Strength Evaluation of Scarf Joint Using Fictitious Interface Crack

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Introduction. In recent years, as an evaluation method of an interface strength, a method used by the singular stress of fictitious small crack at an interface end has been examined ⁽¹⁾. However, the mixed singular stress fields having two singular indexes may occur at the interface end of the scarf joint. Whether a small crack model is appropriate for joints with such stress fields has not been examined. In this research, we focus on the effects of the scarf angle with different singularity indexes on the singular stress field at interface end. A small interface crack is assumed, and the stress intensity factors are analyzed by the crack tip stress method. The normalized stress intensity factors are examined when the bond line thickness and scarf angle of the specimens are changed systematically. By comparing the obtained results with the experimental results, the effectiveness of the method using a small crack will be examined.

Stress intensity factor of small crack. Fig.1 shows an scarf adhesive joint⁽²⁾ under tension analyzed in this study. The scarf angles are set to be $\theta = 45^\circ, 60^\circ$ and 75° . Table 1 shows the material parameters used for analysis. In this analysis, the FEM model is made finely and, the plane strain 8-node quadrilateral element is selected and the crack length is $a = 10^{-2}$ [mm]. The minimum element size e of the crack tip is set so that $e/a = 1/72171$ for the crack length a . In addition, the tensile stress is set to 1 [MPa]. The stress intensity factors K_1 and K_2 can be calculated by the crack tip stress method and the dimensionless stress intensity factors F_1 and F_2 are determined as follows

$$K_1 + iK_2 = (F_1 + iF_2)\sigma\sqrt{\pi a}(1 + 2i\varepsilon) \quad (1)$$

Here, the dimensionless stress intensity factors F_1 and F_2 are expressed as follows using the dimensionless coefficient C_i ($i=1,2$) as a function of the crack length a and the adhesive layer thickness h .

$$F_1 = C_1(h/a)^{1-\lambda} \quad F_2 = C_2(h/a)^{1-\lambda} \quad (2)$$

In Fig.2, the relations between the coefficients C_1 obtained from Equation (2) and the relative crack length a/h are shown. From these results, in the case that the singular stress field near the interface corner has the single singularity, the values of the coefficients C_1 and C_2 converge to the constant value and the dimensionless factors F_1 and F_2 can be represented by Equation (2) when $a/h < 10^{-3}$.

Adhesive strength evaluation. Fig.3 shows the critical stress intensity factors K_{IC} for each adhesive layer thickness at each scarf angle. From Fig.3, it can be seen that the critical stress intensity factors are almost constant for each scarf angle even when the adhesive layer thickness h changes widely. The fracture criterion can be represented as $K_{IC} = \text{constant}$ by using the small

Table 1. Material properties used in the analysis.

Material	Young's moduls E [GPa]	Poisson's ratio ν
Material 1 (SUS 304)	206	0.3
Material 2 (Epoxy)	3.4	0.396
Material 3 (YH75)	71	0.33

Fig.1 Scarf adhesive joint with small interface crack.

Fig.2 Relationship between C_1 and a/h .

Fig.3 Relationship between K_{1c} and h .

crack model when the combination of adhesive materials and the scarf angles are the same. It is concluded that the use of critical the stress intensity factor of the small interface crack K_{IC} is useful for evaluating the the fracture strength of scarf joint.

References.

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