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Recent developments in FSW assisted by electrical current hybrid process

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Abstract:

Friction stir welding (FSW) has increased its usage in the recent years as a joining technology process due to several advantages such as the ability to join dissimilar materials. Nonetheless, defects in the weld root zone can occur and cause premature failure of the welded components. In order to prevent these failures and improve the structural integrity of friction stir welded components, researchers have been proposing various new processes, specially a hybrid process of FSW enhanced by electrical current. This paper describes further developments of FSW assisted by Joule effect, namely developments and test methods of functional back plates and friction stir tools to improve this hybrid process. Several tools and back plates were designed, modeled, and experimentally validated in heat treatable aluminum alloys. A significant reduction of lack of penetration (LoP) and oxide alignment in weld root was seen when applying the electrical current.

Analytical and numerical models were developed and allowed to quantify the temperature increase due to the electrical current. A conductive back plate and alumina shoulder and probe combination generates the highest electrical current density of all the modeled combinations. The zone with the highest value is located directly below the probe.

Keywords: FSW, Electrical current, Hybrid process, Numerical Simulation, Applications

Introduction

The increasingly interest in Friction Stir Welding (FSW) as a joining technology process requires continuous research and developments. Insufficient viscoplastic material flow below the probe tip could result in root defects and are usually caused by an insufficient probe penetration. To increase the viscoplastic material flow on the root it is necessary to increase the overall heat input, e.g. by increasing the rotation to travel speed ratio. A new hybrid process of FSW assisted by Joule effect was proposed to increase the process temperature [1]. It can be also used as a new material processing strategy [2] or in production of composites materials [3].

Developments and results

Defects in FSW, such as root defects, can be overcome with the correct development of shoulders and probe geometric features and processing parameters. Numerical simulations were performed to study the electrical current flow pattern and its effect on the material below the probe tip. The finite element ANSYS[®] Maxwell software was used to create a geometrical model as shown in Fig. 1 with 3 million tetrahedral elements. Several designs of tools and back plates were modelled and simulated to verify the current density below the probe tip. Fig1a)

shows that using an electrical conductive back plate is more suitable to direct electrical current through weld root and consequently increase the temperature in that area.

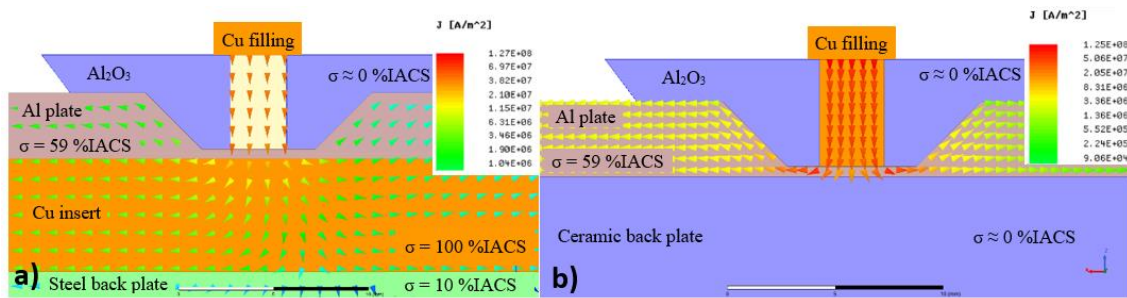


Figure 1 - Graphical representation of the numerical simulation of the electric current flow for the alumina tool and the conductive (a) and isolating back plates (b).

FSW assisted by Joule effect was performed on an 3.5 mm of thick aluminium plate AA1100 using an alumina shoulder with a steel probe and a steel black plate. Fig. 2 c) shows a reduced root defect when a current of 280 A was imposed.

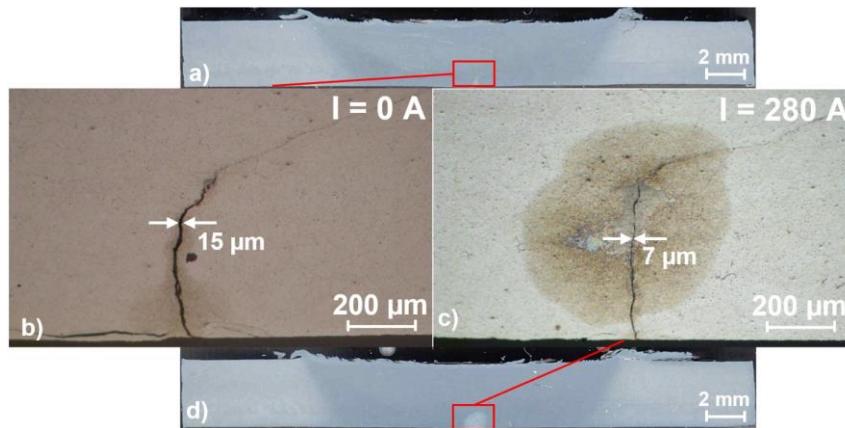


Fig. 1 – Transverse section of weld (alumina shoulder and steel probe), a) macro of sample M1 ($I = 0$ A), b) micro of sample M1, c) micro of sample M2, d) macro of sample M2 ($I = 280$ A).

Conclusions

From the study described it can be concluded that:

- The hybrid FSW assisted by Joule effect can raise the temperature below tip probe, increasing the viscoplastic flow; Numerical simulations has shown the influence of tool and back plate design in electrical current direction and intensity; Experimental results showed that imposing an electrical current through the weld root, reduce the size of the root defect.

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