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Friction crush welding of aluminium, copper and steel sheetmetals with flanged edges

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ABSTRACT

The implementation of friction crush welding (FCW) offers a versatile application in the welding of sheet metals. Three materials (EN AW 5754H22, DC01 and Cu-DHP) were analysed by applying the method with flanged edges. The additional material required to form the weld is provided by the flanged edges of the parent sheet metal. The joint is formed by the relative motion between a rotating disc, which is applied with a crushing force, and two sheet metal parts. The fundamental process variables and the requirements of the welding preparation are shown. Bond strengths, as a percentage of the yield strength of the parent material, of around 95% (DC01) 90% (EN AW 5754H22) and 62% (Cu-DHP) are achieved. Microstructural investigations reveal that a dynamic solid-state deformation and recrystallization of the additional flanged material results in a fine grain microstructure in the weld region. Reduced metallurgical changes along with minimized distortion and residual stresses in the parent material indicate low heat input. By creating a fine grain microstructure in the welding line, the friction crush welding method reveals great potential, especially for welding steel.

1. Introduction

1.1. Friction welding: classification of methods

Friction welding is generally categorised as pressure welding (DIN EN 14610) subordinated and then described according to the relative movement between the interfaces and according to their types of energy supply (EN ISO 15620). Considering the relative velocity and the friction motion between the interfaces, friction welding processes can be classified in two groups. The first group represents the various means where the heat is generated by the relative movement between the surfaces. The classical processes with rotary, linear and orbital motion are representatives of this group. Maalekian (Maalekian et al., 2008) compares the relative velocity between these three welding methods and the influence of the heat generation at their interfaces. This article describes disadvantages of such methods, for instance the non-uniform relative motion over the interfaces experienced in rotary friction welding. The directional and unidirectional relative velocities of the different friction welding techniques are illustrated in Fig. 1 (unlabelled arrows).

Processes generating the friction due to a relative motion between a non-consumable tool and the workpiece surface can be classified as the second group. Friction Stir Welding FSW was developed by W.M. Thomas (Thomas et al., 1991) as a solid-state joining process (Fig. 1d) which operates by way of a non-consumable rotating tool with a specially designed pin and shoulder. When the pin is inserted into the interfaces of metal plates that to be joined and traversed along their mating edges the movement of the tool creates a material flow which produces the joint (Mishra and Ma, 2005). The effect of the tool wear offers a challenge in FSW and may be correlated with the rotational speed of the pin and the welding speed. Fernandez and Murr (Fernandez and Murr, 2004), detected a reduction in tool wear at decrease in rotational speed and increasing welding speed. The influence of a variation in the relative motion between the tool and the workpiece surface in FSW was also investigated by Sato and Kokawa (2001). The article describes the differences between the intrinsic strength and ductility shown by the advancing and the retreating sides; with the retreating side showing a lower strength. Cavaliere (Cavaliere et al., 2008) describes and compare the grain size as a function of the welding speed in friction stir welded aluminium (AA6083). Significant grain fining was found at welding speeds between 100 mm/min

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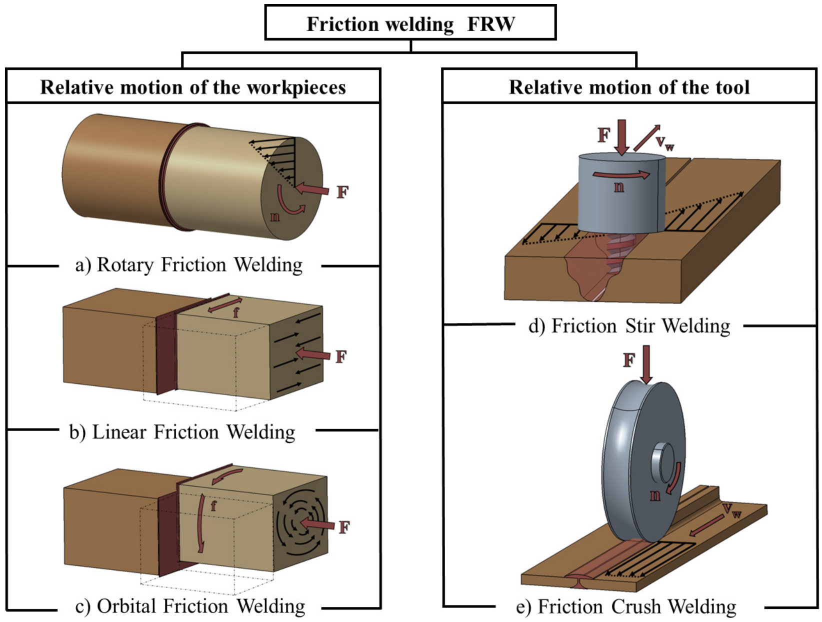

Fig. 1. Classification of friction welding.

and 200 mm/min. Dissimilar FSW of thin sheets (0.8 mm) of aluminium (AA5052) and pure copper (99,999%) is shown by Yusof et al., 2013. The author shows the possibility to weld different materials and describes problems like surface void defects and insufficient material flow relating to the thin metal welding. Developing a joining approach, which eliminates unequal relative stirring velocities and offers the possibility of welding thin sheet metals at high speeds, is the motivation for this work. The use of friction crush welding, FCW, offers such possibilities and is the subject of this article.

1.2. Principal of friction crush welding (FCW)

FCW is based on an invention (patent pending) for joining metal workpieces using frictional heat and pressure with the possibility to produce joints between similar and dissimilar materials (Schindele, 2010). The process operates, similarly to FSW applications, with a friction contact between a non-consumable rotating tool and the workpiece surfaces. The relative motion, in contrast to FSW (Fig. 1d), is accomplished by means of a rotating disc (Fig. 1e) and with a unidirectional uniform relative speed between the disc and sheet metal edges (Besler, 2014).

In this implementation of the technique the edges of the sheet metal parts to be joined are prepared with flanged edges and are then placed against each other (adjacent, in the same plain and contacting). The friction disc traverses with a constant feed rate along the edges of the workpiece which leads to a plastification of the material in the region near the FCW disc. The disc surface, with a specific circumferential profile, shapes the welding line whereby the joint is modelled by the action of crushing a certain amount of additional flanged material into the gap formed by the contacting material (see crushing zone, Fig. 2). Because of these two main processes, the friction based heating and secondly the crushing mechanism of material intermixture, the name of the process was previously defined as Friction Squeeze Welding (Schindele, 2012); however, in this work it is described as Friction Crush Welding (University Kempten, 2016).

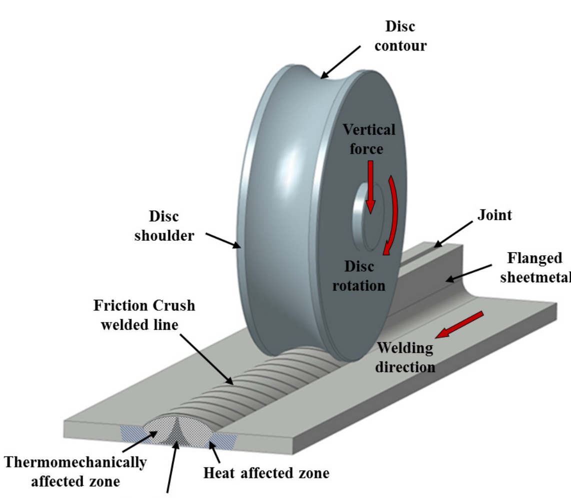

Fig. 2. Principle and microstructural zones of Friction Crush Welding.

2. Preliminary considerations

2.1. Process parameters

FCW involves a complex plastic deformation and material modelling process to form the joint. The preparation of the mating sheet metal parts and the geometry of the rotating disc offer a number of parametric variables which may affect the welding process. Also the effect of the disc rotational speed, its position relative to the work piece and the speed at which it is traversed along the weld line (*welding speed*) need to be considered. The welding speed and the disc rotational speed could be expected to cause a change in the resistance when crushing the additional material, leading to an associated pressure distribution at the contact zone (Fig. 3). This pressure distribution will result in a crushing force F_C that can be resolved into a horizontal component F_H which opposes the welding direction of travel and a vertical component, or vertically downward force, F_V. The geometry of the disc may also be important in this regard.