Impacts on the mechanical properties of aluminum base material due to pin welding

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INTRODUCTION

In modern light weight construction polymer based materials such as carbon fiber reinforced composites have gained popularity in recent years. With increasing use of composites in various fields of technical applications, e.g. automotive and aerospace industries, joining them with metal parts has become an important issue. An innovative way to increase the strength of metal - composite joints is using form lock e.g. using so called pins at the metal's surface. Thereby, several pins of some millimeters in height are welded on a metal sheet using the so called cold metal transfer (CMT) technique [1]. The pins act then as an additional mechanical barrier in the eventual joint, similar to a hook-and-loop fastener. A schematic joint is given in Figure 1.

The present work focuses on the mechanical changes of the base material caused due to the heat input during the pin welding process. Therefore tensile tests of specimens with different numbers of pins and without pins were accomplished. Furthermore, finite element (FE) simulations yielded additional insights on temperature distributions inside the welding zone.

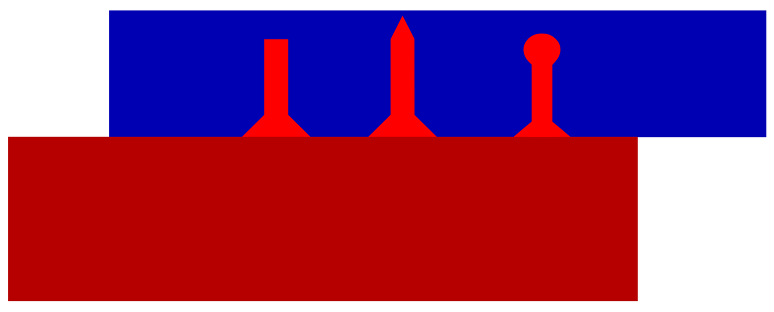


Fig 1. Schematic representation of pin – structures

TENSILE TESTING

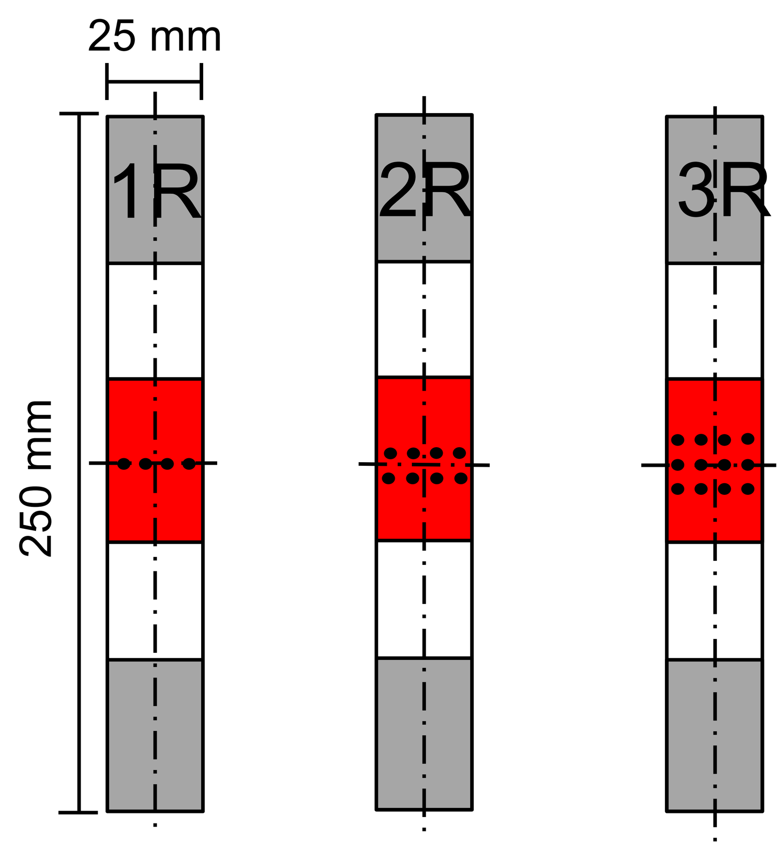
Chemical composition

The material investigated in this survey was an aluminum alloy of the type 6XXX, its chemical composition [weight-%] is listed in the table below:

Mn	Si	Cr	Mg	Ti	Fe
≤ 0,80	≤ 1,5	≤ 0,15	≤ 1,00	≤ 0,25	≤ 0,5

Specimens

Three different configuration of pins were investigated (see below). The specimens had a thickness of 2 mm. For each configuration we tested five specimens.



Results

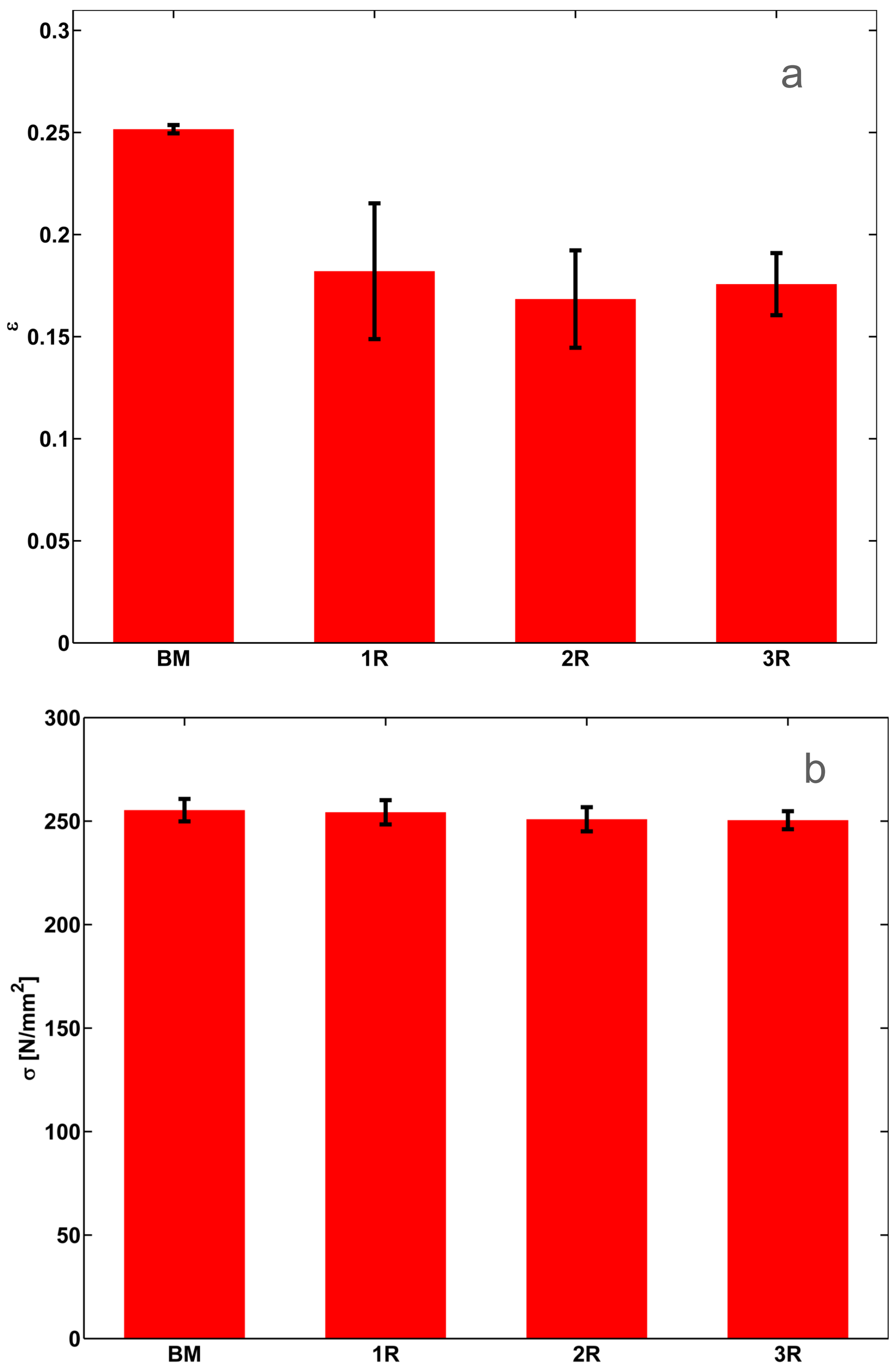


Fig 2. Histograms of the ultimate strain (a) and ultimate stress (b) of the different pin configurations (1R – 3R) and the unaffected base material (BM).

As Figure 2 shows, the ultimate strain decreases significantly after the pins were welded on to the plate. However, the ultimate stress shows no significant changes after welding.

Figure 3 expresses those aspects in a more illustrative manner. It is shown that the variation of the fracture strain is more pronounced (larger area of the ellipses) in the case of pinned samples compared to the unaffected base material.

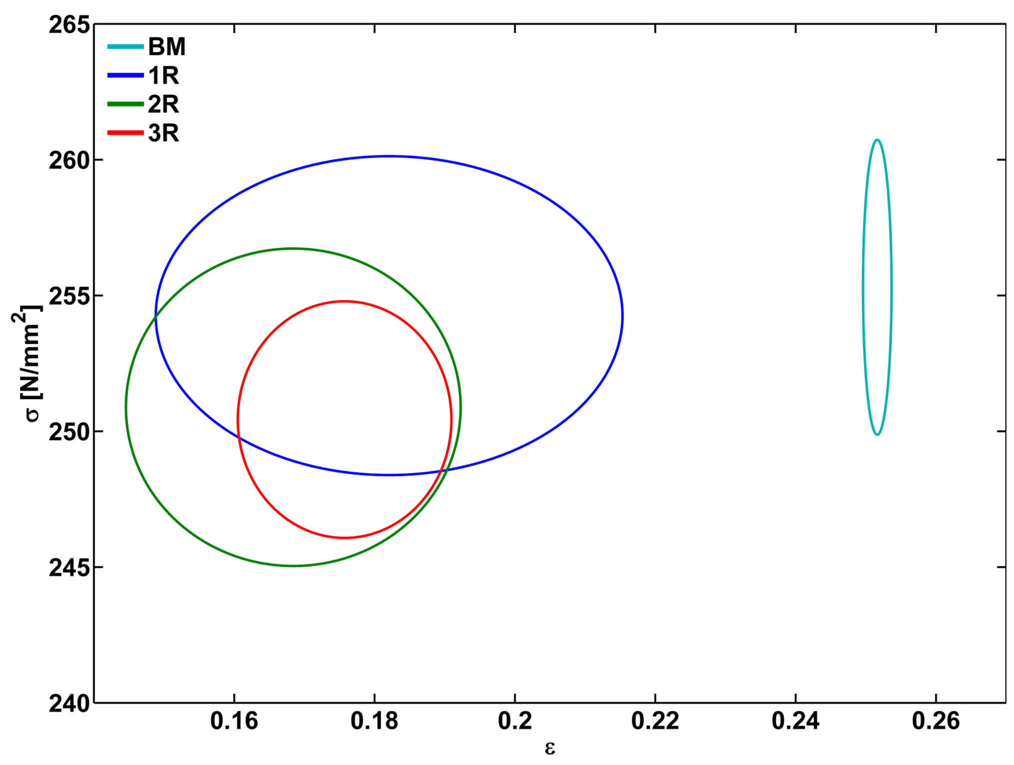


Fig 3. Graphical summary of the ultimate tensile (ordinate) stresses and fracture strains (abscissa).

FE - SIMULATION

In order to get deeper insight in the temperature distributions when multiple pins are welded, we conducted FE simulations (Figure 4).

Figure 5 illustrates that the zones of elevated temperature are concentrated locally to the weld spots.

Considering the temperature time evolution (Figure 6) it becomes evident, that the peak temperature is only present for a short period of time.

However, welding several pins in a short period of time results in a slight increase on the local thermal load (compare zones of elevated temperatures in Figure 5.

At each weld spot:

- Heat input using Goldak heat source [2]
- Cool down
- Cool down + heat input = 1s

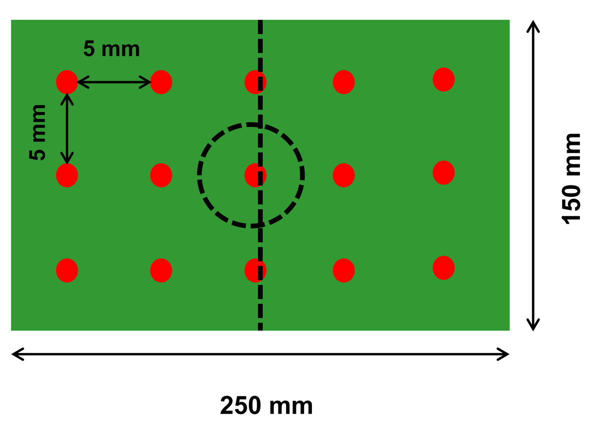


Fig 4 Sketch of the simulated structure; red points indicate weld spots.

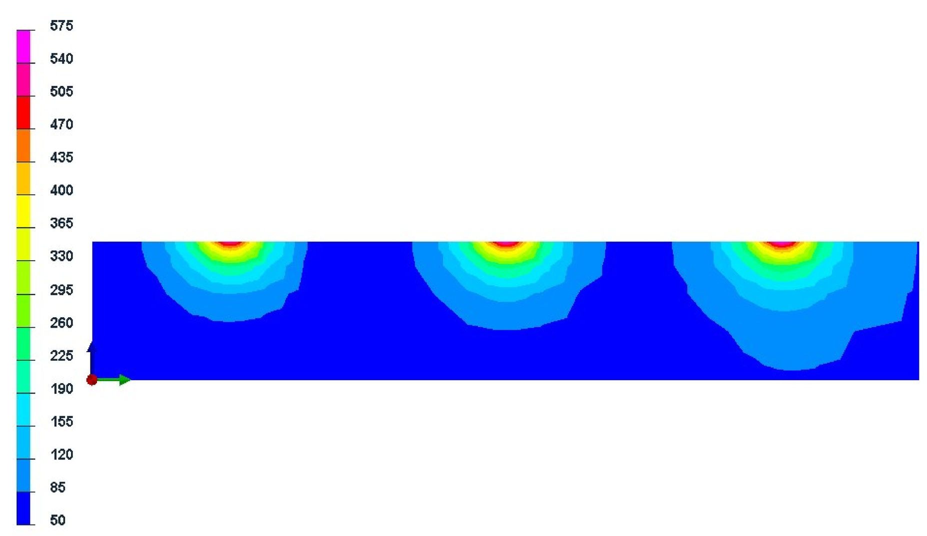


Fig 5 Simulated temperature distribution of the central cross section (dashed line in Fig 4). The depicted temperature field represents the maximum temperature at each node during the computation. The welding order in time was from left to right.

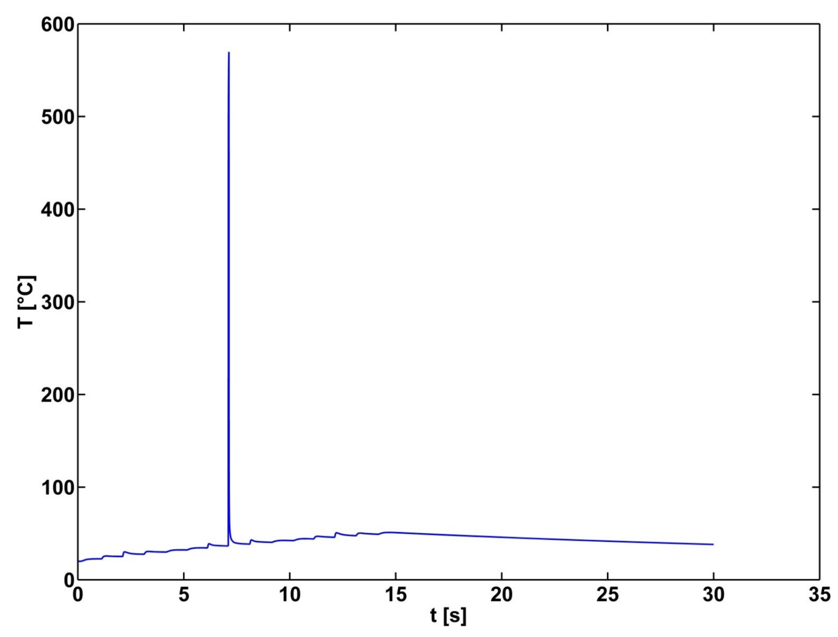


Fig 6 Time temperature curve of the central weld spot (encircled spot Fig 4).

CONCLUSIONS

Tensile tests of unaffected base material as well as pinned specimens showed an decrease in ultimate strain while the ultimate stress remains virtually unchanged. This decrease was rather independent of the number of pins placed at the base material.

FE simulations show that, there is just a short and localized temperature peak during welding, however the heat input has only small impacts on the overall temperature of the work piece.

The fracture strain's drop may mainly result from a geometric notch effect due to the pins at the surface.

REFERENCES

[1] A. Schierl, "The CMT - Process - A Revolution in welding technology," *Welding in the World*, vol. 49, no. 9 SPEC. ISS., p. 38, 2005.

[2] J. Goldak, A. Chakravarti, and M. Bibby, "A new finite element model for welding heat sources," *Metallurgical and Materials Transactions B*, vol. 15, no. 2, pp. 299–305, 1984.

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