CRITICAL INTENSITY OF SINGULAR STRESS FOR ADHESIVE JOINTS

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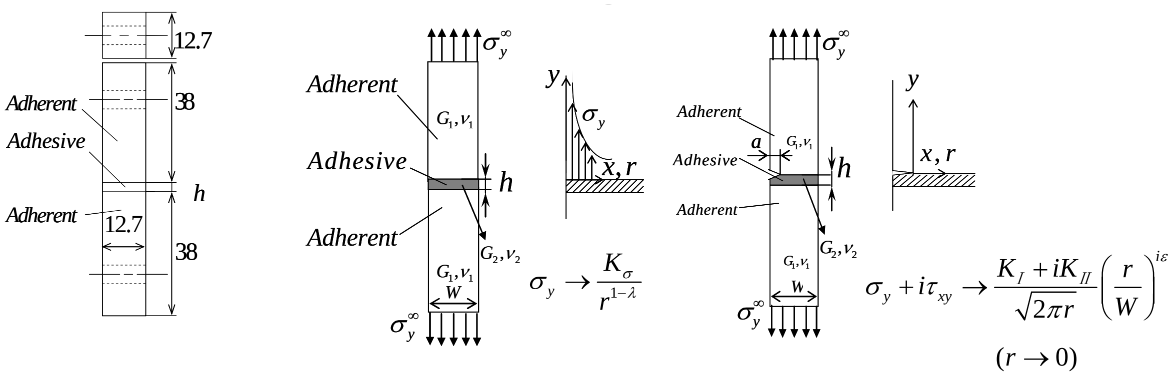
Summary In this study debonding conditions of an adhesively bonded joint are discussed in terms of the intensities of the singular stress fields. Here, two types of models are considered; one is the perfectly-bonded strip model, and the other is partially-debonded model assuming different debonded lengths. The previous experimental data are examined, which were obtained for S35C JIS medium carbon steel plates bonded with epoxy resin Epikote 871. It is found that the critical values of the intensity of singular stress are almost constant independent of the adhesive thickness. In other words, the adhesive strength can be estimated from the intensities of singular stress from both of the perfectly-bonded and partially-debonded models.

INTRODUCTION

Bonded structures are used in wide industrial fields in recent years. It has been told that the adhesive strength increases with decreasing the adhesive thickness. The previous studies suggested that the thicker adhesive layer contains more defects and cavities although a larger amount of glue is used. As an example, Suzuki [1] evaluated the debonding strength experimentally using bonded tensile specimen as shown in Fig.1a. Then, he discussed the adhesive strength is affected by the adhesive thickness when S35C JIS medium carbon steel plates are bonded by epoxy resin Epikote 871. In this study, debonding criterion will be newly considered in terms of the intensities of the singular stress based on analyzing two types of models. One is the perfectly-bonded strip model as shown in Fig.1b, and the other is partially-debonded models as shown in Fig.1c. Then, the critical debonding conditions will be examined from the intensities of singular stress fields.



(a) Experimental specimen (b) Perfectly-bonded model (c) Partially-debonded model $(a/W = 0.01, 0.1)$

Fig.1 Models used in this study with the singular stress field controlled by $K_{\sigma c}$ and K_I

EXPERIMENTAL DATE USED IN THIS STUDY

In this study, the previous experimental data are newly examined in terms of the intensity of singular stress assuming the models in Fig.1. In this experiment [1] the adherents medium carbon steel S35C (JIS) are bonded with adhesive epoxy resin Epikote 871. The elastic parameters of the adherent and adhesives are tabulated in Table 1.

Table 1 Material property of adherent and adhesives

	Elastic modulus E (GPa)	Poisson's ratio ν
Adherent: Medium carbon Steel S35C	210	0.3
Adhesive A: Epikote 871	2.16	0.38

DEBONDING CONDITION IN TERMS OF CRITICAL $K_{\sigma c}$ AND K_{Ic}

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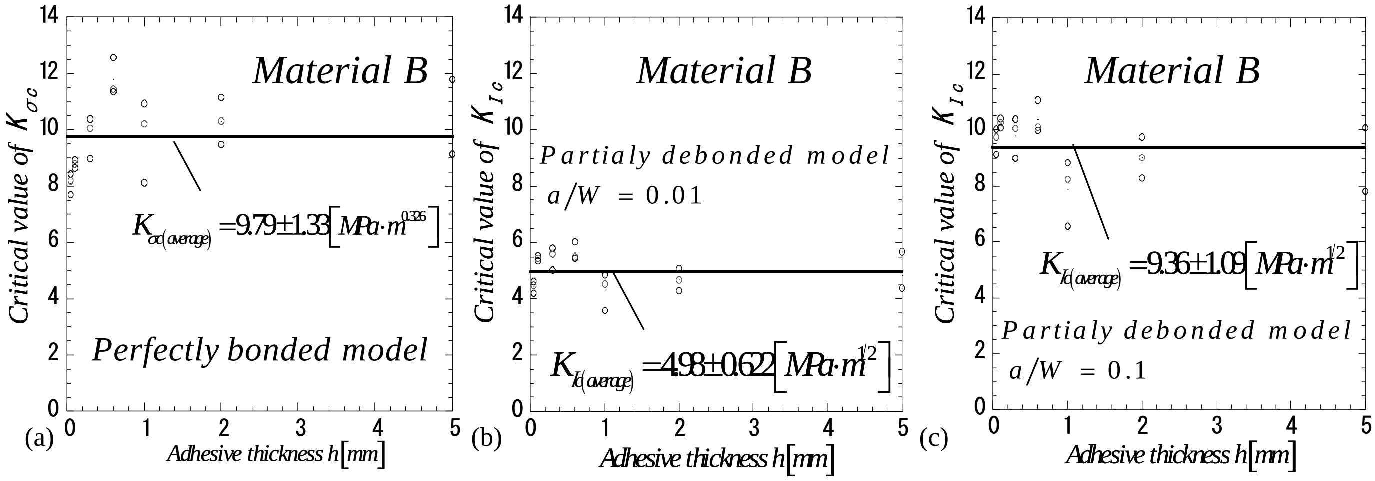
For the perfectly-bonded model, the singular stress can be expressed as $\sigma_y = K_\sigma / r^{1-\lambda} = F_\sigma \sigma_y^\infty (W/r)^{1-\lambda}$ (see Fig.1b). The values of F_σ are provided in Reference [2]. Figure 3(a) indicates that the critical values of the intensity of singular stress K_σ in Eq. (1) are almost constant independent of the adhesive thickness h/W .

$$K_{\sigma c} = F_\sigma \sigma_y^\infty W^{1-\lambda} \tag{1}$$

For the partially-debonded models as shown in Fig.1c, the singular stress for interface cracks can be expressed as $\sigma_y + i\tau_{xy} = K_I + iK_{II} (r/W)^{i\varepsilon} / \sqrt{2\pi r}$. The dimensionless stress intensity factors F_I in Eq. (2) are calculated by applying the method shown in Reference [3]. Figure 3(b), (c) indicates that the critical values of the stress intensity factors K_{Ic} are also constant independent of the adhesive thickness h/W .

$$K_{Ic} = F_I \sigma_y^\infty \sqrt{\pi a} \tag{2}$$



(a) Perfectly-bonded model (b) Partially-debonded model $(a/W = 0.01)$ (c) Partially-debonded model $(a/W = 0.1)$

Fig.3 Relationship between critical values of $K_{\sigma c}, K_{Ic}$ and the adhesive thichness h

CONCLUSIONS

In this study, debonding conditions were considered in terms of the intensity of f singular stress for adhesive joints. Here, two types of models were assumed, that is, perfectly-bonded and partially-debonded models as shown in Fig.1. The conclusions can be summarized in the following way.

(1) By assuming the perfectly-bonded model, the debonding condition can be expressed as $K_{\sigma c}$ = constant as shown in Fig.3 (a). The debonding strength can be estimated from the average critical value $K_{\sigma c}$ =9.79±1.33 $[MPa \cdot m^{0.326}]$ for any adhesive thickness.

(2) By assuming the pertially-debonded model, the debonding condition can be expressed as K_{Ic} = constant as shown in Fig.3 (b), (c). In other words, the debonding stress can be estimated for any adhesive thickness from the average critical stress intensity factors. The average values of K_{Ic} and their standard deviations are 4.98±0.622 $[MPa \cdot m^{1/2}]$ for assumed debonded length $a/W = 0.01$, and 9.36±1.09 $[MPa \cdot m^{1/2}]$ for assumed $a/W = 0.1$.

References

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