Development of defect detection method of steel structures by digital image correlation method using induction heating

Akira DEMIZU¹, Yukihiro ITO², Hiroshi MATSUDA³, Chihiro MORITA⁴, S. Paul Sumitro⁵

¹Nagasaki University; Nagasaki, Japan,
Phone: +81-95-819-2880, Fax: +81-95-819-2879; e-mail: demizu@nagasaki-u.ac.jp
²Saga University; Saga, Japan, e-mail: itoy@cc.saga-u.ac.jp, mita@cc.saga-u.ac.jp
³Nagasaki University; Nagasaki, Japan, e-mail: matsuda@nagasaki-u.ac.jp
⁴Nagasaki University; Nagasaki, Japan, e-mail: cgmorita@nagasaki-u.ac.jp
⁵SMART SENSYS; Champaign, USA, e-mail: paul@smartsensys.com

Abstract
When external force to steel structure is repeated action there is crack occurs in stress concentration member. Crack is localized, it does not affect strength of structure immediately. However, when you leave crack, to progress to serious accident of breaking of member and collapse of structure. Therefore, examined at initial stage of crack, it is important to perform appropriate repair and reinforcement. Is generally widely used magnetic particle testing and penetrant testing are detection of crack. However, those tests it is necessary to remove paint. In addition, inspection method is complicated, there is problem, such as requires skill. To solve the problems described above to, and we developed new crack detection method of steel structure with digital image correlation method using induction heating.

Keywords: steel structure, steel bridge, fatigue crack, digital camera, digital image correlation method(DICM), induction heating

1. Introduction

In recent years, occurrence of fatigue crack has increased in steel bridge. Fatigue crack occur in structural stress concentration part by repeated load. It also occurs in stress concentration part due to welding shape and weld defect. Depending on member, to cause brittle fracture and crack to progress. And, there is fear that to reach significant impact on safety of bridge. Thus, it is early detection, it is important to perform appropriate repair. The inspection method of crack that is often used in implementation field, there is magnetic particle testing or penetrant testing, etc. However, these methods have problems such as ① inspection time is long, ② test range is narrow and ③ necessary inspection to paint removal.

To solve these problems, we have developed method for detecting short time extensively steel crack without removing paint. Development method is to open and close the crack by using induction heating device, it is measured by digital image correlation method(DICM), new crack detection method of the steel member to visualize the crack. In the paper, we describe application examples to verification experiment and real bridges of development method.

2. Crack detection method

DICM [1][2] utilizes randomness of pattern of object surface, method of calculating displacement and strain measurement area. From deformation previous image, specifying arbitrary area of the $N \times N$ pixels(subset) is set to one pixel center (Fig. 1 (a)). When the measurement object is deformed, the position of the subset after deformation is changed (Fig. 1 (b)). Using the image before and after deformation, and calculates the position indicating the high correlation of gray value distribution of a subset. Then, calculate the displacement from the
movement of a subset of the center point. By repeating this process with whole image, it is possible to obtain the displacement distribution. Strain is calculated by the change in distance between two points before and after deformation.

The measurement system and overview of crack detection it is shown in Fig. 2,3. Heating the steel material by induction heating device, forcibly open-close crack. Heating the steel material by induction heating device, forcibly open-close crack. It measures change of the crack by DICM. Measurement system, digital camera, lighting, laptop, and induction heating device. It is simple system with light weight.

3. Basic experiment

We conducted verification experiment of crack detection of development method. Overview of specimen is shown in Fig. 4. Specimen is welded to transverse plate (length 290mm, width 99mm, thickness 7mm) to vertical plate (length 650mm, width 300mm, thickness 12mm). The material is SS400. Using fatigue testing machine, it was generated crack on the specimen. And, it was painting about 240μm from the top of the crack. It was heated using Panasonic Corp. IH heater(Fig. 5). It was heating the back surface of the cracked portion. It has set the heating temperature to about 100 degrees. Using DICM and infrared thermography, it was measured the crack surface. The heat pre-image and about 100 degrees images were analyzed by DICM, to calculate the strain.
The results of the Magnetic testing is shown in Fig. 5. Figure shows the crack width was observed by loupe. Crack length is about 155mm, crack width is 0.01mm ~ 0.07mm. The strain distribution was calculated by DICM shown in Fig. 6. Compressive strain in the crack is confirmed, it is possible to visualize the location of the crack. Back is expanded because of the heat to the back side of the crack surface. The compressive strain is caused by the crack is closed. Compressive strain of more than 10,000μ to crack portion is generated, the strain is decreased in its tip.

4. Application to existing bridge

We have applied the development method to the real bridge (Fig. 8). The measurement situation it is shown in Fig.9. It was measured using CCD camera (5 million pixels). The distance from the measurement surface to the camera it was 650mm. Therefore, image resolution is 0.044mm/pixel. It was subjected to random pattern in spray to measurement surface. It was heated crack surface by using Panasonic Corp. IH heater. After heating the crack surface to about 100 degrees, it was measured in DICM.

The strain distribution was calculated at DICM, it is shown in Fig.10. In the figure, the strain is confirmed from the upper right to lower left. Also it can be confirmed that the crack tip is divided into two. By heating the crack surface, the crack is expanded and opened. Tensile strain is generated in the crack. The results of Magnetic testing is shown in Fig.10.

From Fig.10, the crack length was confirmed to be about 75mm, the crack tip is split in two. Comparing the results of DICM and Magnetic testing, DICM is able to detect cracks. However, DICM was not able to detect the crack tip to detail. This can be solved by improving the imaging resolution.
5. Conclusions

We went crack verification experiment and real bridge measurement of development method. We got the following results.
1) The thermal load is applied to the steel member, and by measuring at DICM, it was possible to detect crack.
2) It was possible to detect crack with high accuracy in bridge.

References
