A new design for improving the joinability of magnesium and aluminum sheets in hole hemming

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Introduction

Nowadays, combinations of aluminum and magnesium alloys have received much attention for manufacturing high-performance vehicle structures [1]. However, joining processes by plastic deformation of magnesium alloys are restricted by their low formability at room temperature. Recently, a new joining process by plastic deformation, called hole hemming (HH), has been developed for joining dissimilar materials with vastly different formability in which only one of the sheets needs to be sufficiently ductile, and there is no need for heating or using additional elements such as rivets (see Figures 1). This process was successfully tested for joining magnesium AZ31 and aluminum AA6082-T4 alloy sheets. However, the joinability of these materials in this process is limited by fractures in the aluminum sheet [2, 3]. This research work proposes a novel design for the hole in the aluminum sheet, which incorporates various branches to reduce the risk of fracture and ensure a tighter mechanical interlock.

Materials and methods

The HH experiments were performed in AZ31 magnesium alloy sheets with 0.9mm thickness and AA6082-T4 aluminum sheets with 2mm thickness (Figure 2). The AA6082-T4 sheet was considered as the outer sheet due to its higher ductility while the AZ31 sheet was used the inner sheet as it only undergoes slight deformation in the hemming stage. The branch geometry and their number and configurations are designed using finite element simulation while the ductile damage is predicted by the Modified Mohr-Coulomb (MMC) model (Figures 3 and 4).

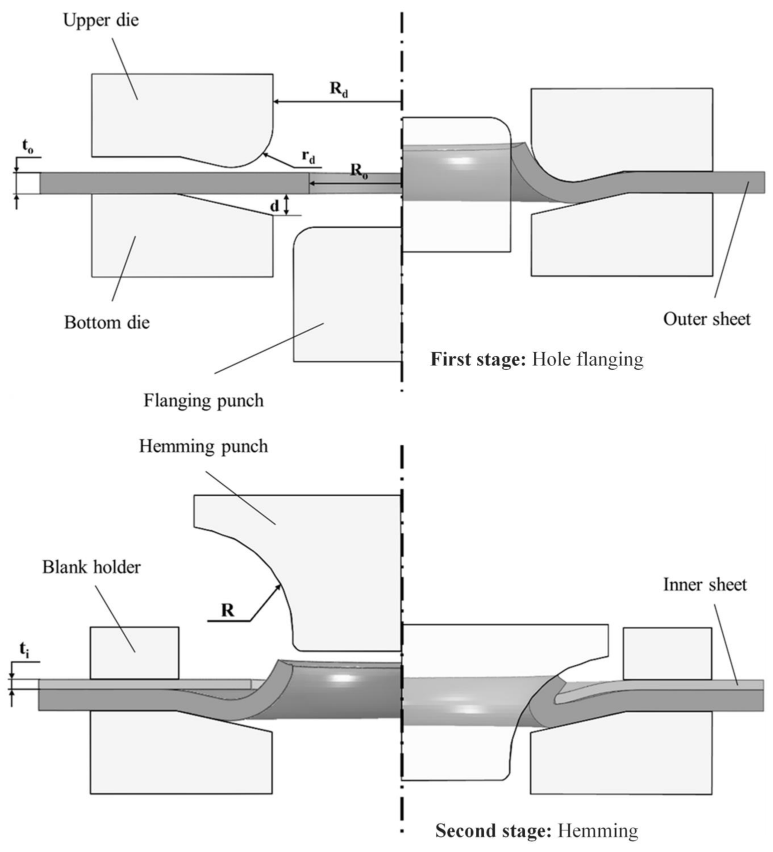

Figure 1 – Hole hemming process

Parameter	Value
R_d	12.5 mm
r_d	4 mm
d	2 mm
R	10 mm
R_i	14.5 mm
R_0	8 mm
F	4.5 mm
B	0, 3 and 4

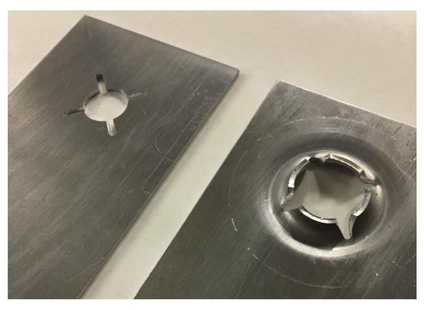

Figure 2 – Hole hemming experiments

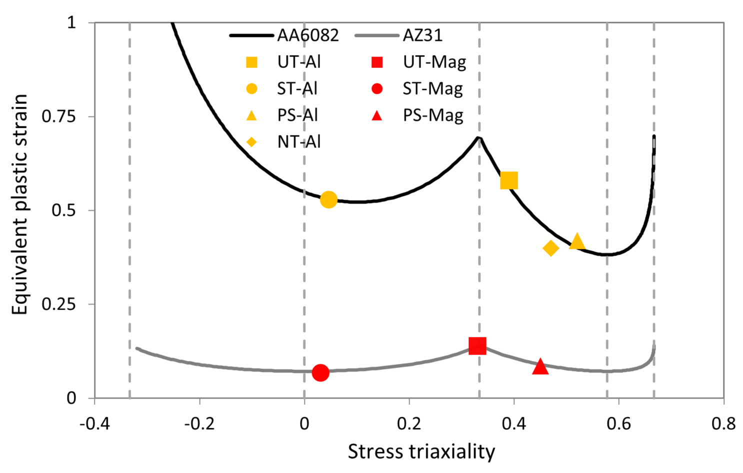

Figure 3 – MMC fracture envelopes [2]

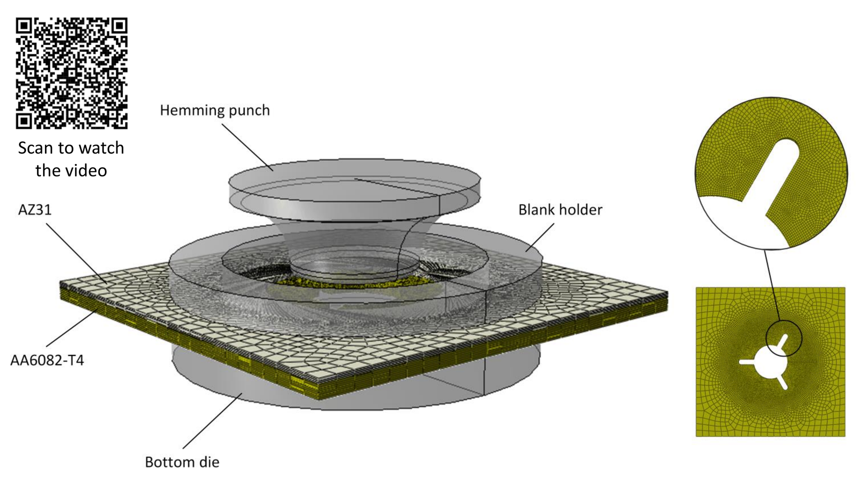

Figure 4 – Hole hemming simulation

Results and discussion

Figures 4 and 5 shows the influence of the branch length (L_B) and width (W_B) on the damage of the HH joints with three branches, respectively.

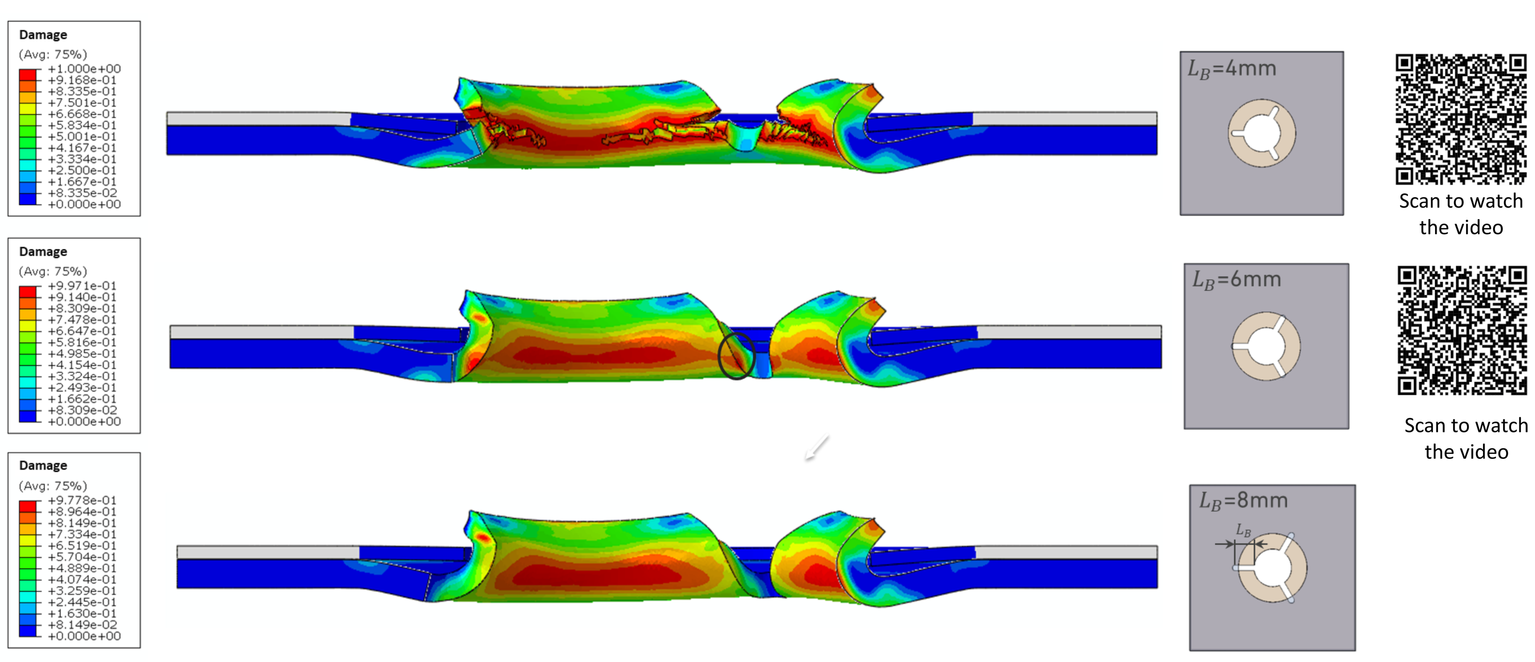

Figure 5 – Influence of the branch length (L_B) on the damage of HH joints

The results indicate that increasing the branch length (L_B) and moving the branch's end away from the bending area, damage in the branch edge is significantly reduced. Therefore, the branch length should be chosen so that the end of the branch is positioned outside the inner sheet's hole ($L_B \geq$ 6mm). The branch width (W_B) also has a significant impact on damage in the critical area. When the branch width is 1.5 mm, excessive damage occurs in this area, leading to the initiation and growth of cracks. Increasing the branch width to 2.5 mm decreases stress concentration in this area, resulting in a mechanical lock without cracks.

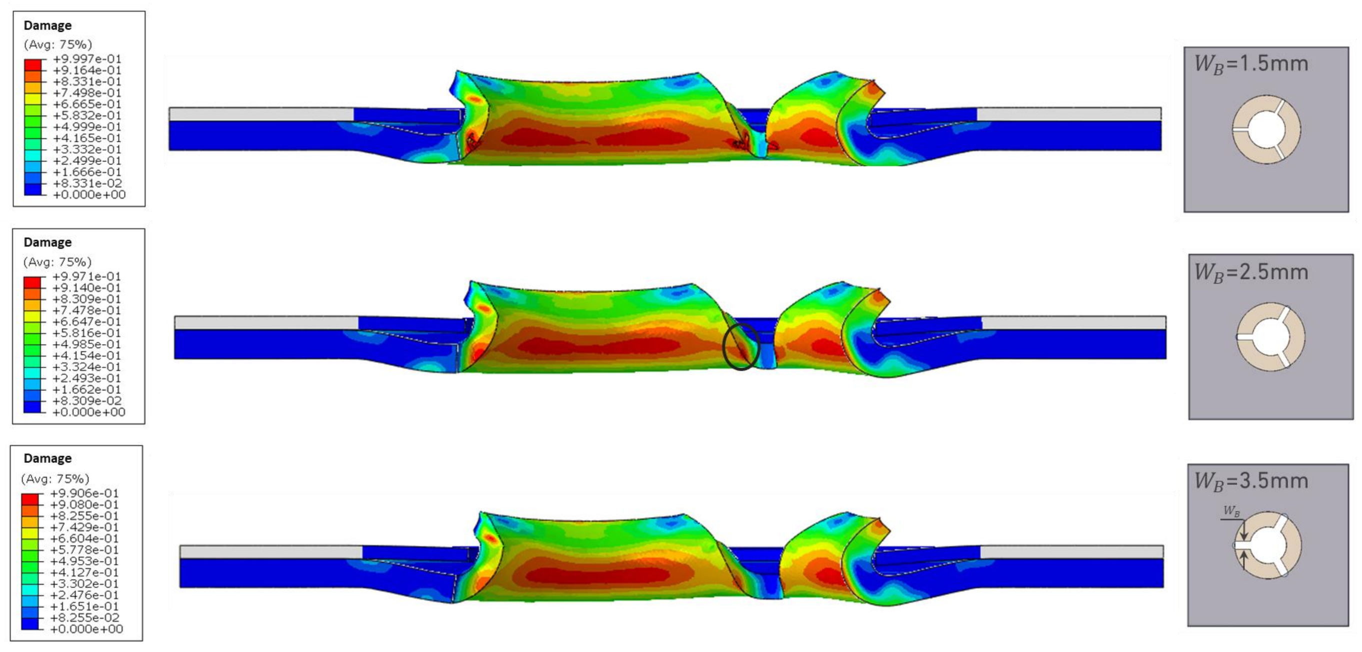

Figure 6 –Influence of the branch length (W_B) on the damage of HH joints

Based on the results obtained, HH joints with three and four branches, each with a length of 6 mm and a width of 2.5 mm, were constructed. Figure 7 provides a numerical and experimental comparison of these connections with the branchless joint. As can be seen, when the flange length is 4.5 mm, fracture occurs at the edge of the branchless flange. In contrast, considering the branch effectively reduces damage at the edge, resulting in a sound connection. Increasing the number of branches further reduces damage at the edge, but it does reduce the connection's load-bearing capacity.

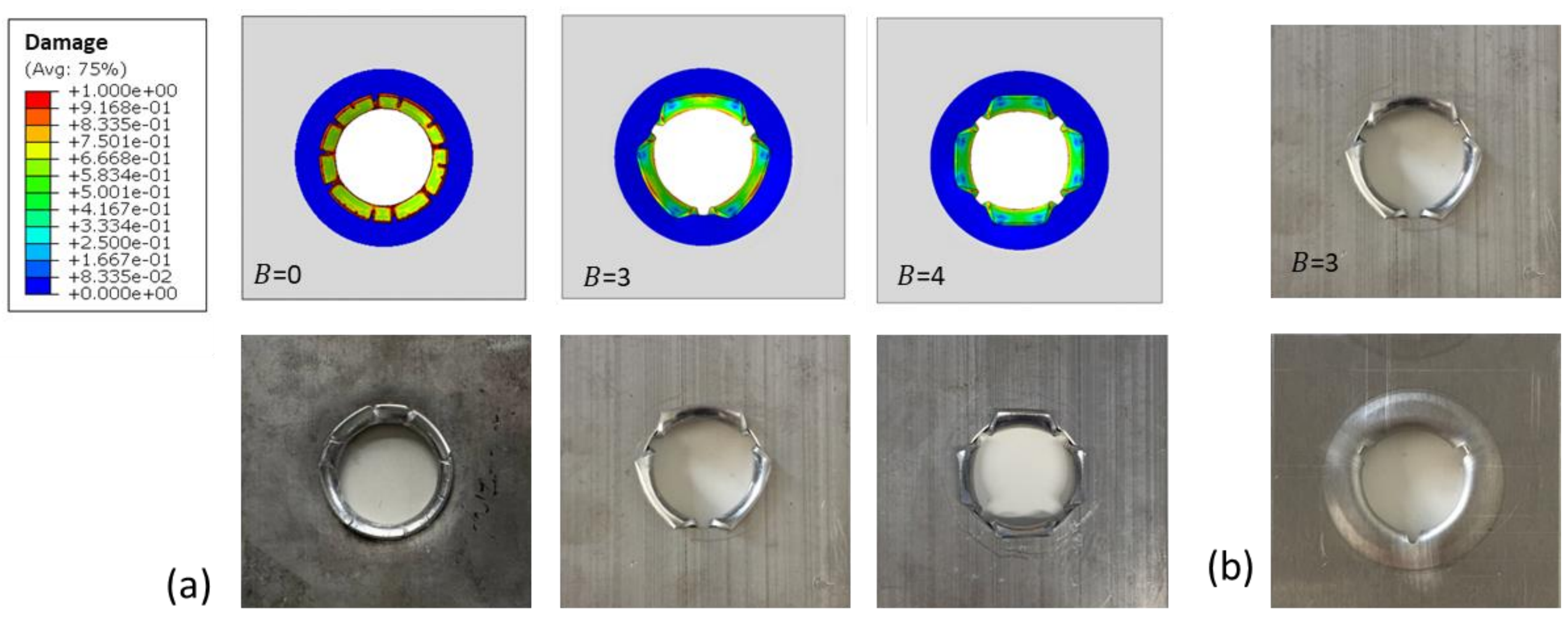

Figure 7 – (a) Influence of the number of branches (B) on HH joints, (b) Top and bottom views of the HH joint with three branches

Conclusions

The experimental and numerical results indicate that incorporating branches into the outer sheet hole effectively reduces damage at the flange's edge. This improvement enhances the ability to join aluminum and magnesium sheets in the hole hemming process. However, to prevent damage at the branch's edge in the bending area, it is crucial to properly design its dimensions. Increasing the length and width of the branch results in a reduced risk of fracture in the critical area. Furthermore, increasing the number of branches can further reduce damage at the branch's edge. Nevertheless, using larger branches or a higher number of them can decrease the load-bearing capacity. In the examined scenario, it is recommended to use three branches with $L_B \geq$ 6mm and W_B =2.5mm.

References

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

[3] MM Kasaei, JAC Pereira, RJ Carbas, EA Marques, and LF da Silva, Metals, 13(2023), 1559.

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