Failure analysis of novel hole-hemmed joints in hybrid metal-polymer structures

M.M. Kasaei (INEGI, Portugal), R.J.C. Carbas, E.A.S. Marques, L.F.M. da Silva

ADVANCED JOINING PROCESSES UNIT

Introduction

To address issues related to environmental pollution and energy shortages, there has been significant interest in developing hybrid structures for constructing high-performance vehicles within the transportation sector [1]. However, a major challenge arises when attempting to join metal sheets to polymer and composite sheets, owing to their markedly different mechanical, physical, and chemical properties. In this work, a novel joining process by plastic deformation known as hole hemming [2, 3] is developed to create novel hybrid joints between AA6082 aluminum and PC sheets. Then, the mechanical behavior of the hybrid joints is assessed through single-lap shear tests.

Materials and methods

The hole hemming experiments were conducted in AA6082-T4 aluminum and PC sheets, both with a thickness of 2mm (Figure 2). The AA6082-T4 sheet was chosen as the outer sheet due to its higher ductility, while the PC sheet was used as the inner sheet. Four different types of hybrid hole-hemmed joints (HHH joints) were made in which the flange length and the number of branches were varied (Figure 3).

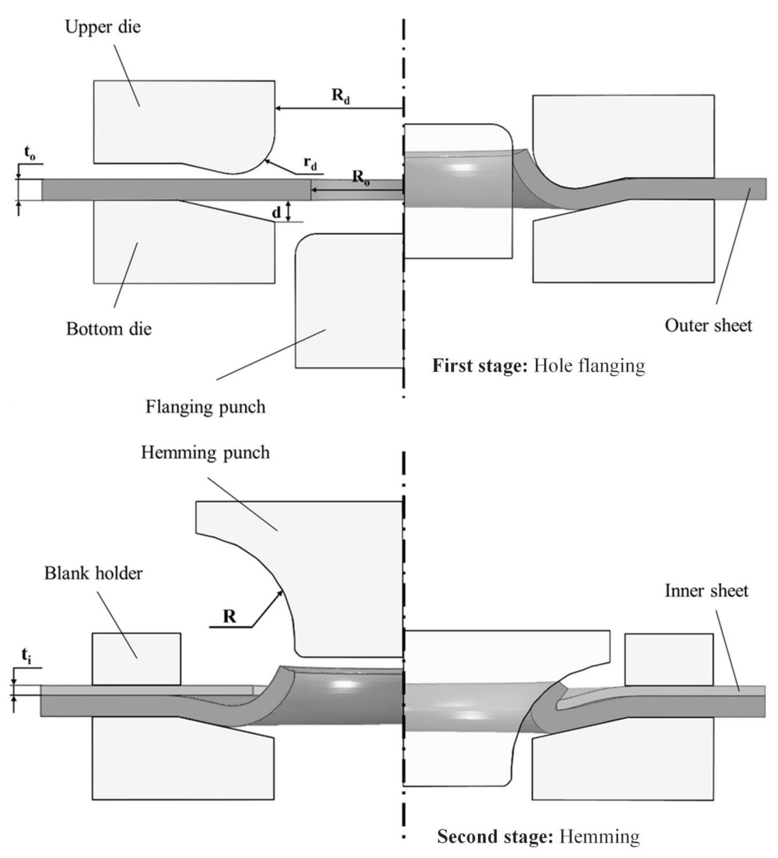

Figure 1 – Hole hemming process

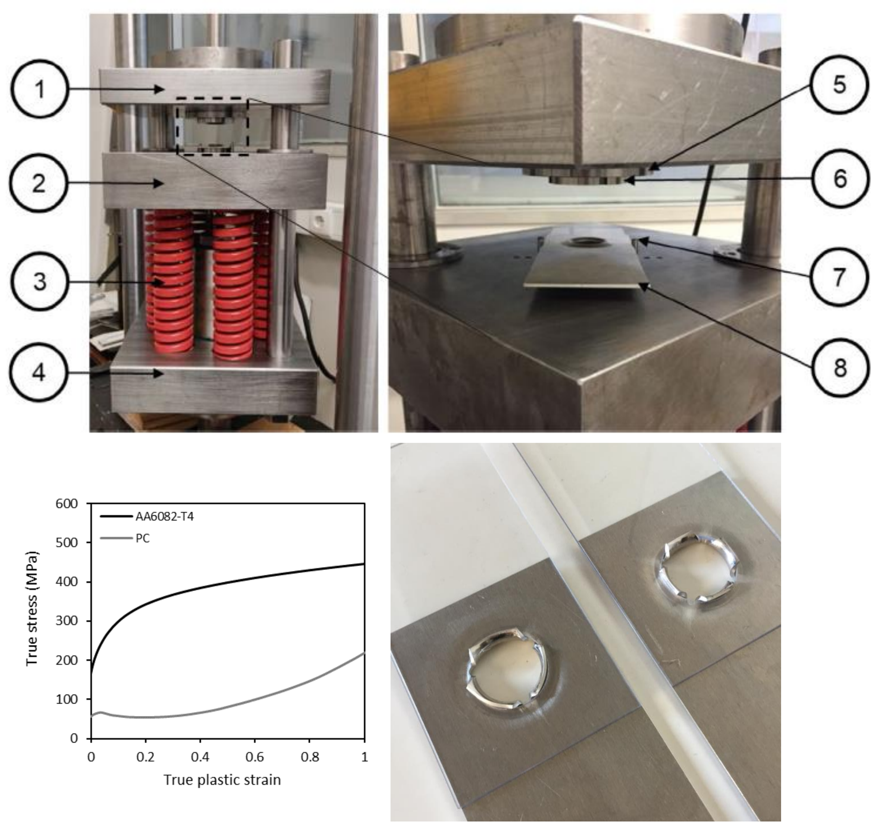

Figure 2 – Hole hemming experiments

In order to evaluate the HHH joints, shear tests were performed using a universal tensile testing machine (Instron 3367) at a constant velocity of 1 mm/min (see Figure 4).

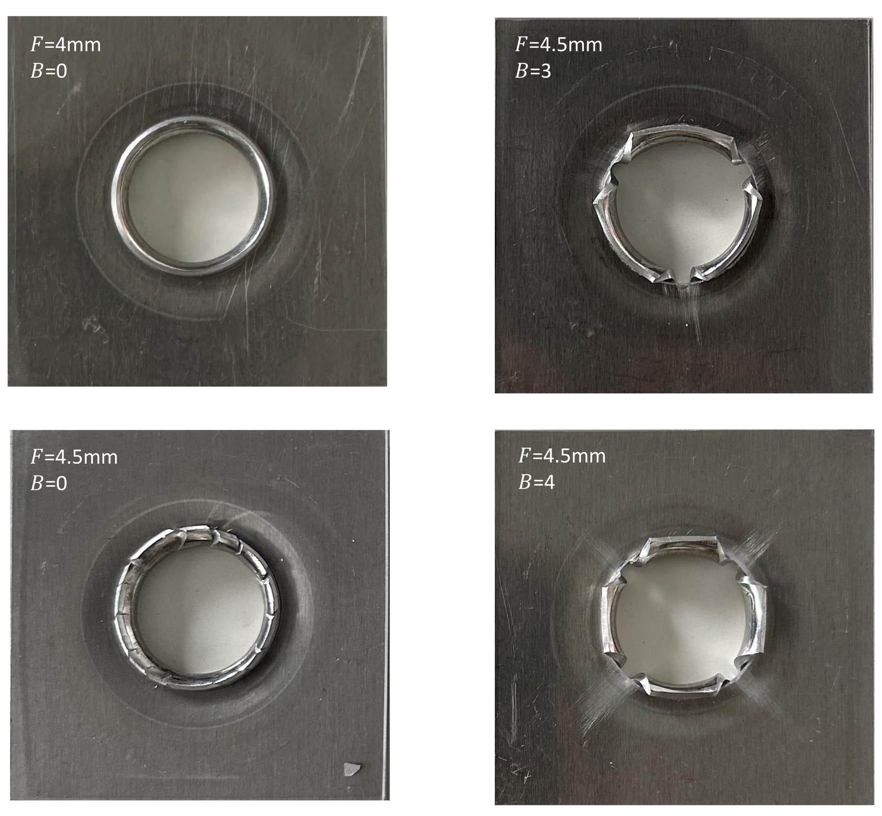

Figure 3 – Hybrid hole-hemmed joints (HHH joints)

Figure 4 – Single-lap shear test

Results and discussion

As shown in Figure 3, increasing the flange length results in fractures occurring at the edge. However, when the branches are taken into account, the strain on the edge is reduced, leading to defect-free connections. All four types of HHH joints underwent shear testing (Figure 5).

In all four joints, except for the joint with a flange length of 4 mm, the failure mechanism is hole bearing. After a rapid increase in force, the PC sheet begins to bend, and its hole deforms against the flange. As the hole's shape changes, the contact surface increases, resulting in a force increase. Finally, cracks initiate and propagate at the hole's edge, leading to a sharp drop in force.

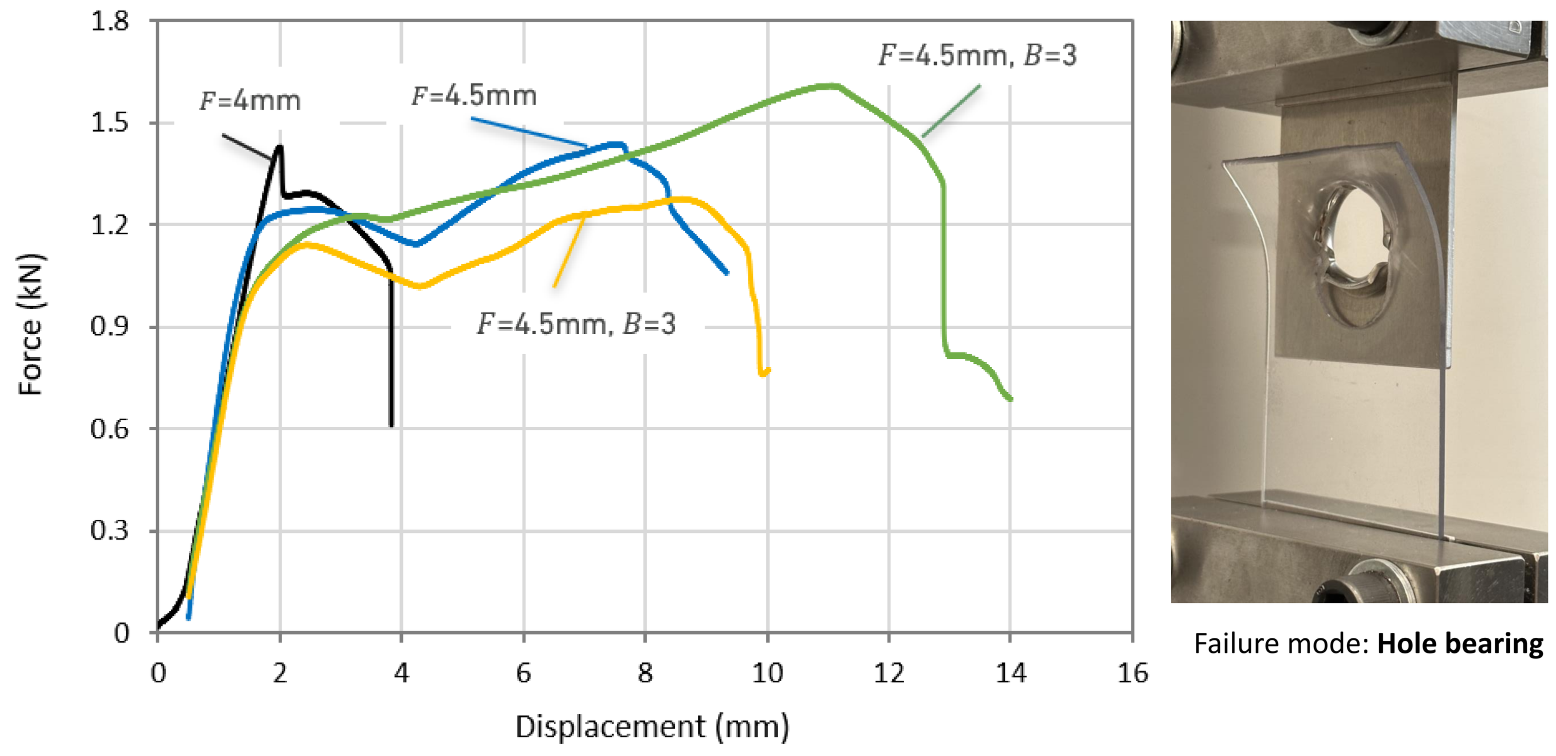

Figure 5 –Load-displacement curves obtained from the shear tests

In the HHH joint with a flange length of 4 mm, the low failure displacement is due to the limited mechanical lock m, which results in the PC sheet disengaging from the lock after a slight deformation (Figure 6). In the HHH joints with branches, cracks initiate from the contact area of the branch edge and the PC sheet. Therefore, because the joint with 3 branches has fewer critical areas compared to the joint with 4 branches, it exhibits maximum strength and displacement.

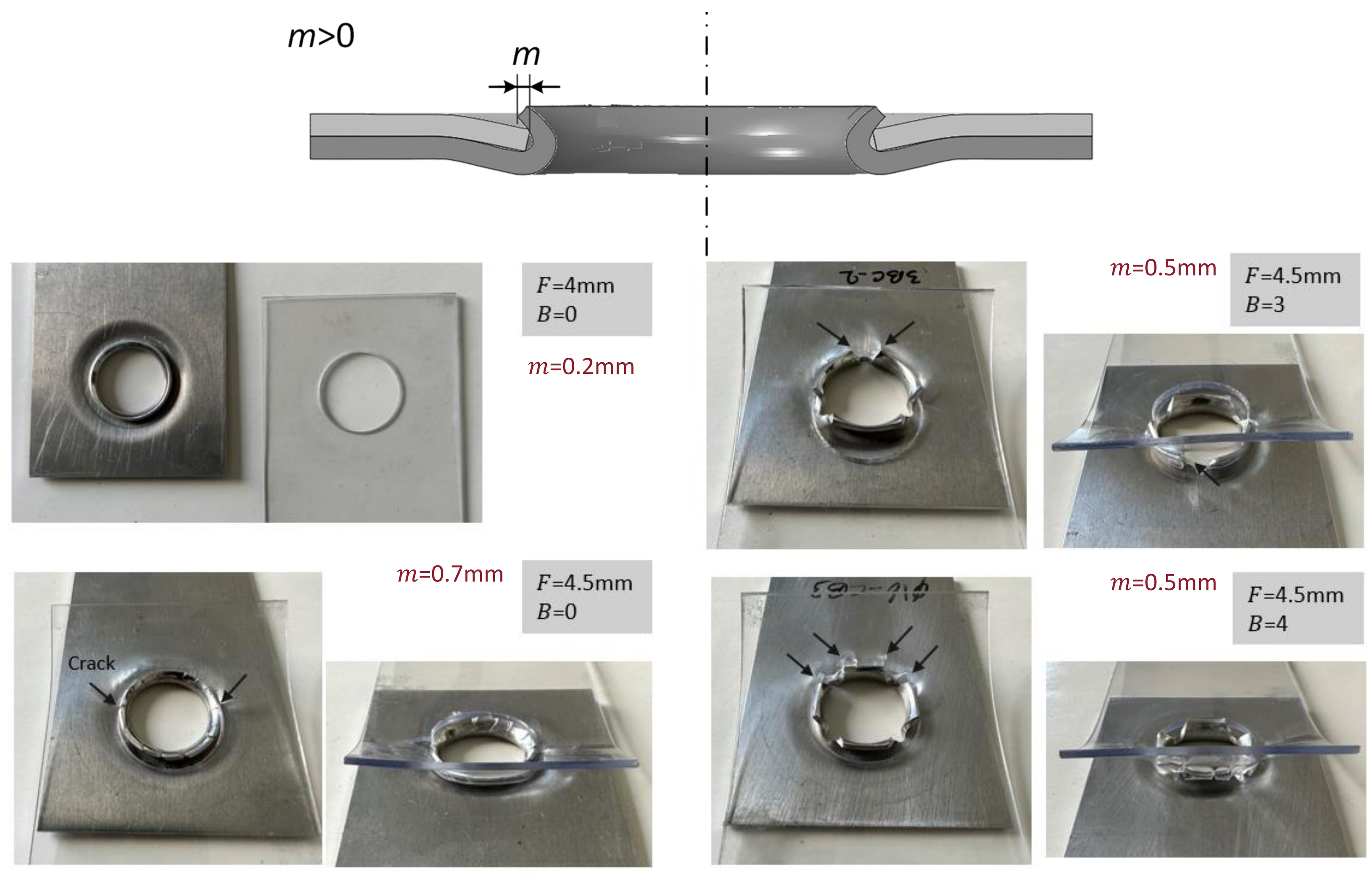

Figure 6 – HHH joints after the shear tests

Conclusions

The results indicate that the hole hemming process can successfully join AA6082-T4 and PC sheets. In a single-lap shear test, the HHH joints withstood a maximum force and displacement of 1.6 kN and 12.9 mm, respectively. They exhibited a failure mode characterized by hole bearing, which is a gradual failure mode. These results demonstrate the significant potential of hole-hemmed joints for constructing hybrid structures.

,

References

[1] MM Kasaei, R Beygi, RJC Carbas, EAS Marques, and LFM da Silva, Discover Mechanical Engineering, 2 (2023), 5.

[2] JAC Pereira, MM Kasaei, RJC Carbas, EAS Marques, and LFM da Silva, Thin-Walled Structures, 187(2023), 110758.

[3] MM Kasaei, JAC Pereira, RJC Carbas, EAS Marques, and LFM da Silva, Metals, 13(2023), 1559.