FRICTION STIR WELDING – INNOVATIVE TECHNOLOGY FOR JOINING ALUMINIUM COMPONENTS

RÜHRREIBSCHWEISSEN (FRICTION STIR WELDING) – EINE INNOVATIVE VERFAHRENSTECHNOLOGIE ZUM FÜGEN VON HALBZEUGEN AUS ALUMINIUM

SOUDAGE FSW – UNE TECHNOLOGIE INNOVANTE POUR LA JONCTION DE PRODUITS SEMI-FINIS EN ALUMINIUM

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SUMMARY

Friction stir welding is suitable for joining semi-finished aluminium products with a wall thickness from 0.3 mm to 35 mm (one side welded, butt joint or lap joint).

In the context of investigations carried out at the MPA University of Stuttgart welded joints of EN AW-6082 and EN AW-5083 (t = 6 and 10 mm) were manufactured and examined regarding the microstructure and tensile test behaviour. High-quality welding seams could be manufactured.

In the year 2004 the MPA University of Stuttgart installed a new system of the type "ESAB FSW Legio 3ST" for friction stir welding. This welding machine is suitable for the production of welded joints of aluminium components with a seam depth up to 12 mm (copper materials up to 3 mm). This offers innovative potential also for applications in civil engineering (metal construction) in the context of research and development on customers order.

ZUSAMMENFASSUNG

Das Rührreibschweißen (Friction Stir Welding) ist geeignet zum Fügen von Halbzeugen aus Aluminiumwerkstoffen von 0,3 mm bis 35 mm Wanddicke (einseitig ausgeführte Naht, Stumpfstoß- oder Überlappstoßverbindung).

Im Rahmen von Untersuchungen an der Materialprüfungsanstalt Universität Stuttgart wurden Schweißverbindungen an EN AW-6082 und EN AW-5083, (t = 6 und 10 mm) hergestellt und hinsichtlich des Gefügeaufbaus und der Festigkeitsverhaltens untersucht. Dabei konnten fehlerfreie Schweißnähte hoher Qualität hergestellt werden.

Das im Jahr 2004 an der Materialprüfungsanstalt Universität Stuttgart beschaffte System vom Typ „ESAB FSW Legio 3ST“ für das Rührreibschweißen ist geeignet zur Herstellung von Schweißverbindungen an Aluminiumwerkstoffen bis zu 12 mm Nahttiefe (Kupferwerkstoffe bis zu 3 mm). Dieses bietet ein entsprechend innovatives Potenzial auch für Anwendungen im Bereich des Bauingenieurwesens (Metallbau) und wird im Rahmen von Forschungsvorhaben und Entwicklungsarbeiten im Kundenauftrag für innovative Produktentwicklungen eingesetzt.

RESUME

Le soudage FSW (Friction Stir Welding) est recommandé pour la jonction de produits semi-finis en aluminium ayant une épaisseur de paroi variant de 0,3 à 35 mm (cordon de soudure d´un côté, joint droit, soudage par recouvrement).

Dans le cadre d´études au MPA de l´université de Stuttgart, des jonctions par soudure entre EN AW-6082 et EN AW-5083, (t = 6 et 10 mm) ont été réalisées et étudiées au niveau micro structurel et au niveau de leur solidité. Des cordons de soudures de haute qualité présentant une haute solidité ont ainsi été réalisés.

Le système de soudage FSW de type « ESAB FSW Legio 3ST » que s´est procuré le Materialprüfungsanstalt de l´université de Stuttgart en 2004 convient parfaitement à la réalisation de jonctions par soudure pour des matières aluminium avec une profondeur de soudure allant jusqu´à 12mm (et jusqu´à 3mm pour des matériaux en cuivre). Ce système présente également un potentiel innovant pour le génie civil (constructions métalliques) et sera employé pour des développements de produits innovateurs dans le cadre de projets de recherche et de travaux de développement pour le compte de clients.

KEYWORDS: Friction stir welding, joining, aluminium, components

INTRODUCTION - FRICTION STIR WELDING

In 1991 Wayne Thomas developed and patented a new welding method, the Friction Stir Welding (FSW) [1]. The principle of the FSW-procedure is shown in Fig. 1. This technology is a modification of the friction welding process. The frictional heat is produced by a wear resistant rotary tool, which is pressed under high axial force into the welding zone.

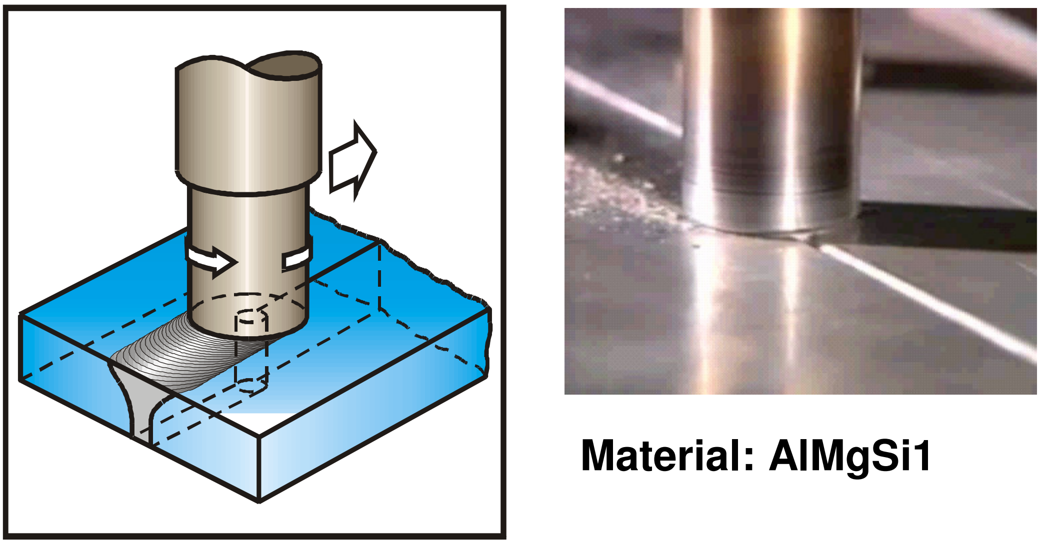

***Fig. 1:** Friction stir welding - procedure principle [2]*

By the use of the described welding tool it is possible to weld butt or lap joints (seam welding) [2-4]. Similar as in the rotation friction welding process, in friction stir welding the join is also formed below the melting temperature of the assembly parts, thus in solid state welding. In the literature the process of FSW is therefore compared with warm forming technologies such as extrusion and forging.

By means of this analogy, the characteristics of this welding process can be explained, e.g. the fine-grained very homogeneous microstructure of the welded seam as well as the joint properties resulting from it. Most advantages of FSW result from the simple process as well as from the solid state welding at comparatively low temperatures [5-7].

Summarizing the following advantages arise:

- simple and robust process
- simple joint preparation
- no fused-on spatters, fume or dust
- no inert protective gas
- low power requirement
- low distortion of the welded parts
- very good mechanical behaviour of the welds
- material mix of different aluminium alloys

The application of the FSW process could be impeded mainly by the high axial process forces and thus the required support of the welding zone as well as the limited possibility for three-dimensional seam welds.

FRICTION STIR WELDING (ALUMINIUM: EN AW-6082, EN AW-5083)

At the MPA University of Stuttgart first investigations on the fundamentals of the friction stir welding process were carried out on aluminium materials [2, 8-10].

For a workable aluminium alloy AlMg4,5Mn (EN-AW-5083) and an age-hardenable aluminium alloy AlMgSi1 (EN-AW-6082) several 10 mm thick friction stir seam welds were realized. During the welding process both the number of revolutions of the tool and the welding speed were varied, in order to get information about the influence of these parameters on the quality of the welding seam. A compilation of the tool and processing parameters is contained in Fig 2.

- tool material
- shoulder diameter (∅)
- pin geometry
- penetration (t)
- overlap (u)
- tilt angle (α)
- number of revolutions (n)
- feed speed, welding speed (v)

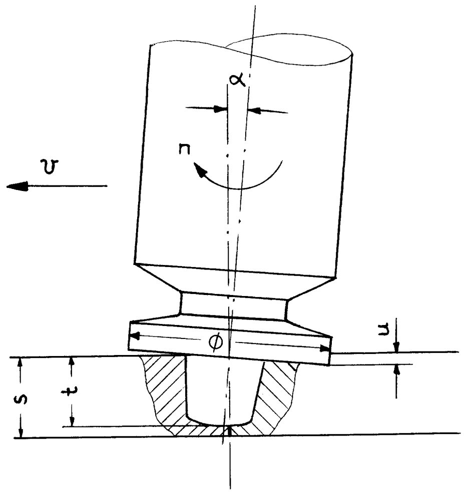

Fig. 2: *Friction stir welding - tool- and processing parameters [2]*

Metallographical examinations including hardness measurements, Fig. 3, and mechanical-technological testing were carried out for the evaluation of the material condition of the welded joints.

Both materials showed defect-free welds, with structures like annual rings ("onion structure") in the centre. For both materials, EN AW-6082 and EN AW-5083, the particles of the phases are arranged rectilinear in the base materials and partly stretched in the direction of the lines. In the region of the welding seam these lines disappear, the particles have a rather globular shape and their size is comparable to the one of the unaffected basic material. In welded EN AW-6082 material the hardness continuum transverse to the welding seam shows a decrease in hardness. In the case of the material EN AW-5083 the hardness did not change transverse to the welding seam. For the material EN AW-5083 flat tensile specimens were taken from a welded joint of higher welding speed range. The fracture of these tensile specimens took place as shear fracture under 45° in the region of the base material. The comparison of the results of the tensile tests on flat specimens with those obtained for round tensile specimens shows a somewhat lower reduction in area of the welded joint sample.

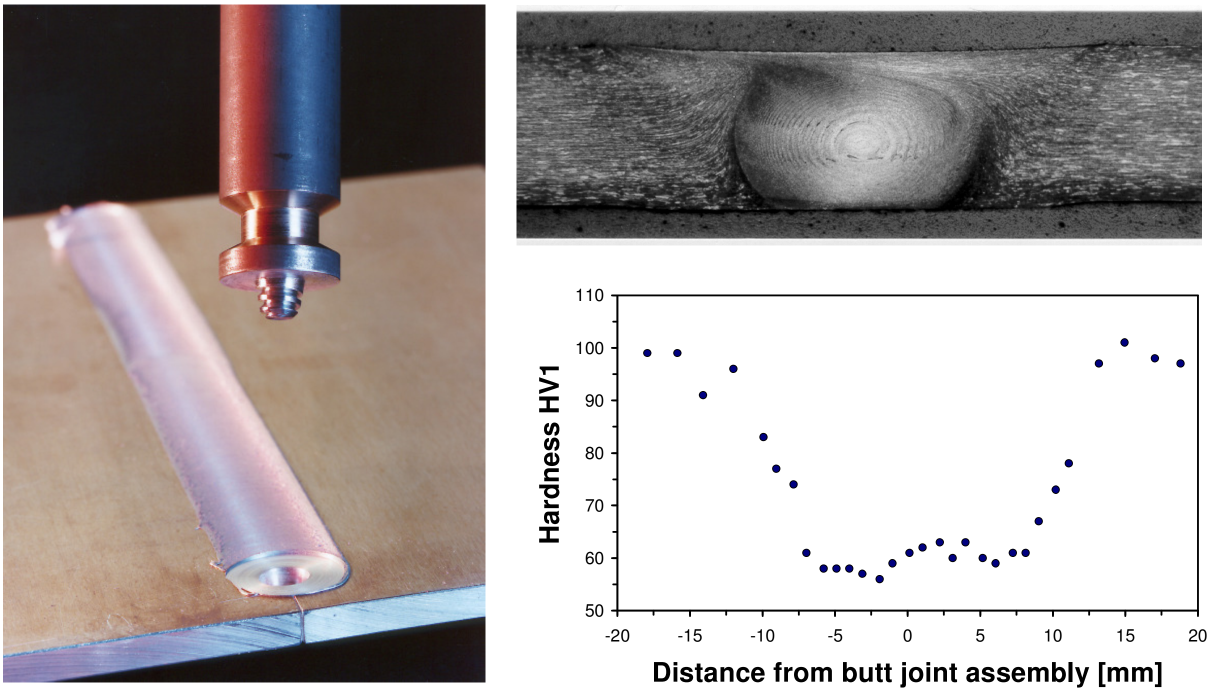

Fig. 3 : *Friction stir welding on aluminium plates made of EN AW6082 material (left: welding seam and tool; right: macro-examination specimen and hardness continuum)[9]*

The investigations performed showed that the material behaviour and process which lead to the formation of the FSW-welded joint are very complex and must be further examined.

In view of the industrial application, the friction stir welding offers advantages in particular for the joining of aluminium components of larger wall thickness (one-side welded: up to 40 mm, both side welded: up to 70 mm), Fig. 4, and for the production of mixed constructions.

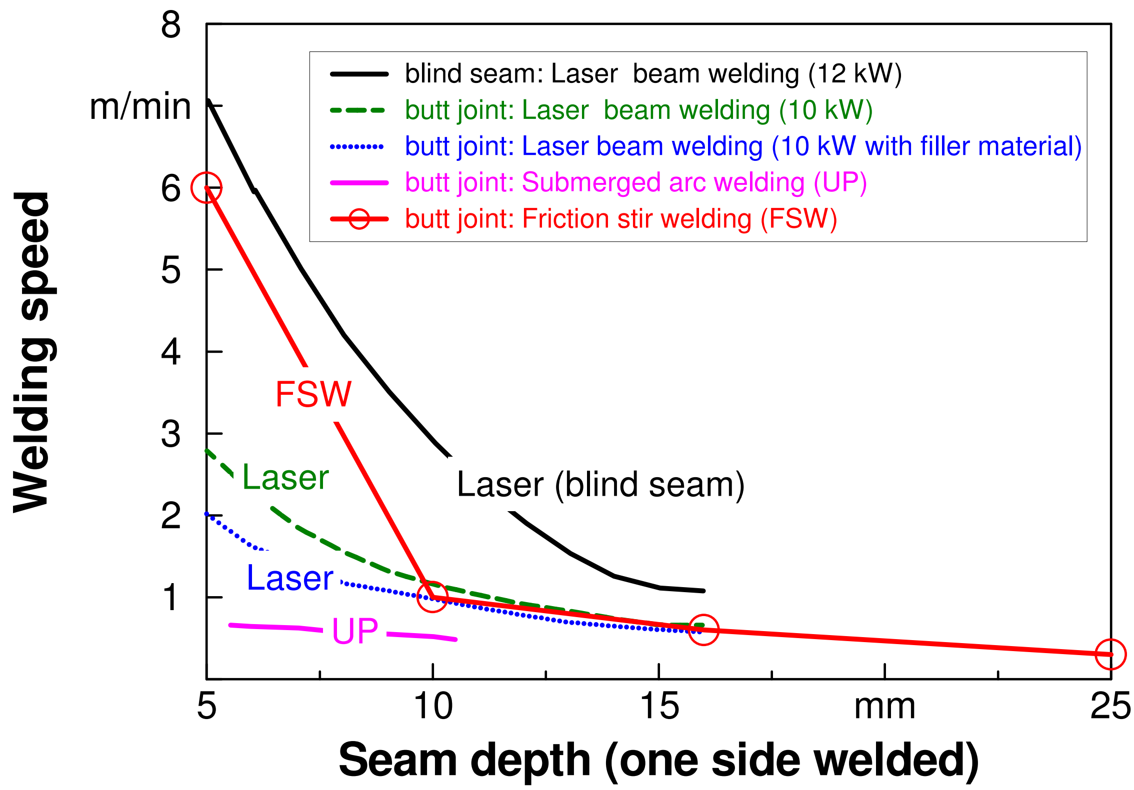

Fig. 4: Seam depth and welding speed of different welding techniques (Aluminium: AA6000-Series)[2]

CONCLUSION

The friction stir welding process has a large development and improvement potential in the area "lightweight construction". Further topics such as "joining of modern materials" (metal matrix composites (MMCs), material mix) and "environmentally friendly production technology" are for many areas of technology (civil engineering, machine and equipment construction, lightweight construction in aviation, vehicle construction and ship building) of increasingly current significance. To achieve these goals, friction stir welding, which was developed at the beginning of the nineties, will make an innovative contribution. In this context it can be assumed that research results in this area will within short time have a broad effect on and also a direct conversion to a lot of possible applications in the industrial manufacturing.

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