УДК 621.791.14.03

M.Spetsyian, S.Khomenko

Friction Stir Welding

Belarusian National Technical University
Minsk, Belarus

Friction stir welding (FSW) was invented at The Welding Institute (TWI) of UK in 1991 as a solid-state joining technique, and it was initially applied to aluminum alloys. The basic concept of FSW is remarkably simple. A non-consumable rotating tool with a specially designed pin and shoulder is inserted into the abutting edges of sheets or plates to be joined and traversed along the line of joint (Fig. 1).

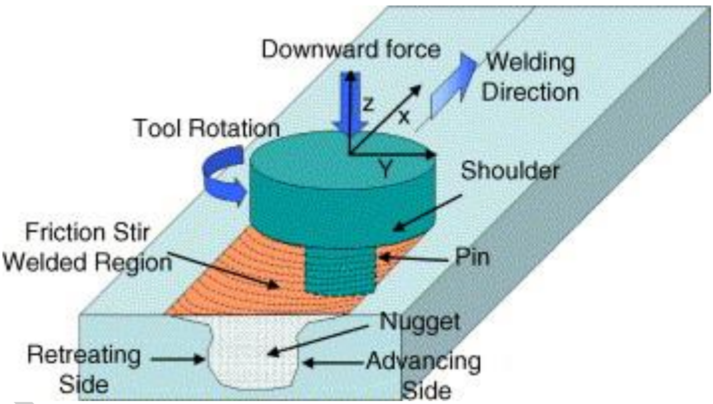

Fig. 1 - Schematic drawing of friction stir welding.

The tool serves two primary functions: (a) heating of a workpiece, and (b) movement of material to produce the joint. The heating is accomplished by friction between the tool and a workpiece and plastic deformation of a workpiece. The localized heating softens the material around the pin and tool rotation leads to movement of material from the front of the pin to the back of the pin. As a result of this process a joint is produced in ‘solid state’. Because of various geometrical features of the tool, the material movement around the pin can be quite complex. During FSW process, the material undergoes intense plastic deformation at elevated temperature, resulting in generation of fine and equiaxed recrystallized grains. The fine microstructure in friction stir welds produces good mechanical properties.

As compared to the conventional welding methods, FSW consumes considerably less energy. No cover gas or flux is used, thereby making the process environmentally friendly. The joining does not involve any use of filler metal and therefore any aluminum alloy can be joined without concern for the compatibility of composition, which is an issue in fusion welding. When desirable, dissimilar aluminum alloys and composites can be joined with equal ease. In contrast to the traditional friction welding, which is usually performed on small axisymmetric parts that can be rotated and pushed against each other to form a joint, friction stir welding can be applied to various types of joints such as butt joints, lap joints, T butt joints, and fillet joints [1].

The process advantages result from the fact that the FSW process takes place in the solid phase below the melting point of the materials to be joined. The benefits include the ability to join materials that are difficult to join by fusion weld, for example, 2XXX and 7XXX aluminium alloys, magnesium and copper. Friction stir welding can use purpose-designed equipment or modified existing machine tool technology. The process is also suitable for automation and is adaptable for robot use.

Other advantages are as follows:

- low distortion and shrinkage, even in long welds

- excellent mechanical properties in fatigue, tensile and bend tests
- no arc or fumes
- no porosity
- no spatter
- the possibility to operate in all positions
- the use of one tool for up to 1000m of weld length in 6XXX series aluminium alloys
- no filler wire is required
- no grinding, brushing or pickling is required in mass production
- aluminium and copper of >75mm thickness can be weld in one pass [2].

Process parameters and tool geometry

For FSW, two parameters are very important: tool rotation rate (ω, rpm) in clockwise or counterclockwise direction and tool traverse speed (v, mm/min) along the line of joint. The rotation of tool results in stirring and mixing of material around the rotating pin and the movement of tool makes the stirred material move from the front to the back of the pin and finishes welding process. Higher tool rotation rates generate higher temperature because of higher friction heating and result in more intense stirring and mixing of material.

Tool geometry is the most influential aspect of process development. The tool geometry plays a critical role in material flow and in turn governs the traverse rate at which FSW can be conducted. An FSW tool consists of a shoulder and a pin. The tool has two primary functions: localized heating and material flow. In the initial stage of tool plunge, the heating results primarily from the friction between a pin and a workpiece. Some additional heating results from deformation of material. The tool is plunged till the shoulder touches a workpiece. The friction between the shoulder and a workpiece results in the biggest component of heating. From the heating aspect, the relative size of a pin and a shoulder is important, and the other design features are not critical. The shoulder also provides confinement for the heated volume of material. The second function of the tool is to ‘stir’ and ‘move’ the material. The uniformity of microstructure and properties is governed by the tool design. Generally a concave shoulder and threaded cylindrical pins are used.

The most convenient joint configurations for FSW are butt and lap joints. Two plates or sheets with the same thickness are placed on a backing plate and clamped firmly to prevent the abutting joint faces from being forced apart. During the initial plunge of the tool, the forces are fairly large and extra care is required to ensure that the plates in butt configuration do not separate. A rotating tool is plunged into the joint line and traversed along this line when the shoulder of the tool is in intimate contact with the surface of the plates, producing a weld along abutting line [3].

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