FRICTION STIR WELDING PROCESS: A GREEN TECHNOLOGY

ALTAMASH ZAFAR[1], DHANANJAY SINGH[2]

[1]P.G, Student, Department of Mechanical Engineering, KIT Kanpur, AKTU, U.P India
[2]Assistant Prof., Department of Mechanical Engineering, KIT Kanpur, AKTU, U.P India

---

ABSTRACT: Friction stir welding (FSW) is a solid state welding process invented and patented by the Welding Institute (TWI) in the UK in 1991 for butt and lap welding of metals and plastics. This article highlights the advantages of the friction stir welding process as a green and energy efficient technology process in the field of welding. Compared to other conventional welding processes, its advantages, typical applications and use in joining similar and different materials are also presented.

Keywords: Dissimilar materials, Friction Stir Welding, Green technology, similar materials.

I. INTRODUCTION

Friction stir welding (FSW) is considered the most important development in assembly during the last two decades. FSW was invented and validated by Dr Wayne Thomas and his team in 1991 at the Welding Institute (TWI), UK, as a solid state joining technique. FSW has become increasingly popular in applications in the aviation, manufacturing, electrical and automotive industries due to the energy efficiency, environmental friendliness and safety and versatility of the FSW technique [1]. The number of applications is expected to grow exponentially as manufacturers discover the ease of application and the ownership benefits attributed to FSWs. The FSW process is remarkably simple, but it does involve thermal dynamics and material flow. Many weld configurations can be achieved using the FSW process. The FSW process involves dipping a non-consumable tool between the butt edges of the two butt weld plates, crossing the tool along the parting line (at a predetermined rotational speed and feedrate), and at the end , the tool is removed from welding. The fundamental difference between conventional welding techniques and solid state friction welding (FSW) technique is that no heat is added to the "system"; instead, heat is generated inside by friction between the tool-material interfaces, resulting in plastic deformation of the material around the hustle and bustle area.

The tool is the fundamental component of friction stir welding (FSW) and has evolved empirically based on observations of forces, weld defects, rotational speeds, transverse speeds, and material flow [2]. Attributes of the tool that the characteristics of an FSW joint are the diameter of the shoulder and the size of the pin (length, thickness and shape). Since its invention, the process has continued to improve and its field of application has expanded. The relative movement between the tool and the substrate generates frictional heat that creates a plasticized region around the submerged part of the tool and the shoulder of the tool prevents the plasticized material from being forced out of the weld, forcing the material plasticized to be mixed behind the tool to form a solid phase seal. A diagram of the process is shown in Figure 1.

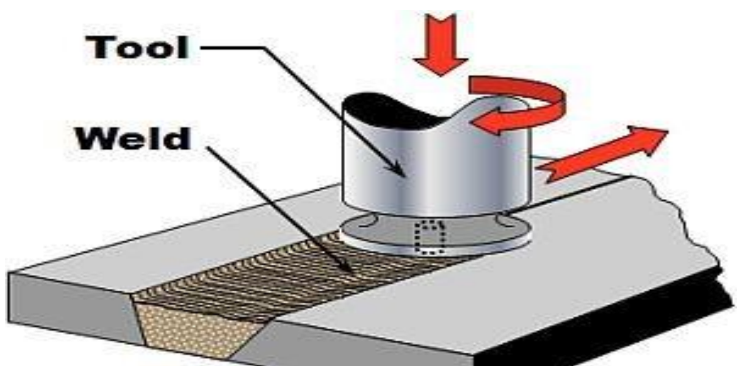

Fig. 1 Schematic diagram of the Friction Stir welding Process [3]

TABLE I

BENEFITS OF THE FSW PROCESS [4]

Metallurgical benefits	Environmental benefits	Energy benefits
1. Solid– phase process. 2. Low distortion. 3. Good dimensional stability and repeatability. 4. No loss of alloying elements. 5. Excellent mechanical properties in the joint area. 6. Fine recrystallized microstructure. 7. Absence of solidification cracking. 8. Replaces multiple parts joined by fasteners.	1. No shielding gas required for materials with low melting temperature. 2. Minimal surface cleaning required. 3. Eliminates grinding wastes. 4. Eliminates solvents required for degreasing. 5. Consumable materials saving. 6. No harmful emissions.	1. Improved materials use (e.g. joining different thickness) allows reduction in weight. 2. Only 2.5% of the energy needed for a laser weld. 3. Decreased fuel consumption in lightweight aircraft, automotive, and ship applications.

Friction stir welding (FSW) can be considered a green technology, as no gas is released during the process. Furthermore, no toxic fumes or fumes are produced during or after the welding process. The process is energy efficient and environmentally friendly. Compared to other conventional fusion welding methods, FSW offers many advantages: the benefits of the process in terms of metallurgy, environment and energy savings are shown in Table I.

TYPICAL APPLICATIONS OF FRICTION STIR WELDING

FSW is becoming the choice of many industries for structurally demanding applications, as the process lacks severe distortion. Currently, FSW is used to bond similar and different alloys in shipbuilding, maritime industries, aerospace, railway industries, container and fuel tank industries. Replacing stationary joints with friction stir welded lap joints has been found to result in significant weight reduction and cost savings for many industries and weight savings can be achieved by eliminating fasteners. Cost savings can be achieved by reducing design, manufacturing, assembly and maintenance times, and by improving corrosion performance by eliminating fasteners as a source of contact with different metals [6]. In addition, the technology offers a significant advantage for the aluminum industry; and car suppliers are already using the technique for tires and suspension arms. The rail industry is also not left out with the rapid development of high-speed wagons. The FSW process was used to manufacture high-quality seals on the car body, windows, side walls, and coupling gears [7]. The use of the robot in FSW is also becoming popular. Typical applications of the FSW process are shown in Table II.

TABLE II

TYPICAL APPLICATIONS OF FSW [PARTIALLY ADAPTED FROM SMITH ET AL)

Industry category	Specific applications	Present process	Advantages of using FSW
Electrical	Heat sinks – welded laminations	Gas Metal Arc Welding (GMAW)	Higher density of fins – better conductivity.
Electrical	Cabinets and enclosures	GMAW	Reduced cost, weld through corrosion coatings.

Batteries	Leads	Solder	Higher quality.
Military	Shipping pallets	GMAW	Reduced cost
Extrusions	Customized extrusions	Not done today	Can be customized to reduce need for large presses.
Boats and ship building	Keel, tanks and the hull	Rivets and GMAW	Stronger, Less Distortion
Golf Cars, Snowmobiles	Chassis, Suspension	GMAW	Less distortion, better fatigue life properties.
Tanks, Cylinders	Fittings, Long & Circumferential Seams	GMAW	Higher quality - less leaks, higher uptime.
Aerospace	Floors, wing and fuselage.	Rivets	Higher quality, cheaper (no rivets and holes).
Automotive	wheel rims and suspension arms	GMAW, MIG	Better joint integrity.
Rail industry	Rail car body, window, side wall and coupling gears	GMAC	High quality joints

The next section in this paper highlights some successful joining of similar materials using the FSW process.

FRICTION STIR WELDING OF SIMILAR MATERIALS

FSW has been used successfully to weld similar materials. Numerous investigators [8-10] have reported research studies conducted on friction butt welds of similar aluminum alloys in which process windows have been established and successfully applied in industry. Similar copper plates have also been friction stir welded by Sun and Fujii; and Hwang et al [11], the appropriate temperature and processing parameters were also achieved to join the copper plates. The magnesium plates were also assembled by friction stir welding by Suhuddin et al [12], good quality welds were produced and it was concluded that FSW has very good potential to join magnesium and its alloys. The next section of this article focuses on the application of FSW in the assembly of dissimilar materials.

FRICTION STIR WELDING OF DISSIMILAR MATERIALS

Research studies on friction and stir welding of dissimilar metals are hereby highlighted and featured. Yoshikawa [13] established a joint criterion for lap welding of different aluminum and stainless steel and Fukumoto et al [14] obtained good welding seam efficiency in different seams between steel and stainless steel, normal carbon (S45C) and alloy of 6063 aluminum. Another success Different assemblies using the FSW process include aluminum and brass from Esmaeili et al [15], aluminum and titanium from Wei et al [16]; Aluminum and magnesium by Yan et al [17] and magnesium and titanium by Aonuma and Nakata [18]. Akinlabi [19] has also reported satisfactory aluminum and copper welds with good joint integrations [19]. These studies revealed that there is great potential to successfully join dissimilar materials using the FSW process.

CONCLUSION

The friction stir welding process as a green technology has been reviewed, analyzed and presented. The metallurgical, environmental and energy advantages of the process over conventional arc welding processes were also presented. The process is becoming increasingly popular and is adopted by many industries. It can be concluded that FSW is green technology.

REFERENCES

1. Thomas WM, Nicholas ED, Needham JC, Murch MG, Templesmith P & Dawes CJ. (1991). Improvements relating to Friction Welding. International Patent Application. PCT/GB92/02203 (Patent).

2. Akinlabi E (2011). Characterisation of dissimilar friction stir welds between aluminium and copper. Lambert Academic Publishing.

3. Germany. ISBN 978-3-8443-9042-1. p. 12-17

4. Friction stirs welding process. www.engineering.und.edu/research/aemc/fswprocess.php Assessed on 8th June 2012.

5. Mishra RS & Mahoney MW. Introduction. In: Friction stir welding and processing. Mishra RS, Mahoney MW (ed.) Materials Park Ohio: ASM International; 2007.

6. Smith CB, Hinrichs JF & Ruehl PC (2012). Friction Stir and Friction Stir Spot Welding - Lean, Mean and Green. Available online from: www.frictionstirlink/Pub14AwssmcLeanMeanGreen-UnitedStates accessed on 30th July 2012.

7. Khaled T. An outsider looks at Friction stir welding. Federal Aviation Administration. Report number: ANM-112N-05-06, 2005.

8. Friction Stir Welding Products for industrial Applications. Available from: www.cfswt.com/en/uploadpic/2010102216396671.pdf accessed on 30th July 2012.

9. Lakshminarayanan A K, Malarvizhi, S & Balasubramanian V (2011). Developing friction stir welding window for AA2219 aluminium alloy. Transactions of Nonferrous Metals Society of China. 21, 2339-2347.

10. Xu WF, Liu JH, Chen DL, Luan GH and Yao JS (2012). Improvements of strength and ductility in aluminium alloy joints via rapid cooling during friction stir welding. Materials Science and Engineering A. 548, 89-98.

11. Zhang G, Su W, Zhang J, Wei Z and Zhang J (2010). Effects of shoulder on interfacial bonding during friction stir lap welding of aluminium thin sheets using tool without pin. Transactions of Nonferrous Metals Society of China. 20, 2223-2228.

12. Hwang YM, Fan PL & Lin CH (2010). Experimental study on Friction Stir Welding of copper metals. Journal of Material Processing Technology. 210, 1667-1672.

13. Suhuddin UFHR, Mironov S, Sato YS, Kokawa H & Lee CW (2009). Grain structure evolution during friction-stir welding of AZ31 magnesium alloy. Acta Materialia. 57, 5406-5418.

14. Yoshikawa K (2003). A joining criterion for lap welding of dissimilar metal materials of aluminium and stainless steel. 4th International FSW symposium, Park City, Utah. 14-16. TWI (UK). Retrieved: CD-ROM.

15. Fukumoto M, Yasui T, Shinoda Y, Tshubaki M & Shinoda T (2004). Butt welding between dissimilar metals by friction stirring. 5th International FSW symposium, Metz, France. 14-16. TWI (UK). Retrieved: CD-ROM.

16. Esmaeili A, Besharati Givi MK & Zareie Rajani HR (2011). A metallurgical and mechanical study on dissimilar Friction Stir welding of aluminium 1050 to brass (CuZn30). Materials Science and Engineering A. 528, 7093-7102.

17. Wei Y, Li J, Xiong J, Huang F Zhang F and Raza SH (2012). Joining aluminium to titanium alloy by friction stir lap welding with cutting pin. Journal of Material Characterization. 71, 1-5.

18. Yan Y, Zhang D, Qiu C & Zhang W (2010). Dissimilar frictions stir welding between 5052 aluminium alloy and AZ31 magnesium alloy. Transactions of Nonferrous Metals Society of China. 20, 619-623.

19. Aonuma M & Nakata K (2012). Journal of Materials Science and Engineering B. 177, 543-548.

20. Akinlabi ET (2012). Effect of shoulder size on weld properties of dissimilar metal friction stir welds. Journal of Materials Engineering Performance. DOI: 10.1007/s11665-011-0046-6. 21, 1514-1519.

BIOGRAPHIES

ALTAMASH ZAFAR
P.G Student,
Department of Mechanical Engineering,
KIT Kanpur AKTU, U.P India.

DHANANJAY SINGH
Assistant Prof., Department of Mechanical Engineering,
KIT Kanpur AKTU, U.P India.