A Study on Delamination Behavior between Aluminum and CFRTP

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Abstract

In the near future, it is predicted that automobiles will use extensive amount of light weight material such as aluminum and CFRP. However, joining these material needs structural adhesive on the purpose of isolation and avoiding local stress concentration. In this paper, a simulation model has been built up using LS-DYNA® for DCB (double cantilever beam) test. Combination of various thicknesses in aluminum and CFRTP specimen has been studied to assess structural toughness. Validity of the simulation model has been confirmed by comparing the results with experiments, and trends and detailed mechanisms are discussed.

Background

Light weight design for better mileage is one of key issues for automotive manufacturers. In order to achieve challenging design target, use of lightweight materials such as aluminum and CFRP is unavoidable. However, joining these material has issues known as galvanic corrosion so that these material needs to be isolated from each other. DCB (Double Cantilever Beam) test is a standard way to characterize structural toughness of an adhesive layer, but running tests takes efforts and time. In this context, Finite Element Analysis is a powerful tool studying behavior of material and components under different conditions including the situation where plastic deformation occurs to the adherent.

Double Cantilever Beam test

DCB test is conducted [1] as shown in Fig. 1. The surfaced-treated Al5052 and CFRTP were adhesively bonded using non-oriented polyamide-based film at 245 °C for 30 min. DCB is basically for adherents which is elastic, but for this test, aluminum adherents showed plastic deformation.

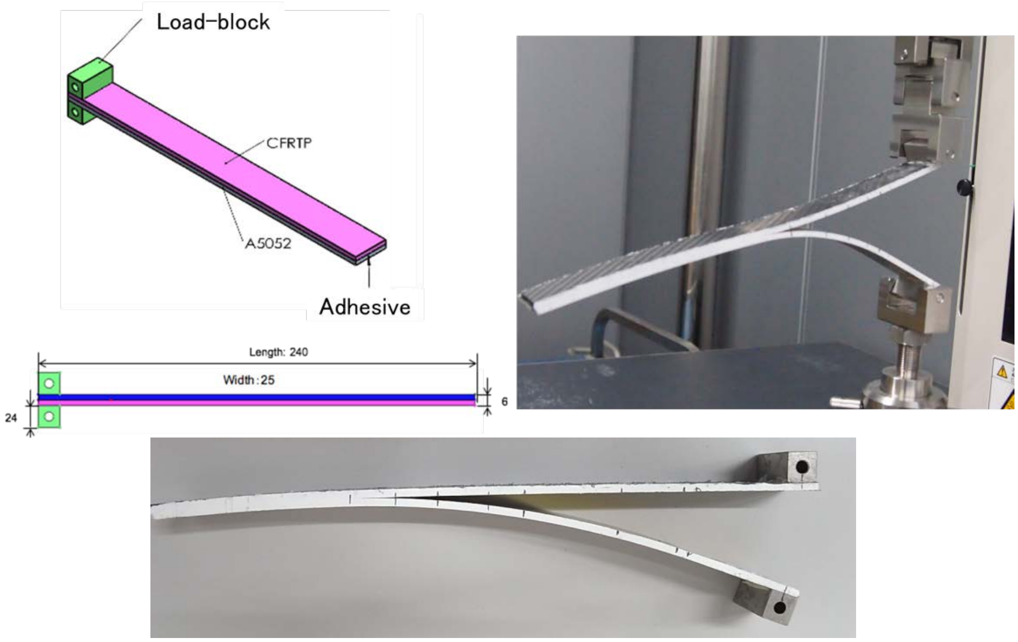

Fig.1: DCB test set up (TOP: CFRTP, BOTTOM: A5052)

Modeling of the DCB test with LS-DYNA

DCB test set up is built up using LS-DYNA double precision. Aluminum and CFRTP plate is modeled with fully integrated SLOID elements with at least 3 elements through thickness. CFRTP is modeled as isotropic elastic material and aluminum is modeled with elastplastic material (*MAT_024). Adhesive layer is modeled with *MAT_169. Material characterization of CFRTP is done by 3 point bending test in different thickness, and that of aluminum is done by tensile test. The fracture toughness of the adhesive layer is identified by the DCB test, and the maximum traction force is measured by butt joint tensile test.

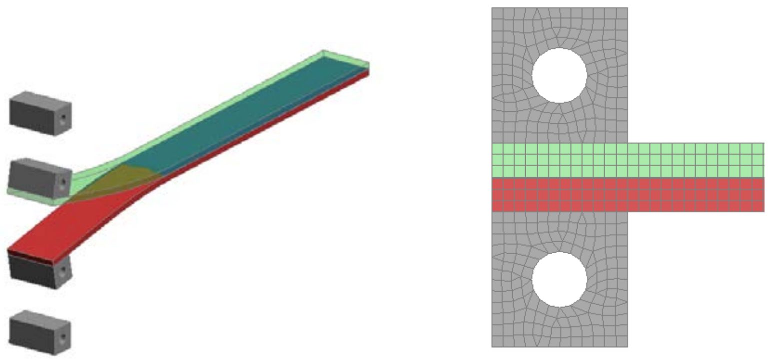

Fig.2: DCB test simulation model

Validation of the simulation model and discussion on plastic deformation of adherent

Force - crack opening displacement (COD) diagram and crack length is shown in Fig. 3. The peak level and relaxation trend of the simulation result shows very good match with test result. Fig. 4 shows plastic deformation of the aluminum adherent, and Fig. 5 shows the energy balance of the calculation. Dissipated energy indicates the energy absorbed by the adhesive failure, and internal energy which consists of elastic and plastic work of CFRTP and aluminum adherents.

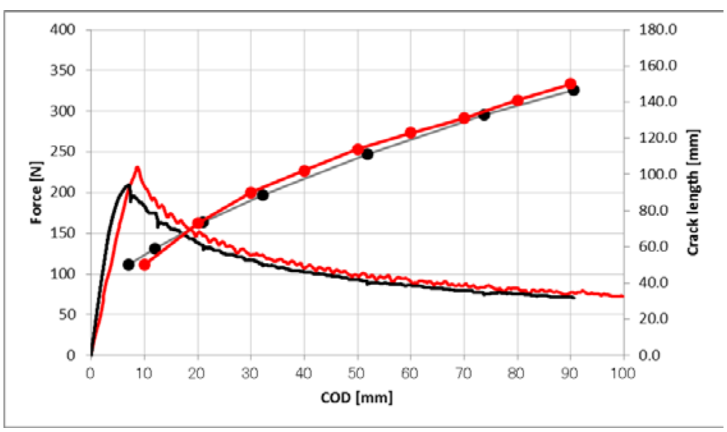

Fig.3: Comparison between test result (black) and simulation (red)

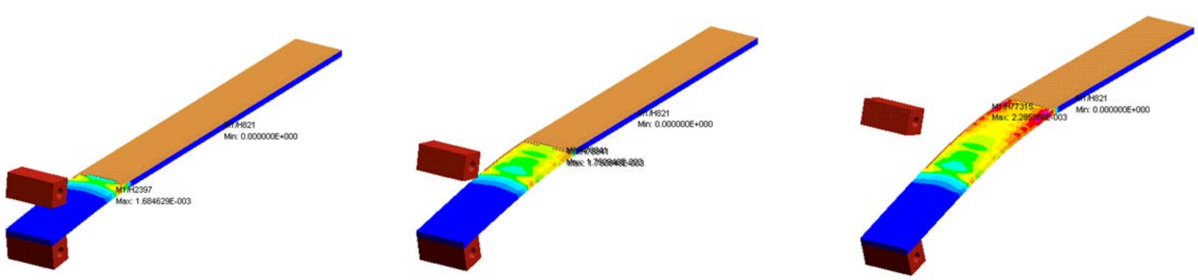

Fig.4: Adhesive failure propagation and plastic strain of aluminum in contour plot

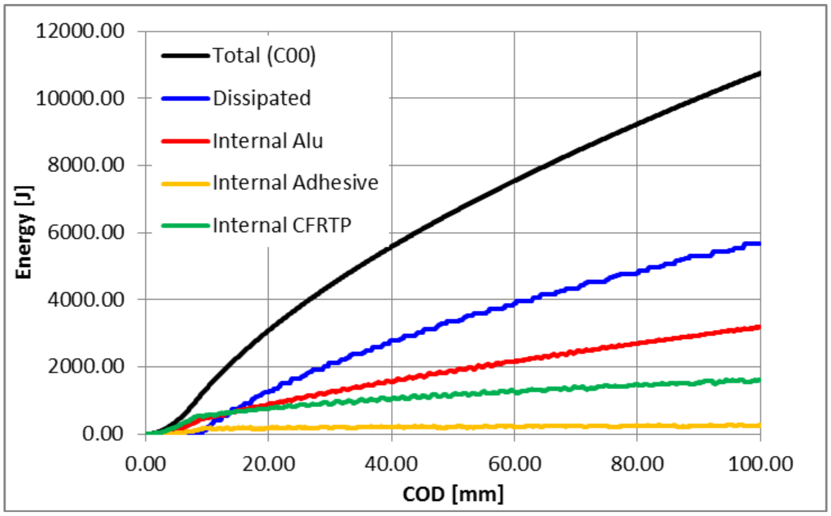

Fig.5: Energy balance plot including energy dissipation by adhesive layer and plastic deformation of aluminum

Summary

A simulation model for DCB test of CFRTP and aluminum has been built up, and the result is compared with a test result. It showed a reasonable correlation to the test result, and it is confirmed that the model can be used for studying energy absorption mechanism of adhesive between CFRTP and aluminum.

References

[1] S. Horiuchi, et. al, Characterization of bonding properties of dissimilar joints of carbon fiber reinforced thermoplastic (CFRTP) and metals, 4th International Conference on Structural Adhesive Bonding