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Assessment of the feasibility of joining the AMCs composites reinforced with Ti_3Al intermetallics particles by the resistance butt welding

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Abstract: The present work investigates the feasibility of joining the aluminium AA6061 matrix composite materials reinforced with Ti_3Al particles by the resistance butt welding. Results of investigation carried out shows that the best mechanical properties of joints can be achieved applying soft conditions of butt welding process e.g. current 1300 A and current flow time 1,2 s. To improve hardness and tensile properties of butt welding joints age hardening is necessary.

Keywords: Composite materials, Intermetallics, Resistance butt welding, Mechanical properties

1. INTRODUCTION

One of the obstacles to using high –performing metal matrix composites is the scarcity of known, proven joining methods, especially when it is hard to imagine equipment or machinery where no kind of joint has been used. The most recommended method of joining in case of metal matrix composites is the formation of disjunctive joints, riveting and also cold gluing, therefore methods, which do not introduce a heat into joining zone. However in case of equipment made of composites, where it is required to have a good sealing and high level of service properties than it is necessary to use other joining methods. Some of the common joining techniques are welding, butt welding, soldering and a specialised gluing. The formation of the durable joint between two composite materials depends on the ability of these materials to create a common structure at the joint.

The basic phenomena which took place during the welding processes of composites materials are reactivity, wettability, diffusion and sintering. The standard requirements for welding processes of composites materials are:

- maintenance of the reinforcements arrangement continuity in the joining zone,
- limit of the diffusion interaction between reinforcements and matrix materials in the process temperature – time condition,

- pursuit to reduction of local thermal stresses between reinforcements and matrix materials

It can be achieved by:

- minimizing the melting zone and mutual exchange of components in the joined materials,
- minimizing the time of joining process, in order to reduce the presence of high temperatures,
- using of small welding pressures,
- accurate control of the chemical composition of additional materials (electrodes, solders) in order to control eventual reactivity during joining process.

Analysing the above facts, one can conclude that to join composites the ideal operation would be the one, which takes place at low temperature, in shortest possible time and with minimum possible compression [1-5].

The present work investigates the feasibility of joining the aluminium AA6061 matrix composite materials reinforced with Ti_3Al particles by the resistance butt welding.

2. EXPERIMENTAL PROCEDURE

Aluminium matrix composites were produced employing the atomised aluminium alloy AA 6061 as metal matrix when Ti_3Al intermetallics particles were used as reinforcement. Particles size less than 75 and 50 μm respectively. Three sets of samples with 5, 10 and 15 % (wt.) of reinforcement were prepared. Prior to pressing and extrusion the mechanical milling process with a high energy planetary ball mill were used in order to refine and homogenize the particle distribution. Details of composite materials production were described in [6]. Extruded bars of 5 mm diameter and near theoretical density were obtained. Welding process was made on resistance butt welding machine. Welding currents were 1200, 1300 and 1600 A, welding time 1.2 and 0.3s respectively, pressure force 225 N and jaw distance 3 mm. Bevelling and mechanical polishing of samples before joining were made. To determine the ultimate tensile strength (UTS) of joints tensile tests were performed on samples with 50 mm measuring length. To determine hardness of joints, heat affected zones and base materials micro Vickers tests were performed. Microstructure observations were made by optical microscopy and scanning electron microscopy SEM.

3. RESULTS

Metal matrix composites, as a class, are extremely versatile materials, enabling the designer to combine the properties of various metals and non-metals in one piece. One of their drawbacks, though is the difficulty of connecting such pieces to themselves or to monolithic metals –it has become evident, that the joining process can impair the properties of the MMC to the level of matrix material or even lower. Al alloys are not especially well suited for bonding because of natural tendency to stable surface oxide formation, however by careful process control suitable properties can be achieved.

Basing on macroscopic observation of resistance butt welds it was found that the smallest and most regular flash was obtain for current 1300 A (Fig 1). Microstructural investigation of welds allows to reveal heat affected zone and changes of reinforcement particles orientation (initially compound parallel to extrusion direction) in accordance with flash materials flow.

Additionally into central zone of welds one can see presence of small crevice indicating scarcity of joints (Fig 2).

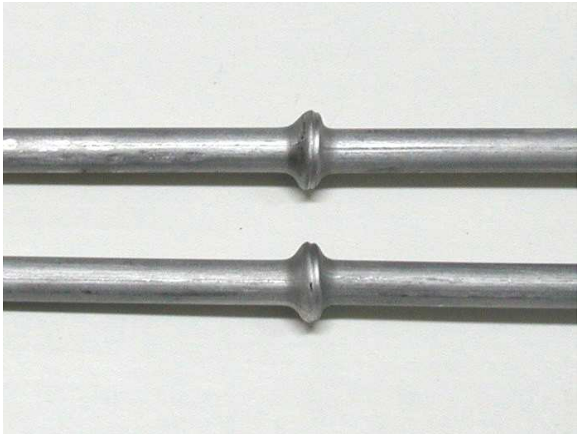


Figure 1. Macro-photographs of butt welded joint for investigated AMCs reinforced with 15 % of Ti_3Al

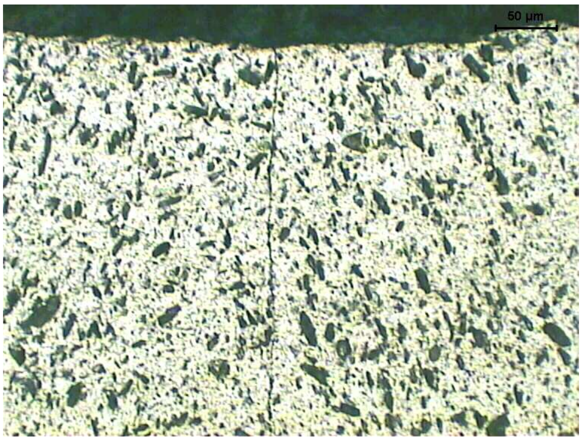


Figure 2. Microstructure of weld central part for investigated AMCs reinforced with 15 % of Ti_3Al

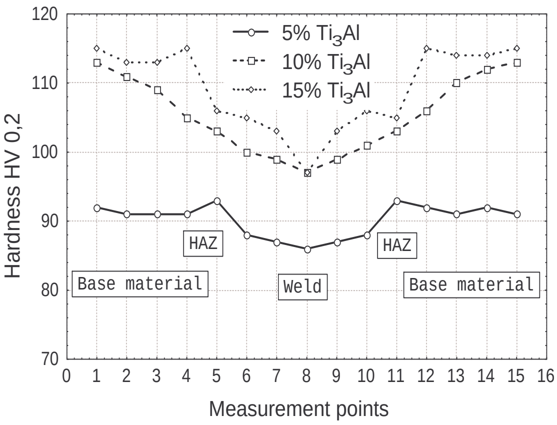


Figure 3. Microhardness change along the joint for investigated AMCs

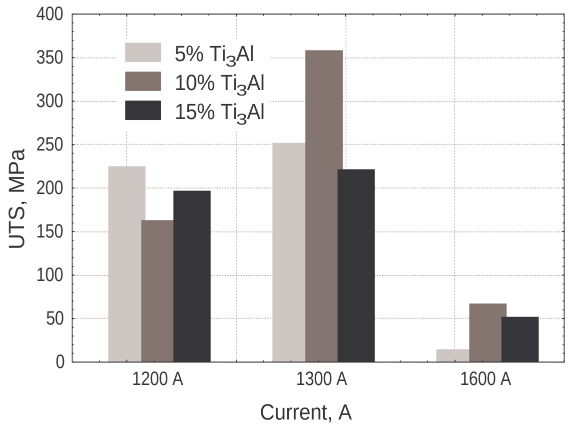
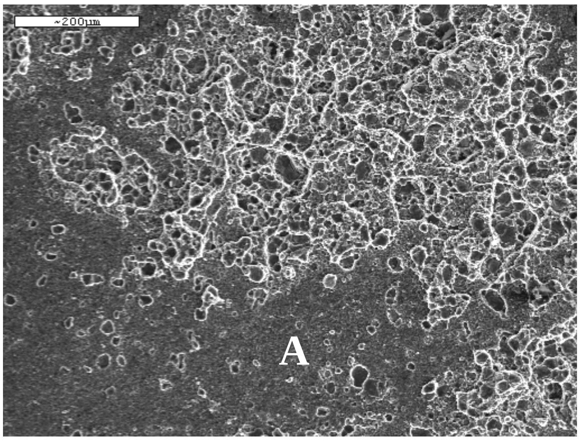


Figure 4. Ultimate tensile strength for investigated AMCs, welded in different conditions

Hardness measured along the line perpendicular to the joint reveal their decrease into the central part of weld (Fig 3)

Mechanical properties investigations carried out in the static tensile test indicating that for the applied condition of butt welding process highest ultimate tensile strength was obtain for current 1300A, inferior for 1200A and almost lack of strength for 1600 A (Fig 4).

Fractographic investigation of tensile test fractures confirms presence of small areas cowered with oxide layers in which the joint was not obtained as well as typical for matrix materials ductile fractures (Fig 5, 6).



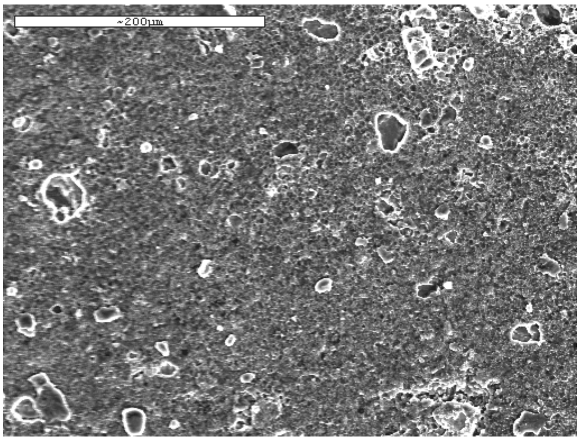


Figure 5. Tensile test fracture topography of butt welded joint for investigated AMCs reinforced with 5 % of Ti_3Al

Figure 6. Tensile test fracture topography of butt welded joint for investigated AMCs reinforced with 5 % of Ti_3Al, - detail A

4. SUMMARY

In case of aluminium alloy AA 6061 matrix composite materials reinforced with 5-15 wt % of Ti_3Al intermetallic particles it is possible to obtain joints by use of resistance butt welding techniques applying soft parameters of welding process. In certain conditions tensile strength of butt welded joints reaches 90% of composite materials tensile strength. Decrease of tensile properties for the other one can be explain basing on the metallographic and scanning electron microscopy investigations. It shows that inside the butt welding joint one could observe incomplete fusion areas most probably because of raw material oxidation. Also hardness measurement revels that butt welding joints has lower hardness than composite materials itself. When matrix material is heat treatable one, temperature cycle of resistance butt welding, could promote overageing of raw material (solution heat treatment could be made during extrusion) leading in hardness decrease. To improve hardness and tensile properties of butt welding joints age hardening is necessary. Another thing which is not unimportant one is a change of reinforcement intermetallic particles orientation within joints caused by flash of materials during weld pressing.

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