Development of Mechanical Parameters Evaluation Method for Stress Concentration Part Using Digital Image Correlation

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1. Introduction

On mechanical structures, Cracks are caused of serious destructive accidents. Therefore, a convenient and high accurate method for detecting the crack is necessary to prevent from serious destruction.

Digital Image Correlation method (DIC) is one of the nondestructive inspections. DIC is an easy procedure for measurements without complicated optical systems. Furthermore, it is nondestructive, contactless and full-field measurement method with high precision.

In this research, a new DIC which adopted to singular stress field around the crack tip was developed.

2. Principle Digital Image Correlation

DIC is a method to detect the displacement by template matching technique using pixel brightness in captured images before and after displacement.

Procedures of DIC method is as follows:

(i) Coarse search

Coarse search was performed by using Sequential Similarly Detection Algorithm (SSDA) as shown in Eq.(1). In this method, the accuracy of determination is pixel spacing.

$$\min(\Sigma|f(x,y)-g(x+u,y+v)|) \quad (1)$$

f and *g* are pixel brightness value of images before and after displacement. (x, y) is coordinate of interest point before displacement. Σ means sum of brightness value of each pixel in a subset. The displacement (u, v) is calculated by searching a position at which a sum of residual takes a minimum value.

(ii) Precision search

Precision search detects the displacement with a high accuracy of determination less than pixel spacing using Newton-Raphson method. Following equation gives correlation coefficient *S*.

$$S = 1 - \frac{\sum\{f(x,y)\cdot g(x^*,y^*)\}}{\sqrt{\sum\{f^2(x,y)\}\cdot\sum\{g^2(x^*,y^*)\}}} \quad (2)$$

(x^*, y^*) is coordinate of interest point after displacement. This equation is used for determining the position at which the S value takes a minimum value.

The coordinate at the crack tip, x^* and y^* are given as following equations under the assumption of small template deformation.

$$x^* = x + u - y_t R + u_K \quad (3)$$

$$y^* = y + v + x_t R + v_K \quad (4)$$

u and v represent displacements of rigid motion. x_t and y_t represent distances between target position and center position of template. $-y_tR$ and x_tR mean displacements for small rotate of rigid. u_k and v_k represent displacements which generated by stress singularity field at crack tip.

Stress intensity factor (K) can be directly estimated by using these equations.

3. Results K range

Evaluation accuracy of K value by KDIC was investigated by comparing with a setting value of K and an evaluated value of K.

3.1. Specimen

Center cracked tension (CCT) aluminum (A5052) specimen was prepared. Cyclic loading was added to this specimen to propagate fatigue crack from a notch. Fig.1 shows the shape of specimen. The width "*W*" was 12mm and the thickness "*t*" was 6mm. In this specimen, a crack propagation direction was a direction of z-axis, a load direction was a direction of y-axis.

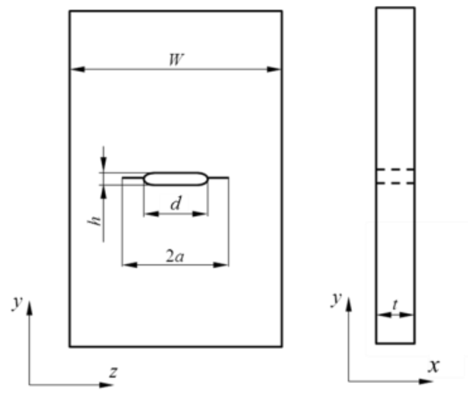


Fig.1 CCT specimen

3.2. Experimental conditions

In the experiments, images were taken at the side surface of CCT specimen before and after displacement and captured image size was 1280 pixels × 980 pixels. The crack position in a captured image before displacement was set at the center position of the image. The calculation was carried out on each position from 300pixels to 980 pixels. Subset size was 500pixels × 500pixels and setting value of K was 2.0. The values of K were evaluated on some dimensionless crack length ξ (=2a/W).

3.3. Experimental results

3.3.1 Evaluation of K at ξ=0.4

At first, the K value at ξ=0.4 was evaluated. Fig.2 shows the results. From Fig.2, it was found that the evaluated values of K were almost the same as setting values of K.

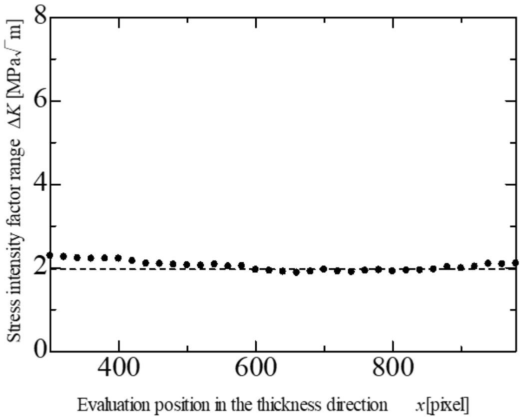
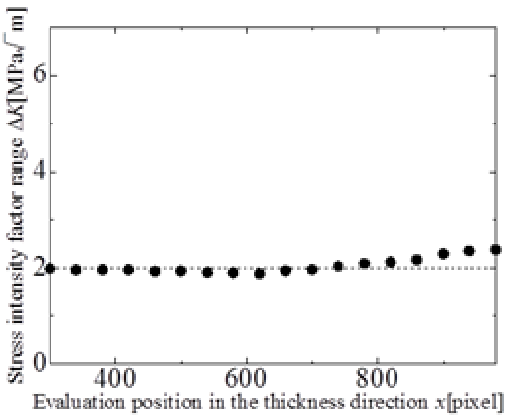


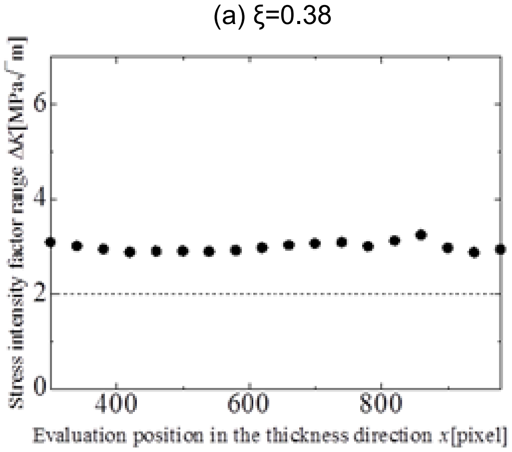
Fig.2 Evaluation of K (ξ=0.4)

3.3.2 Evaluation of K for short crack

The K for short crack which length is less than 0.4, were evaluated. The selected values of ξ were 0.38 and 0.2. Fig.3 shows the results. From Fig.3(a), it was found that the evaluated value of K was similar to 2MPa $\sqrt{\mathrm{m}}$. On the other hand, from Fig.3(b), it was found that the K value was overestimated.



(a) ξ=0.38

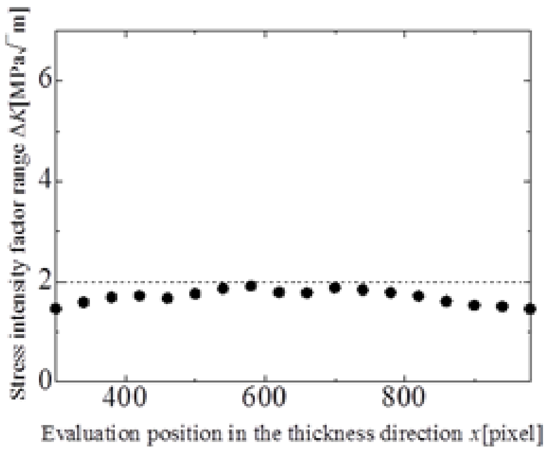


(b) ξ=0.2

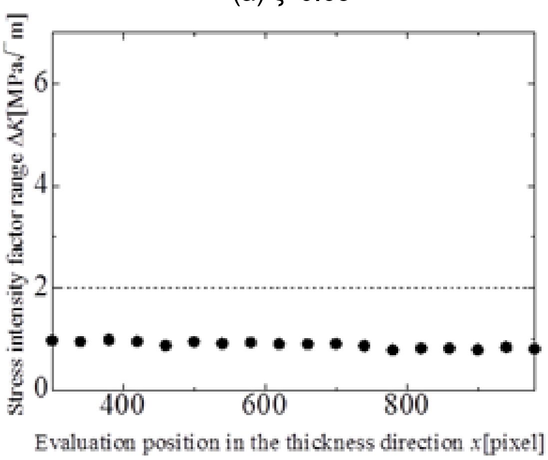
Fig.3 Evaluation of K for short crack

3.3.3 Evaluation of K for long crack

Next, the values of ξ were selected as 0.65 and 0.82. Fig.4 shows the results. From Fig.4(a), it was found that the evaluated value of K was relatively similar to 2MPa $\sqrt{\mathrm{m}}$. On the other hand, from Fig.4(b), it was found that the K value was underestimated.



(a) ξ=0.65



(b) ξ=0.82

Fig.4 Evaluation of K for long crack

4. Conclusion

The K range which can be evaluated by KDIC was investigated. As the results, it was found the following things:

・The K for short crack ξ < 0.38 was overestimated.

・The K for short crack ξ > 0.65 was underestimated.

From the results of these experiments, it was found that valid K values can be estimated using the developed DIC method if a dimensionless crack length is in the range from 0.4 to 0.6

References

[1] M. Kitada and I. Nishikawa, Evaluation of fracture mechanics parameter of the crack from back surface using by DIC [Proceedings of the 90th JSME Annual Meetings](2015), CD-ROM