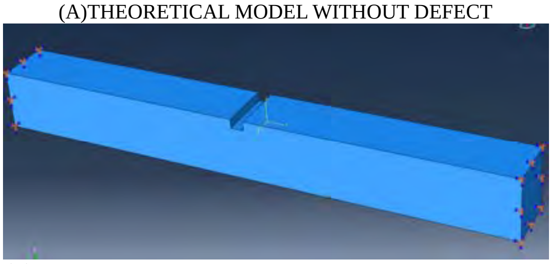
In this paper, a method to detect steel defects based on modal analysis is proposed. Abaqus was used for theoretical simulation of steel without defect, steels with corrosion and with crack. The influence of defects shape and size on modal parameters was studied by theoretical simulation. The results showed that the size of defects can be characterized by the frequency variation of some orders.

II. THEORETICAL MODEL

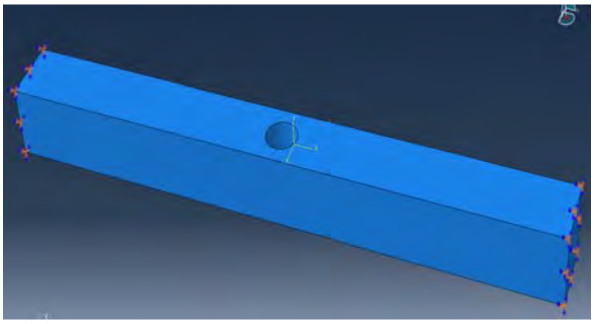
The theoritical models of square steels were established, which mainly includes three types. Figure I (a) is a model without defect, Figure I (b) is a model with rectangular crack, and Figure I (c) is a model with circular corrosion.



(A)THEORETICAL MODEL WITHOUT DEFECT



(B)THEORETICAL MODEL WITH RECTANGULAR CRACK



(C)THEORETICAL MODEL WITH CIRCULAR CORROSION

FIGURE I. THEORETICAL MODELS OF SQUARE STEELS

Table I shows the sizes of rectangular cracks. The width and depth of rectangular cracks are same in four models. The length of rectangular crack is 2mm, 4mm, 6mm, 8mm respectively. These models were established to calculate the influence of crack width on modal parameters. By calculation, the relationship between modal parameters and crack width was established. So, the detection method was established to characterize the crack width with modal parameters.

TABLE I. SIZE OF RECTANGULAR CRACKS

No.	*Length (mm)*	*Width (mm)*	*Depth (mm)*
1	2	20	3
2	4	20	3
3	6	20	3
4	8	20	3

Table II shows the sizes of circular corrosions. The depth of circular corrosions is same in three models. The radius of circular corrosion is 3mm, 6mm, 10mm respectively. These models were established to calculate the influence of the corrosion radius on modal parameters. And, the relationship between modal parameters and the corrosion radius was established by calculation. So, the detection method was established to characterize the corrosion radius with modal parameters.

TABLE II. SIZE OF CIRCULAR CORROSIONS

No.	*Radius (mm)*	*Depth (mm)*
1	3	3
2	6	3
3	10	3

III. RESULTS ANALYSIS

The first 15th order natural frequencies were calculated for samples without defects and with different width cracks. Figure II showed the normalized frequency vs. the fist 15th order of the different crack width sample. The normalized frequency increases with the increase of crack width when the order number is 5, 8 and 12 respectively. The normalized frequency decreases with the increase of crack width when the order number is 1, 6, 9 and 12 respectively. Therefore, the normalized frequency can be used to characterize the change of crack width at specific orders.

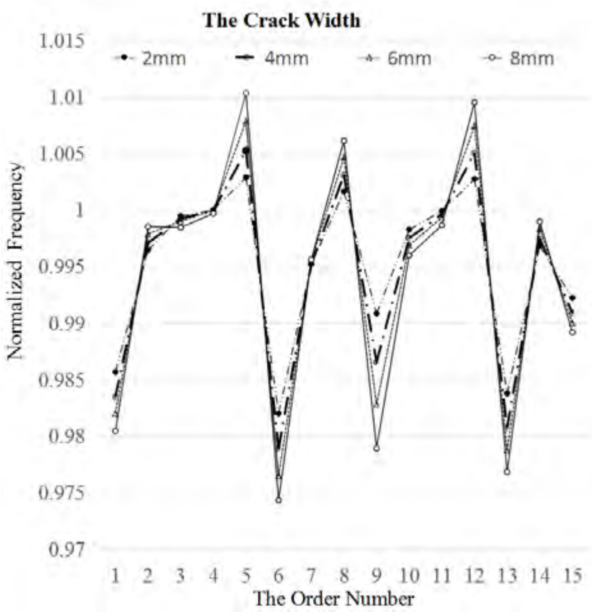


FIGURE II. THE NORMALIZED FREQUENCY VS. THE FIST 15TH ORDER OF THE DIFFERENT CRACK WIDTH SAMPLE

Figure III showed the regularity of normalized frequency changes with the crack width when the order is 5, 8 and 12 respectively. That is, the normalized frequency increases with the increase of crack width. As can be seen from the figure, when the order is 5, the normalized frequency has the highest rate of change, which indicates that its sensitivity is the highest.

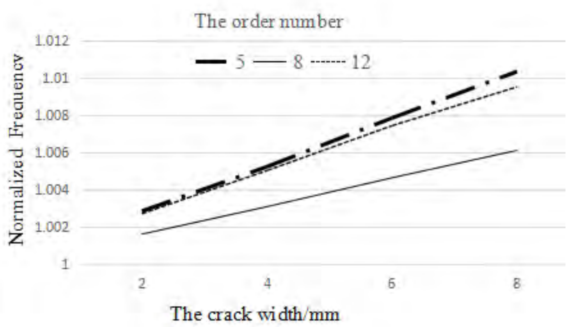


FIGURE III. THE NORMALIZED FREQUENCY VS. THE CRACK WIDTH WHEN THE ORDER NUMBER IS 5, 8,12 RESPECTIVELY

Figure IV showed the regularity of normalized frequency changes with the crack width when the order is 1, 6, 9 and 13 respectively. That is, the normalized frequency decreases with the increase of crack width. As can be seen from the figure, when the order is 9, the normalized frequency has the highest rate of change, which indicates that its sensitivity is the highest.

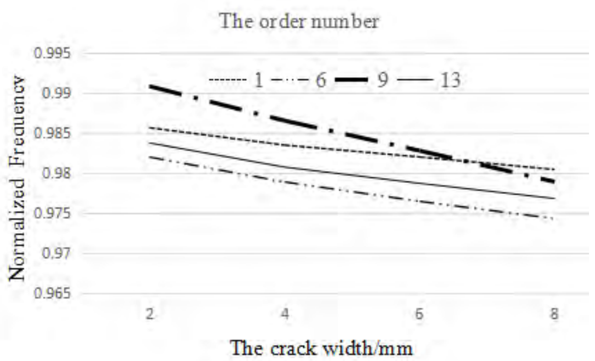


FIGURE IV. THE NORMALIZED FREQUENCY VS. THE CRACK WIDTH WHEN THE ORDER NUMBER IS 1,6,9 AND 13 RESPECTIVELY

Figure V showed the normalized frequency vs. the fist 15th order of the different corrosion radius sample. The normalized frequency increases with the increase of corrosion radius when the order number is 5, 8 and 12 respectively. The normalized frequency decreases with the increase of corrosion radius when the order number is 1, 6, 9, 12 and 15 respectively. Therefore, the normalized frequency can be used to characterize the change of corrosion radius at a specific order too.

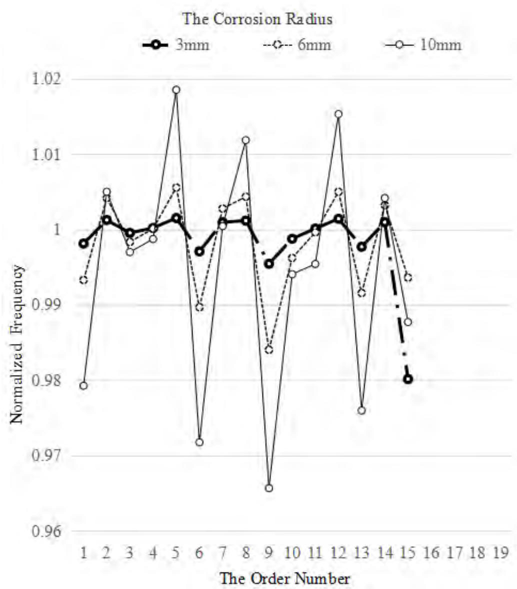


FIGURE V. THE NORMALIZED FREQUENCY VS. THE FIST 15TH ORDER OF THE DIFFERENT COROSION RADIUS SAMPLE

IV. CONCLUSIONS

The effects of rectangular defects and circular defects on the first 15 order modes are calculated by using simulation software, and the following conclusions are drawn

(1) The normalized frequency can be used to characterize the width change of the rectangular crack at specific orders.

(2) The normalized frequency can be used to characterize the radius change of the circular defect at specific orders.

In order to find the corresponding relation between defect and modal parameters, a lot of research needs to be done.

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