第 I 部門　Stress Intensity Factor For Cracked Flat Plate Retrofitted By Automatic Center Punch

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1. Introduction

To delay or stop crack propagation, several retrofitting techniques were proposed. However, the common retrofitting tools are difficult to be carried in the regular inspection which results in that small cracks could not be treated timely. Against this background, crack closing technique by applying automatic center punch, ACP treatment, was proposed to retrofit small cracks. The effect of ACP treatment can be evaluated by stress intensity factor range.

In order to clarify the variation of stress intensity factor range after ACP treatment, FEM models are created to simulate the peening effect and several parameter's influences on stress intensity factor range were considered, such as crack length, crack depth and load type.

2. Residual stress induced by ACP treatment

2.1 FEM analysis description

The minimum mesh size in the peened region was 0.25×0.25×0.25 mm. The model generated by using 8-node three dimensional elements is shown in Fig.3 and there is no external load for Chapter2 model. Residual stress is generated by thermal expansion strain to simulate ACP treatment and the value of thermal expansion strain is 3,000μ.

2.2 Stress distribution

The equation used to calculate the stress due to temperature variations for composite steel girder with concrete deck, was employed to calculate stress induced by ACP treatment.

The stress distribution is shown in Fig.2 which also included FEM results. At the crack tip on depth direction, tensile stress was generated, which decreased gradually in the depth direction and shifted to compressive stress for the bottom of the plate.

3. Stress intensity factor for tension condition

To investigate the influence of crack size, 7 models were applied as shown in table 1. The load type is face load which is 200N/mm^2 (see Fig.1). Fig.3 shows the FEM results of model 4. K_{open} which means cracked model without ACP treatment and K_{close} which means the crack surface do not open under the load as the

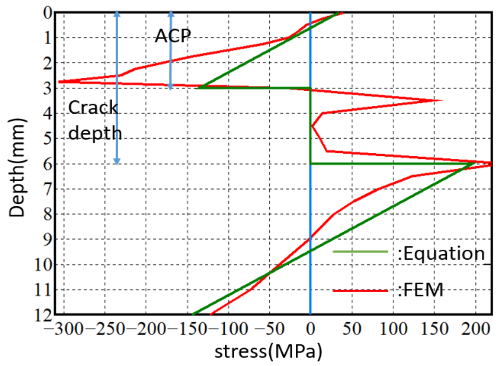

Fig.2 stress distribution

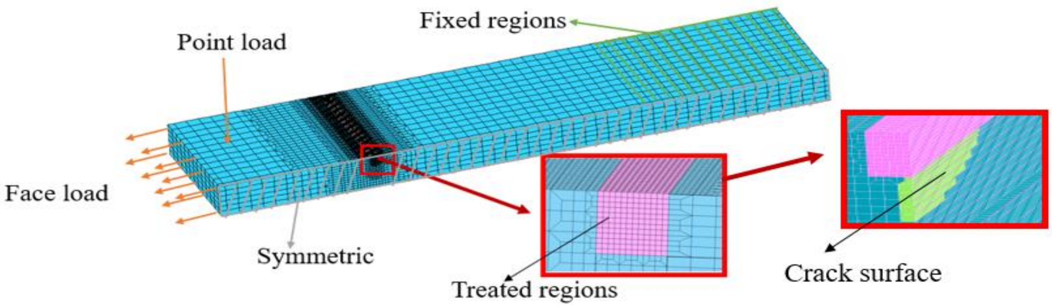

Fig.1 Symmetric FEM model

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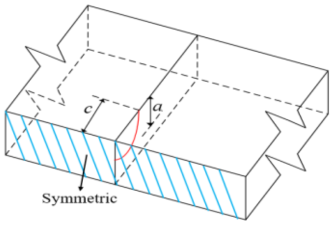

Table1. models of FEM

model	1	2	3	4	5	6	7
Crack depth *a* (mm)	4	4	6	6	6	9	9
Crack length *c* (mm)	9	12	6	9	12	9	12

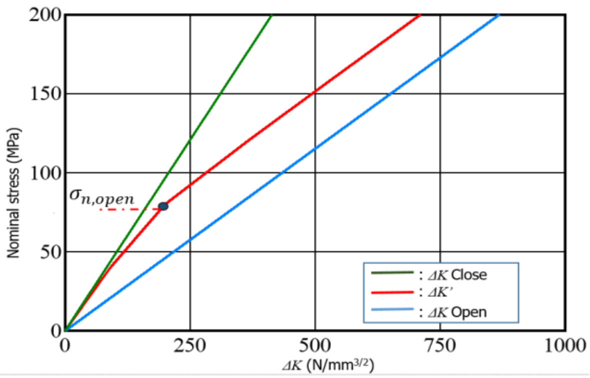

Fig.3 Relation between $\Delta K'$ and Nominal stress for model 4

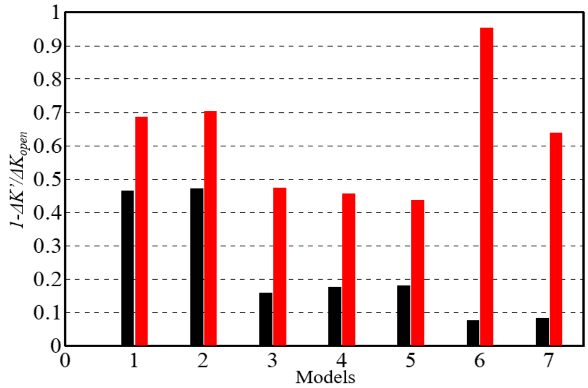

Fig.4 ACP treatment benefit for each model for 200N/mm^2 nominal stress

internal crack, are shown in the figure to estimate the ACP treatment benefit. After treatment, the crack surface is closed so the slope of $\Delta K'$ is the same as ΔK_{close}. As the load increases, the crack surface is gradually re-open and the slope is getting close to ΔK_{open}. The nominal stress of turning point is called σ_{open} which represent crack totally re-open under this nominal stress. And treatment benefit defined as $1-\Delta K'/\Delta K_{open}$, which means ACP treatment reduce stress intensity factor range what percentage in comparison with untreated model.

Fig.4 shows the ACP treatment benefit for each model under nominal stress being 200N/mm^2. It can been seen that when the crack depth is smaller than the half of plate thickness, being 4mm for this study, ACP treatment reduce stress intensity factor range 40%-50%, whereas crack depth being equal to or greater than the half of plate thickness, being 6mm and 9mm respectively, ACP treatment reduce stress intensity factor rang 5%-20%.

4. Stress intensity factor for bending condition

In the bending condition, the models are same as Chapter3, but the load type is point load being 4,660N (see Fig.1). Therefore, the nominal stress on surface is 200N/mm^2.

In the bending condition, if the crack depth is greater than neutral axis, at the crack tip, compressive stress would be partly offset by the tensile stress induced by ACP treatment. And stress intensity factor increases more slowly than other models, influenced by crack length. In addition, σ_{open} decreases with crack length increasing that means crack is easy to re-open as the crack get longer, that phenomenon is not observed for other models.

Form the Fig.4, it can be known that when the crack depth smaller than or equal to the half of plate thickness, the variations of crack length almost has no influence on treatment benefit. If crack depth equals the half of the plate thickness, the ACP treatment benefit reduces the stress intensity factor range about 45%, which is smaller than other crack depths.

5. Conclusions

1. Once the cracked plate is retrofitted by ACP treatment, tensile stress will generate at the crack tip on depth direction.

2. ACP treatment has a better effect under bending load than under tensile load and the benefit is predominated by crack depth.

REFERENCES

1) Toshiyuki Ishikawa, et al: Tentative repair of fatigue crack in steel bridge by automatic punch, Journal of structural Engineering, Vol.65A, 2019. (in Japanese, in press)