# Durability of hole hemmed joints in hybrid busbars for electric vehicle batteries

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## INTRODUCTION

In electric vehicles (EVs), the transmission of electrical power often relies on a combination of cables, wires, and busbars, with busbars being preferred for low-voltage applications requiring high electric currents. Traditionally made of copper due to its superior electrical conductivity, busbars are both costly and heavy. To reduce battery cost and wight, a transition toward hybrid busbars made from copper and aluminium has gained traction. This study explores the fatigue behaviour and failure modes of innovative hole hemmed joints, evaluating their feasibility for hybrid busbars in EV batteries. The hole hemming process offers a sustainable alternative by eliminating the need for additional elements, heat, or welding [1].

## METHODS

Load-controlled cyclic shear fatigue tests were performed on HH joints (Figure 1) using an INSTRON 8801 testing machine at room condition. A loading frequency of 5Hz with a sine waveform was considered. The load ratio (R) was set at 0.1. Different values for the maximum load were tested to predict the fatigue life of hole hemmed joints by plotting a load-cycle (L-N) curve. Additionally, the fatigue failure criterion considered was a limit of displacement of 1.4 mm. Quasi-static shear post-fatigue tests were also performed on the fatigue damaged joints using the same testing machine and set-up, with a constant speed of 1mm/min.

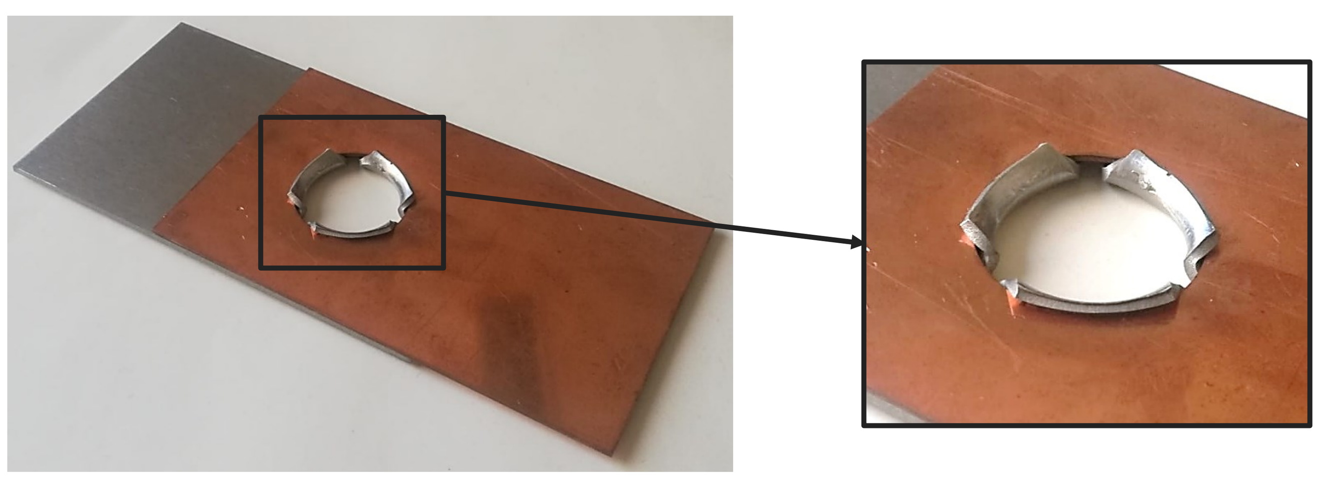

Figure 1– Novel joints between copper and aluminum busbars produced by hole hemming.

## RESULTS

Under cyclic loading (Figure 2), two distinct fatigue failure modes were observed. At a high fatigue load close to the initial strength, significant bending of the copper inner sheet occurred without any observable cracks (mode A). In contrast, at a fatigue load lower than the initial strength, a crack was detected at the edge of the branch of the HH joint (mode B). During post-fatigue tests in these cases, the crack propagated from one edge to the other along a circular trajectory, nearly severing the joint's branch (Figure 3).
According to the obtained results, if failure mode A is observed, it indicates that the joint design is inadequate and needs to be adjusted to achieve failure mode B.

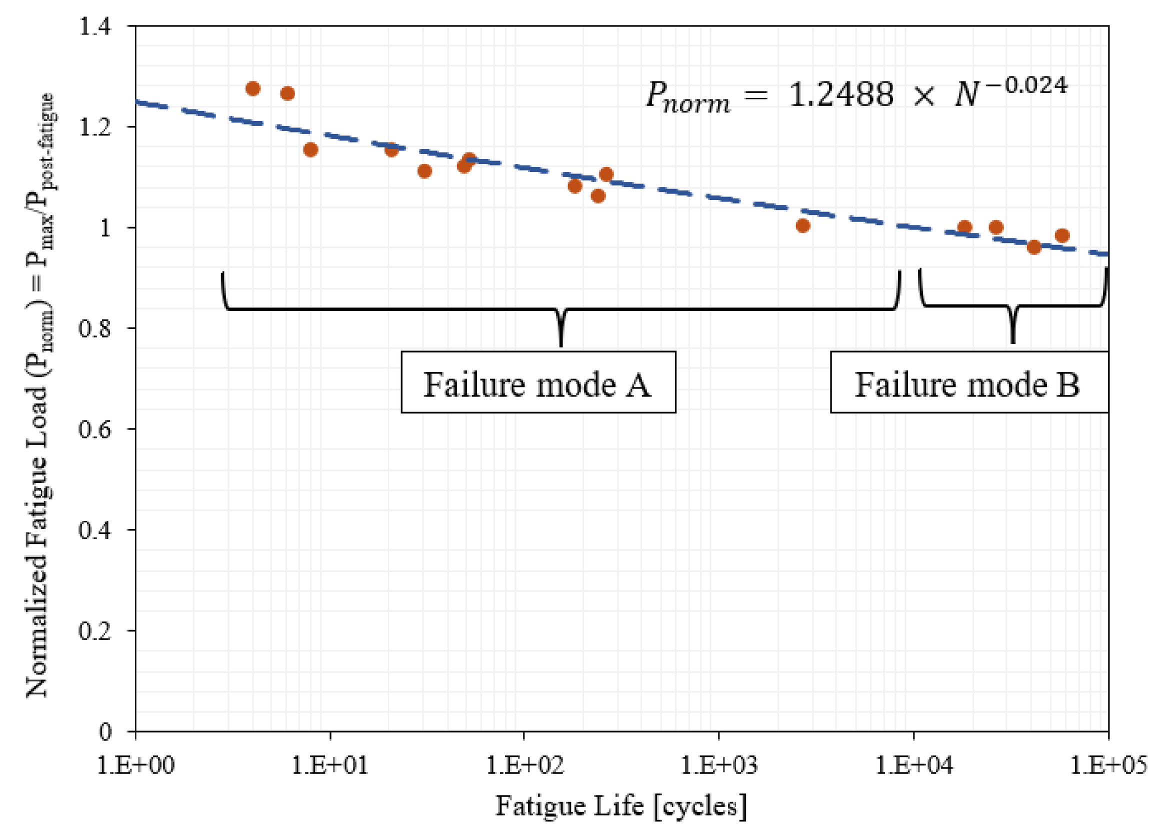


Figure 2– Normalized fatigue load vs fatigue life curve of the hole hemmed joints.

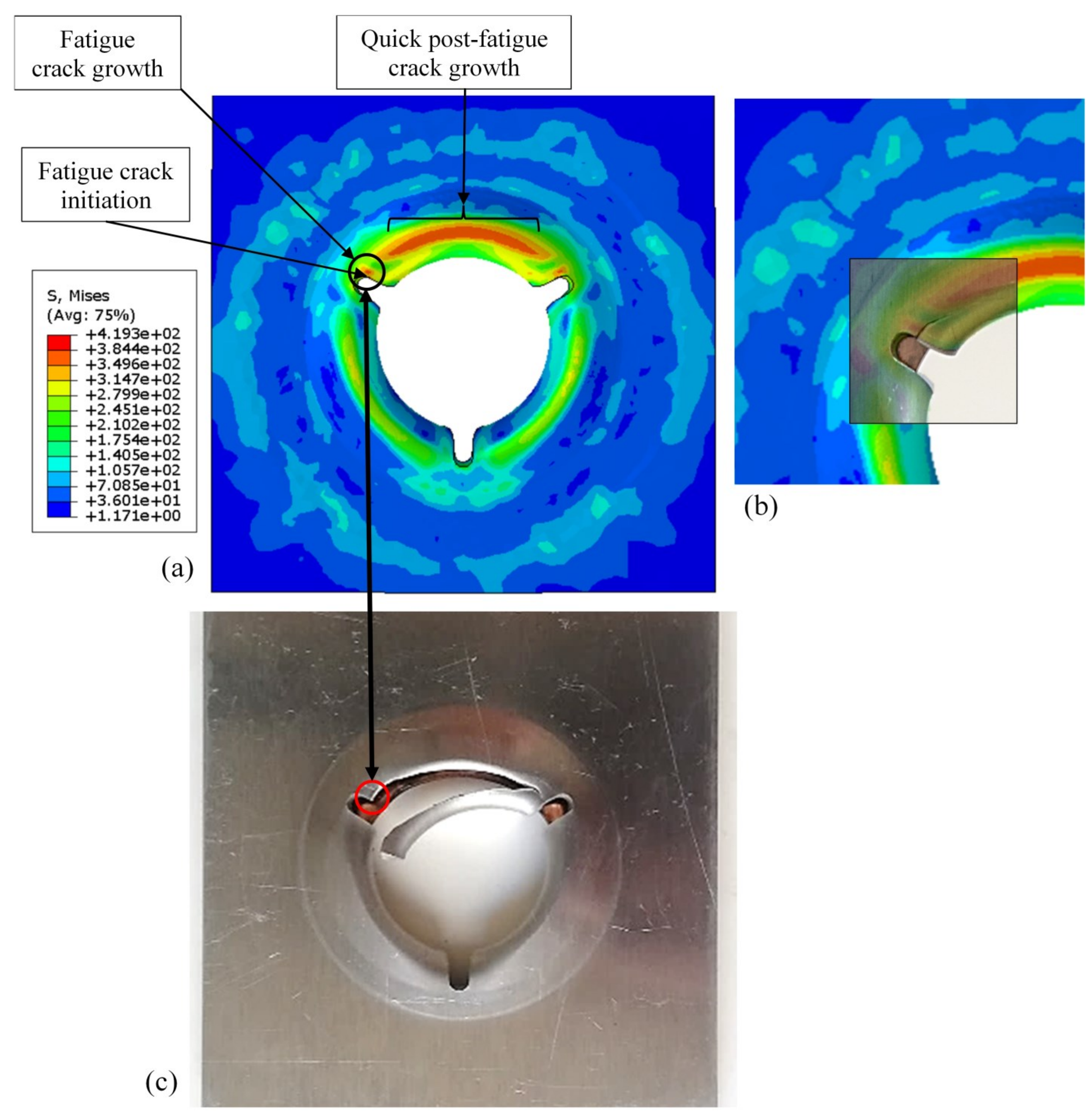


Figure 3– Comparison of the FE-predicted critical region in static analysis with the crack region observed in the experimental tests (mode B). (a) von Mises stress contour plot in the outer sheet, (b) fatigue crack from the experimental test (shown in transparency) superimposed over the von Mises stress contour plot, both scaled identically, and (c) crack propagation observed after the post-fatigue test.

## CONCLUSION

In conclusion, these findings suggest that hole-hemmed joints demonstrate promising durability, withstanding over 1 million cycles when the normalized fatigue load is below 0.9. This makes them a viable option for manufacturing hybrid busbars in EV battery applications.

## REFERENCES


[1] B.F.A. da Silva, M.M. Kasaei, A. Akhavan-Safar, R.J.C. Carbas, E.A.S. Marques, L.F.M. da Silva, Engineering Fracture Mechanics, 311, 110590 (2024).



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