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FATIGUE CRACK GROWTH SIMULATION USING S-VERSION FEM.

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ABSTRACT

Evaluation of fatigue life of mechanical component is one of the most important problems for the integrity of mechanical system. Fatigue crack initiates at stress concentrated zone, and grows gradually. By the growth of the crack, stress intensity factor increases and finally it reaches to some critical value. Before it reaches to this critical value, mechanical engineers should find this crack and manage to avoid a final fracture accident. If there are plural fatigue cracks, they grow by interacting each other. In this case, crack tip stress field becomes complicated, and stress state at the crack tip becomes mixed mode loading condition. Usually finite element method (FEM) is used to simulate the crack growth behavior. But under mixed mode loading condition, crack shape changes with the crack growth, and re-modeling of the crack configuration is needed. This is really tough and time consuming work. Many numerical techniques have been developed to solve this problem. They are ; Element Free Galerkin method[1], Free Mesh method[2], X-FEM[3] and S-version FEM[4]. Authors have developed S-FEM code to solve crack problem[5] and solved plural crack problem using S-FEM and simulated fatigue crack growth considering interactions between two cracks in two-dimentional field[6].

In this paper, S-version FEM (S-FEM) is employed to solve three-dimensional fatigue crack growth problem. In S-FEM, crack area is modeled by local mesh. Re-modeling of new crack configuration due to fatigue crack growth is done only in local mesh. Whole structure is modeled by global mesh, and it is not necessary to re-model it. By combining auto-mesh technique, local mesh is re-meshed automatically. As a result, fatigue crack growth simulation is done automatically by changing crack configuration.

At first, surface crack under pure mode I loading condition is simulated. Stress intensity factor is evaluatead along crack front using virtual crack closure technique [7], and crack growth rate is determined by Paris' law. Change of aspect ratio of surface crack is studied and discussed. Rresults are compared with experimental ones.

Next, slant surface crack problem is solved. In this case, crack tip stress field is mixed mode condition, and stress intensity factors, K_I, K_{II} and K_{III}, are evaluated. Crack growth direction is determined using these values as follows [8].

$$\varphi_0 = \mp\left[A\frac{|K_{II}|}{K_I + |K_{II}| + |K_{III}|} + B\left(\frac{|K_{II}|}{K_I + |K_{II}| + |K_{III}|}\right)^2 \right] \qquad (1)$$

where $\varphi_0 < 0^\circ$ for KII > 0 and $\varphi_0 > 0^\circ$ for KII < 0 and KI $\geqq$ 0.with A=140°, B=-70°

It is shown that crack surface configuration changes in a complicated manner, as shown in Figure 1, and finally it grows under pure mode I loading condition. The changes of K_{II} and K_{III} at crack front and change of aspect ratio of surface crack due to crack growth are evaluated and discussed.

Finally, interaction of two surface cracks is evaluated. By changing distances between two surface cracks, interaction effect between two cracks is studied and discussed.

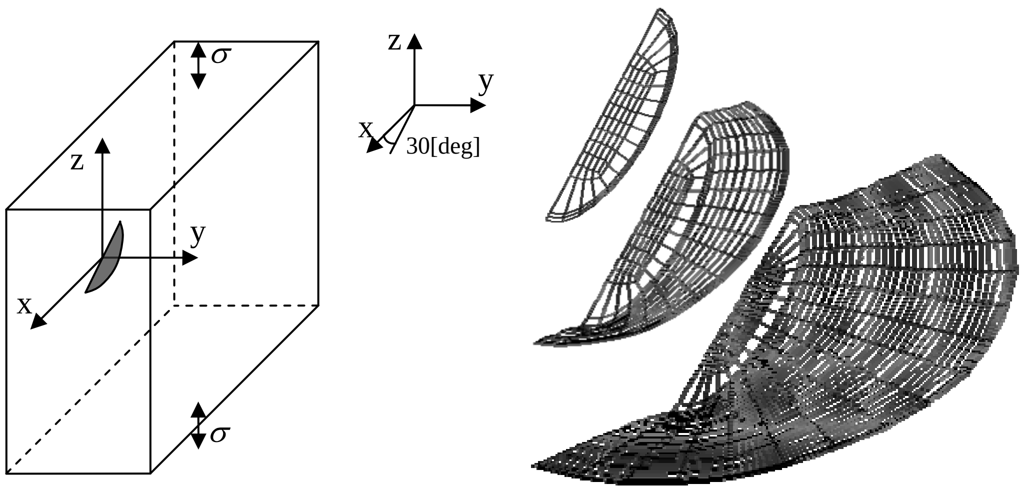

Fig.1 Growth of slant surface crack in a plate.

REFERENCES

[1] Belytschko,T., et al., ,Int.J.Numer.Methods.Eng.,30(1994),229-256.

[2] Yagawa,G.,Yamada,T.,Comput,Mech,18 (1996),383-386

[3] Belytschko,T.,Black,T.,Int,J,Numer.Methods Eng,.45(1999),601-620.

[4] Fish,J. et al., Appl. Numer. Mathematics, 14 (1994), 135-164.

[5] Okada, O., Endoh, S. and Kikuchi. M., Eng. Fra. Mesh., 72(2005),773-789

[6] Kikuchi, M. et al., Proc. 7th FEOFS (2007)

[7] Rybicki E.F., and Kanninen M. F., Eng. Frac. Mech., 9(1977), 931-938

[8] H. A. Richard, M. Fulland, M.Sander, Blackwell Publishing Ltd. Fatigue & Fracture of Engineering Materials and Structures, (2005),3-12