

Investigation of Fatigue Characteristics of Adhesive–Rivet Hybrid Joints under Peel Loading

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The increasing demand for lightweight and multi-material automotive body structures has accelerated the adoption of advanced joining technologies. Adhesive–rivet hybrid joints are expected to improve structural performance by combining the load-distribution capability of adhesive bonding with the load-carrying function of mechanical fastening. However, previous studies have mainly focused on tensile and shear loading conditions, and limited information is available regarding peel loading, which is dominant in automotive flange structures. Furthermore, the fatigue behavior of hybrid joints after adhesive degradation and under elevated-temperature conditions has not been sufficiently clarified. Therefore, this study investigated the static and fatigue characteristics of adhesive–rivet hybrid joints under peel loading after adhesive degradation and under elevated-temperature conditions and examined the load-sharing mechanism through finite element analysis.

Specimens were fabricated from 6000-series aluminum alloy sheets. Adhesive joints (AD), riveted joints (R2 and R3), and adhesive–rivet hybrid joints (AD-R2 and AD-R3) were evaluated. Specimens containing adhesive were subjected to hot-water immersion to simulate environmental degradation, and static and fatigue tests were conducted at 80°C. Finite element analysis was also performed for R2 and AD-R2 joints.

The static test results indicated that the maximum load was primarily governed by the rivets, while the contribution of the adhesive layer to static strength was limited. The fatigue test results showed that adhesive–rivet hybrid joints exhibited higher fatigue strength than riveted joints, particularly in the high-cycle fatigue region. At high load levels, the difference between R2 and AD-R2 was relatively small, whereas a significant improvement in fatigue life was observed at low load levels. Finite element analysis revealed that the adhesive layer redistributed the applied load and reduced the maximum principal stress around the rivet holes. This reduction in stress concentration is considered to be a key factor contributing to the improved fatigue performance of the hybrid joint.

Consequently, even after environmental degradation and under elevated-temperature conditions, the adhesive layer contributes to fatigue-life improvement by reducing local stress concentration through stress redistribution. These results suggest that the reduction in stress concentration achieved by the adhesive layer contributes to improved fatigue durability under peel loading.

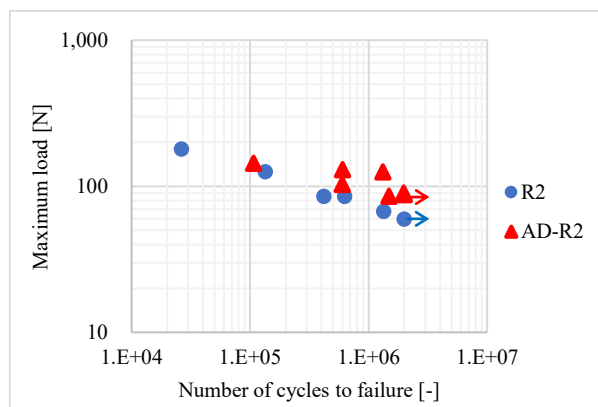


Fig. 1 Fatigue test results of R2 and AD-R2

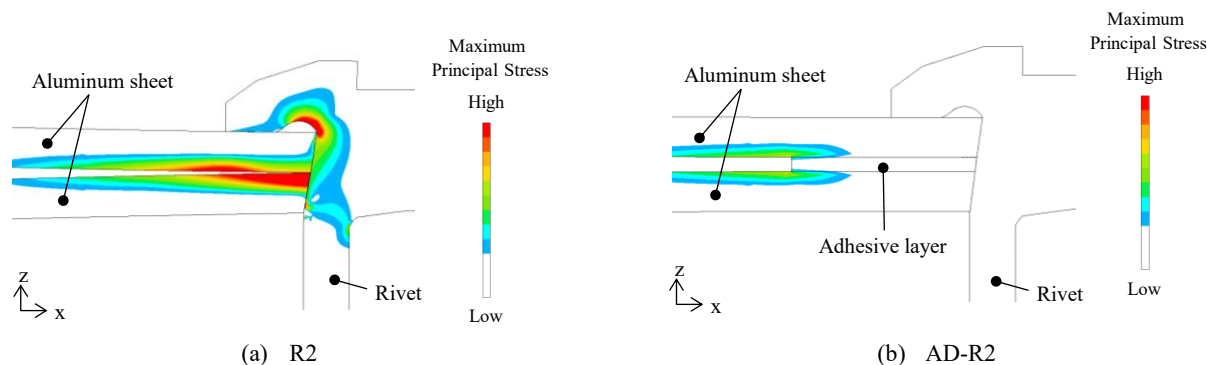


Fig. 2 Maximum principal stress distributions of R2 and AD-R2