International Journal of Enhanced Research in Science Technology & Engineering, ISSN: 2319-7463
Vol. 3 Issue 10, October-2014, pp: (172-176), Impact Factor: 1.252, Available online at: www.erpublications.com

Friction Stir Welding: Review

Priti Tanwar[1], Dr. Vineet Kumar[2]
[1]M. Tech. Scholar, U.I.E.T, MDU Rohtak, Haryana, India
[2]Professor, Mechanical Engg., U.I.E.T., MDU Rohtak, Haryana, India

Abstract: Friction stir welding (FSW) is a relatively new joining process that has been used for high production since 1996. Because melting does not occur and joining takes place below the melting temperature of the material, a high-quality weld is created. In this paper working principle and various factor affecting friction stir welding is discussed.

Keywords: Friction stir welding, tool material, working principle, application and limitations.

FRICTION STIR WELDING (INTRODUCTION)

In late 1991, a very novel and world beating welding method was conceived at TWI (The Welding Institute) in the UK that specializes in materials joining technology. This process is suitably named friction stir welding. Friction Stir Welding is a solid-state process, which means that the base materials to be joined do not melt during the joining process which is used where the original metal characteristics must remain unchanged as much as possible. It works by mechanically intermixing the two pieces of metal at the place of the join, transforming them into a softened state that allows the metal to be fused using mechanical pressure.

The friction stir process involves a rotating cylindrical tool which translates along the interface between two plates. Due to Friction between workpiece and tool, frictional heat will generate which enhances the material to soften without melting under mechanical pressure. The weld is formed by the deformation of the material at temperatures below the melting temperature. The simultaneous rotational and translational motion of the welding tool during the welding process creates a characteristic asymmetry between the adjoining sides. On one side, where the tool rotation is with the direction of the translation of the welding tool is known as the advancing side, whereas on the other side, the two motions, rotation and translation counteract and is known as the retreating side.

WORKING PRINCIPLE

In Friction stir welding, the cylindrical tool is clamped on the rotation spindle of the friction stir welding machine. And the work piece plates are to be securely clamped on a fixture in a manner that prevents the joint faces from being forced apart. Then the rotating tool is slowly plunged between the parting line of the two plates that need to be weld. The friction between rotation tool and the work piece produces frictional heat which softens the work piece material without reaching its melting point. The friction heat also helps the tool to move along the weld line during welding. The maximum temperature reached is of the order of 0.8 of the melting temperature of the material. The plasticized material is transferred to the trailing edge of the tool pin and is forged by the intimate contact of the tool shoulder and the pin profile. The process can be regarded as a solid phase keyhole welding technique because a hole to accommodate the probe is generated, which can be filled during the welding sequence. The working principal of friction stir welding is shown in figure 1.1.

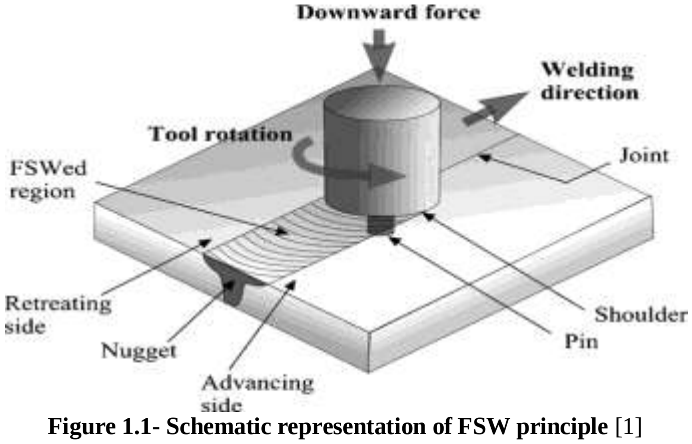

Figure 1.1- Schematic representation of FSW principle [1]

TOOL MATERIAL

In friction stir welding the welding is done by thermo-mechanical deformation process where the tool temperature approaches the solidus temperature of base metal. Welding is carried out around 70 – 90% of the material melting point so it is important that the tool material has sufficient strength at this temperature otherwise the tool can twist and break. Thus, it is undesirable to have a tool that loses dimensional stability, the designed features, or worse, fractures [2].

The following characteristics have to be considered for material choice:

- Ambient and elevated temperature strength
- Elevated temperature stability
- Wear resistance
- Tool reactivity
- Fracture toughness
- Coefficient of thermal expansion
- Machinability.

A FSW tool may be made out of a number of different materials like steel, polycrystalline cubic boron nitride (PCBN), W based tools, Ni-alloys etc. For this research, a tool made of high carbon steel with heat treatment and oil quenched is used.

MICROSTRUCTURE CLASSIFICATION

All the micro-structure investigation is basically consist of four distinct regions in the welding zone. The micro structure zone of AA 5083 is shown in figure 1.3.

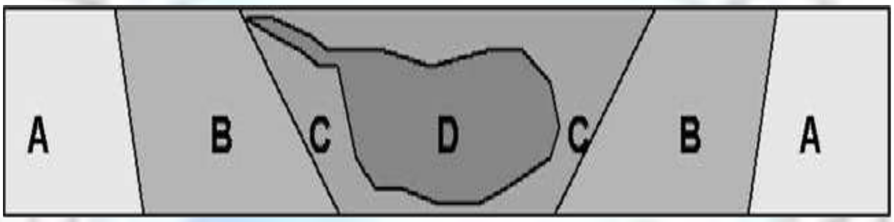

Figure 1.3 Cross-section of a FSW joint of AA 5083 [3]

The system divides the weld zone into distinct regions as follows:

A. Unaffected material (Base material)
B. Heat affected zone (HAZ)
C. Thermo-mechanically affected zone (TMAZ)
D. Weld nugget (Part of thermo-mechanically affected zone)

Unaffected material or parent metal (A)
This is material remote from the weld, which has not been deformed, and it is that part of the material which is not affected by the weld heat in terms of microstructure or mechanical properties.

Heat affected zone (B)
This region clearly lies closer to the weld centre. In this region the material has experienced a thermal cycle, which has modified the microstructure and/or the mechanical properties.but, there is no plastic deformation takes place in this area.

Thermo-mechanically affected zone (C)
In this region, the material has been plastically deformed by the tool, and the heat from the process will also affects the properties of the material as well microstructure. In the case of aluminium, it is possible to get significant plastic strain without recrystallization in this region, and there is generally a distinct boundary between the recrystallized zone and the deformed zones of the TMAZ. But in other materials, the distinct recrystallized region (the nugget) is absent, and the whole of the TMAZ appears to be recrystallized.

Weld nugget (D)
The recrystallized area in the TMAZ is known as the weld nugget. It is the area immediately below the tool shoulder (which is clearly part of the TMAZ) should be given a separate category, as the grain structure is often different here. It is suggested that this area is treated as a separate sub-zone of the TMAZ.

International Journal of Enhanced Research in Science Technology & Engineering, ISSN: 2319-7463
Vol. 3 Issue 10, October-2014, pp: (172-176), Impact Factor: 1.252, Available online at: www.erpublications.com

FACTORS AFFECTING WELD QUALITY

Type of metal

The weld quality is greatly depends on the type of metal on which welding is to be done. Friction Stir Welding is most suitable for the Aluminum alloys. However it can be used for the welding of other materials like: Copper and its alloys, Lead, Titanium and its alloys, Magnesium and its alloys, Zinc, Plastics, Mild steel etc.

Angle of tool

During Friction Stir Welding, the weld quality is also depends on the angle of the tool with respect to the workpiece. Generally the angle remains 90^0 but in some cases there can be at variation of up to 3^0.

Traversing speed of the tool

The Joint characteristics are also depends on the traversing speed of the tool. That means the speed with which the tool travels on workpiece in forward direction. Different traversing speed of tool varies the heat input in the work-piece during welding. Tool's translation speed can be controlled easily.

Tool rotation speed

Tool rotation speed of tool is the speed of rotation of the tool along its axis. It is a significant parameter in friction stir welding. Different tool rotation speed also varies the heat input in the work-piece during welding. It is measured in rpm.

Pressure applied by the tool

The download pressure applied between tool and work piece is also considered as important parameter in friction stir welding. The downward pressure is applied to maintain contact between tool and workpiece.

Tool pin length

This is very important factor to determine the joint characteristics. The length of pin should be slightly less than the thickness of the workpiece. So the length of tool pin can also be considered as a important parameter in friction stir welding.

Tool pin diameter

Tool pin diameter is used to produce friction heat during welding and it stirs the material during welding. So the tool pin diameter is an important parameter in friction stir welding. Higher the tool pin diameter higher will be friction heat in the weld zone.

Type of tool pin

Various types of tool pin profile can be used during the friction stir welding. And various tool shapes affects the weld joint quality.
Commonly tool pin shapes which can be used are cylindrical, square, trapezoidal and cylindrical with threads etc.

Shoulder diameter

The tool shoulder diameter is used to produce additional heat in welding and also cap the plasticized material as it "stirred. Tool shoulder diameter also affects the weld quality. Because higher the tool shoulder diameter bigger will be the weld zone.
Research is going on to combine the above factors in order to control the process in a better way.

ADVANTAGES OF FSW

This is clear and environment protective process because of not having negative subjects such as arc formation could be caused industrial accident, radiation, releasing of toxic gas or harmful laser beam for humanbeing eyes. Other advantages are as follows:

- The process is environment friendly since no fumes or spatter is generated and no shielding gas is required.
- A non-consumable tool is used.
- Since the weld is obtained in solid phase, gravity does not play any part and hence the process can be done in all positions (vertical, horizontal, overhead or orbital).
- No grinding, brushing or pickling is required.
- Since the temperature involved in the process is quite low, shrinkage during solidification is less.
- No fusion or filler material is required.
- No oxide removal necessary as in fusion welding.

- The weld obtained is of superior quality with excellent mechanical properties and fine micro structure.
- The process is cost effective since mechanical forming after welding can be avoided.
- dissimilar metals can be welded
- Automation is possible.

APPLICATIONS OF FSW

Shipbuilding and marine industries

The shipbuilding and marine industries are two of the first industry sectors which have adopted the process for commercial applications. The process is suitable for the following applications:

- Panels for decks, sides, bulkheads and floors.
- Aluminium extrusions.
- Hulls and superstructures.
- Marine and transport structures.
- Masts and booms, e.g. for sailing boats. .

Aerospace industry

At present the aerospace industry is welding space vehicle parts by friction stir welding. Longitudinal butt welds and circumferential lap welds of Al alloy fuel tanks for space vehicles have been friction stir welded and successfully tested. The friction stir welding process can therefore be considered for:

- Wings, fuselages, empennages.
- Cryogenic fuel tanks for space vehicles.
- Aviation fuel tanks.
- External throw away tanks for military aircraft.
- Military and scientific rockets.
- Repair of faulty MIG welds.

Railway industry

The commercial production of high speed trains made from aluminium extrusions which may be joined by friction stir welding has been published. Applications include:

- High speed trains
- Rolling stock of railways, underground carriages, trams
- Railway tankers and goods wagons
- Container bodies

Land transportation

The friction stir welding process is currently being experimentally used by several automotive companies and suppliers to this industrial sector for its commercial application. Potential applications are:

- Engine and chassis cradles
- Wheel rims
- Truck bodies
- Tail lifts for lorries
- Mobile cranes
- Fuel tankers
- Buses and airfield transportation vehicles
- Motorcycle and bicycle frames

Construction industry

The use of portable FSW equipment is possible for:

- Aluminium bridges
- Facade panels made from aluminium, copper or titanium
- Window frames
- Aluminium pipelines
- Aluminium reactors for power plants and the chemical industry

- Heat exchangers and air conditioners
- Pipe fabrication

Electrical industry

The electrical industry shows increasing interest in the application of friction stir welding for:

- Electric motor housings
- Bus bars , Electrical connectors
- Encapsulation of electronics

Other industry sectors

Friction stir welding can also be considered for:

- Refrigeration panels
- Cooking equipment and kitchens and furniture
- Gas tanks and gas cylinders, connecting of aluminium or copper coils in rolling mills

LIMITATIONS

- Welding speeds are moderately slower
- Work pieces must be rigidly clamped
- Keyhole at the end of each weld
- Requirement of different length pin tools when welding materials of varying thickness.

REFERENCES

[1]. P. Cavalierea, R. Nobilea, F.W. Panellaa, A. Squillace. Mechanical and microstructural behaviour of 2024–7075 aluminium alloy sheets joined by friction stir welding.International Journal of Machine Tools & Manufacture 46 (2006) 588–594.

[2]. Scialpi, L.A.C. De Filippis, P. Cavaliere. Influence of shoulder geometry on microstructure and mechanical properties of friction stir welded 6082 aluminium alloy. Materials and Design 28 (2007) 1124–1129.

[3]. P. Cavaliere, G. Campanile, F. Panella, A. Squillace. Effect of welding parameters on mechanical and microstructural properties of AA6056 joints produced by Friction Stir Welding. Journal of Materials Processing Technology 180 (2006) 263–270.

[4]. T4 S.T. Amancio-Filho, S. Sheikhi,J.F. dos Santos, C. Bolfarini. Preliminary study on the microstructure and mechanicalproperties of dissimilar friction stir welds in aircraft aluminium alloys 2024-T351 and 6056- journal of materials processing technology 206 (2 008) 132–142.

[5]. P. Cavalierea, R. Nobilea, F.W. Panellaa, A. Squillace. Mechanical and microstructural behaviour of 2024–7075 aluminium alloy sheets joined by friction stir welding.International Journal of Machine Tools & Manufacture 46 (2006) 588–594.

[6]. P. Cavaliere, M. Cabibbo, F. Panella, A. Squillace. 2198 Al–Li plates joined by Friction Stir Welding: Mechanicaland microstructural behavior. Materials and Design 30 (2009) 3622–3631.