International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 5 Issue 12 ǁ December. 2017 ǁ PP. 23-27

Friction Stir welding Technology

[1]Zhao Hanwen,[2]Zhang Liqiang
College of Mechanical Engineering, Shanghai University of Engineer Science, 201620, China
Corresponding Author: [1]Zhao Hanwen

ABSTRACT: Since it was invented in the early 1990s, friction stir welding (FSW) has come through simple testing stage both at home and abroad, and it is a solid-state welding technology which has replaced the fusion welding technology. The paper briefly introduces the working principle and characteristics of this welding technology. The applications of the friction stir welding technology in the field such as aerospace, shipbuilding, land transportation was described in the paper. And at the end of the paper, the development trend of friction stir welding is predicted. The FSW technology is mainly applied to the joining of light metal like aluminum alloy, magnesium alloy, etc. Meanwhile, it developed into some new technique study based on the welding technology, for example, Surface Modification, Friction Stir Spot Welding (FSSW), etc. These are the important development direction as well.

Keywords: Friction Stir Welding; working principle; characteristic; application

---

Date of Submission: 04-12-2017 Date of acceptance: 18-12-2017

I. Introduction

Friction Stir Welding (FSW) is the patented welding technology invented by The Welding Institute (TWI) in 1991[1,2]. FSW is a new solid-phase welding technology, first and mainly for the aluminum alloy, magnesium alloy and other light metal structure, steel, titanium alloy and other material of high melting point also has a certain development. At the same time, on this basis, a lot of derivative technology, such as friction plug welding, friction spot welding and surface modification and fine crystal material preparation technology [4]. Friction stir welding break through the conception that the friction welding is limited to the material welding of circular cross section. Since FSW is invented, scholars and research institutions around the world have paid extensive attention to this and carried out in-depth and meticulous research, in many areas it has been successfully applied, which has become a gradually mature welding technology.

II. Working Principle of FSW

Just as conventional friction welding, FSW is also make use of friction heat as a welding heat source. The difference is the welding process that a cylindrical pin is inserted into the joints of workpiece, and the tool is rubbed against the workpiece material by high-speed rotation of the tool so that the temperature of the material at the connection site rises and is softened. Meanwhile, the material is stirred and rubbed to complete the welding. The welding process is shown in Fig.1.

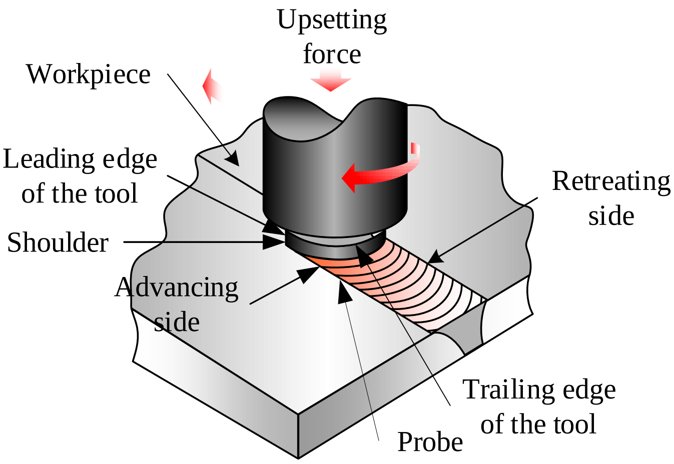

Fig.1 Schematics of the FSW principle

When welding the workpiece is rigidly fixed on the backplate, the tool begins to move along the welding seam under the high-speed rotation. The pin is inserted into the material for friction and stir. The shoulder is rubbed against the surface of the workpiece and is used to avoid spillage of the plastic material and serves to remove the oxide film on the weld boundary. During the welding process, the pin is rotated and inserted into the joint of the workpiece. The friction heat between the shoulder and the workpiece causes a strong plastic deformation of the material at the leading edge of the tool. As the tool moves, the material of highly plastic deformation gradually flows to the trailing edge of the tool, forming a friction stir welding seam. The requirements of friction stir welding equipment are not high, a milling machine can also achieve the rotation and movement of the tool. However, the rigidity requirements for welding equipment and fixtures are high. It should be noted that the end of the friction stir welding in the end will form the keyhole. A telescopic tool has been successfully developed for keyhole problems, and post-welding will not leave the keyhole. In addition, the movement of interface atoms in the welding process is still in the research stage.

2.1 Technological Process of FSW

Technological Process of FSW can be divided into four stages: rotation, insert, weld, leave. The tool is rotated and started to be inserted into the workpiece at a certain speed. For a period of time, the joint material near the tool gets sufficient heat input to produce softening deformation and a little material is squeezed to the outside of the joint. At this point the material can be welded, welding thermoplastic material continues to shift back, and under the action of a certain forging pressure, the material and the surrounding material are firmly diffusion bonded; When the welding is completed, the tool is away from the surface of the workpiece at a certain speed, the welding process is over [5]. The temperature of welding process is always below the melting point, and the material will not melt, which avoids the defects of fusion welding process caused by the existence of melting - solidification phenomenon. As a solid-phase welding, the softened material of FSW joint will form a firm forged fine grain structure because of the extrusion.

2.2 Microstructure distribution of FSW joints

Through the metallographic analysis and microhardness analysis of the FSW welded joint, it can be found that the weld structure of the FSW joint can be divided into four regions (Fig. 2): a zone is the base metal zone, which has no heat effect and no deformation; b zone is the heat affected zone (HAZ), which has no plastic deformation, but this zone is affected by the heat transferred from the welding nuclear zone; c zone is the thermo-mechanically affected zone (TMAZ), which has a serious plastic deformation; d zone is the welding nugget zone (WNZ), which is the zone closest to the shoulder, the structure of the microstructure will usually have a greater change.

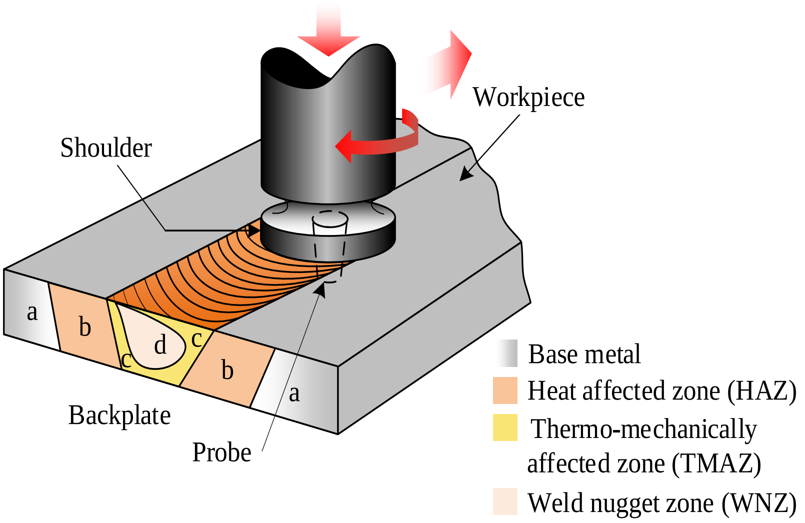

Fig.2 Microstructure distribution of FSW joints

2.3 Factors of affecting FSW

Friction stir welding process is complex, and many factors affect the stability of the welding process and welding quality, including the shape and position of the tool, spindle speed, welding speed and joint accuracy, etc. Table 2-1 lists the main factors that affect FSW and their content points.

Tab.1 Technological factors of FSW

Technological factors	Content
Shape of the tool	Length of the pin: approximately equal to the base metal thickness Shape of the pin: to fit different materials, thickness Angle of the tool: a certain inclination
Position of the tool	Insertion depth of the pin: about the workpiece thickness Position of the centerline: just in the weld centerline Shoulder: contact degree
Joint accuracy	The joint gap is recommended for 0 mm gap Material extrusion processing accuracy, joint processing accuracy are important factors to avoid defects.
Spindle speed	According to the workpiece thickness, the shape of the tool Output power of the motor, stiffness Spindle speed is generally hundreds - thousands of revolutions per minute
Welding speed	Welding speed is selected according to the spindle speed Welding speed of 60~150 mm/min [6], the same as the arc welding
Fixation of the workpiece	In order to ensure the joint accuracy, dedicated fixture design is very important.

III. Characteristics of FSW

3.1 Advantages of FSW

As a new welding method, compared with the traditional method, the advantages of friction stir welding is very much.

(1) Low cost. It is a simple, efficient, energy-saving, non-consumable welding method. There is no other consumption except the tool and electric power; It doesn't need filling material and protective gas; There is no need opening the groove, and there is no need for special treatment of the surface before welding; Requirements of the joint shape, clearance, cleanliness is not too high; It's easy to achieve automation and mass production.

(2) FSW is suitable for the welding of strongly thermal-sensitive and dissimilar materials. For aluminum alloy materials, excellent FSW solid-phase joints, the welding process of high reliability and repeatability can promote the improvement of existing industrial products; Strongly thermal-sensitive duralumin and other materials can be welded; There are no pores, cracks and other defects; It's easier to achieve the welding of dissimilar materials, for example, aluminum alloy and stainless steel.

(3) FSW can complete the welding of a longer weld, a larger cross section and different positions. FSW doesn't rely on the friction between the two workpieces to carry out welding, changing the limitations of welding a simple section, and expanding the application range.

(4) High quality

· It is not easy to produce defects, and joint performance is good. The maximum temperature generated by the FSW is generally less than 80% of the melting point of the material [7], which avoids the cracks, pores, shrinkage and other defects caused by the fusion welding. Furthermore, The grain structure of weld metal is much smaller than that of the base metal, and the strength is beyond the strength of heat affected zone. The composition of the alloy isn't changed, so the mechanical properties of the joint are good, especially in the anti-fatigue aspects.

· Post-weld Small deformation. As the welding temperature of the FSW is low, there is no large-scale thermoplastic deformation, the residual stress of the post-weld joint is small, and the deformation is also small, which can basically achieve the welding of low stress and small deformation [3].

· FSW is a purely mechanical welding technology that enables precise control of the process and energy input. Welding quality of FSW is entirely decided by the shape of tool and welding parameters, and it can achieve strict process monitoring; As the welding process is mechanical, it is possible to realize the digital input and control of the welding parameters.

(5) Safety. We only need to carry out the operation of ordinary machine equipment protection; Compared with the fusion welding method, the FSW process has no splashing, dust, arc radiation and other hazards to the body.

3.2 Existing problems

After the people's tireless efforts, in the applications of FSW, the restrictions gradually narrowed, but due to the limitations of the welding principle, it still has the following questions: (1) FSW needs to exert a huge upsetting pressure, limiting the applications of the technology in robot and other aspects; (2) Due to the post-weld withdrawal of the tool, the weld terminal usually left the keyhole, which can be eliminated by adding "lead plate" or "solder plate"; (3) The workpiece needs to have a certain structure rigidity. Workpiece must be clamped when welding, and needs to add a welding plate on the back of the weld; (4) FSW requires strict control of the unfitness and gap size of the joint. In addition, there are problems such as the tool wearing too fast and no wire welding.

III. APPLICATIONS OF FSW

Friction stir welding has been applied to aluminum alloy, magnesium alloy and other materials on a large scale. Here are some typical examples.

4.1 Applications of FSW in foreign countries

Friction stir welding is regarded as a preferred welding technology of the light alloy materials, which has been from the technique study to a higher level of engineering applications, forming a new industry. In the American aerospace manufacturing, Nordic shipbuilding, Japanese high-speed train manufacturing and other fields, the applications of FSW are quite extensive.

4.1.1 Applications of FSW in Aerospace

The aluminum alloy, titanium alloy and other light alloy materials can be widely used in order to reduce the weight of aircrafts and launch vehicles. The FSW will have a revolutionary impact and breakthrough on the aluminum alloy and other light alloy materials as a new type of welding technology [5]. Its application in aerospace is mainly in the following aspects: wings, fuselages, aircraft fuel tanks, aircraft external fuel tanks, launch vehicles, space shuttles' low temperature fuel tubes and so on. In the aircraft manufacturing, FSW can replace more than 60% of the riveting so as to reduce the weight of the aircraft.

4.1.2 Applications of FSW in Shipbuilding

Friction stir welding is firstly used in shipbuilding. Its first application example is a hollow aluminum plate used as a frozen handle on fishing vessels. The post-weld small deformation and high repeatability make the FSW become the preferred method of welding this kind of plates. In shipbuilding, FSW technology has a wide range of applications: decks, shells, helicopter landing platform, offshore water observation stations and so on.

4.1.3 **Applications** of FSW in Land Transportation

With the further study of FSW technology, its application potential in land traffic has gradually emerged. It is mainly used in high-speed trains, subway cars and tramcars, etc. At the same time, the automotive applications of FSW include the engines, chassis, body brackets, wheels and fuel tank, etc. [8] The development of friction stir spot welding (FSSW) has become a new hotspot in automobile manufacturing industry.

4.1.4 Applications of Friction stir welding in other industries

FSW effectively solves the welding problem of light alloy. The applications are more extensive in the construction, power and other industries. In the construction industry, FSW is mainly used for welding aluminum alloy bridge, aluminum alloy, copper alloy decorative panels and frames of doors and windows. In the power industry, the applications of FSW mainly include engine shells, electrical package, etc. In the household appliance industry, FSW is mainly used for refrigerator heat sink, natural gas, liquefied petroleum gas storage tanks, metal furniture, and so on.

4.2 Applications of FSW in China

In 2002, the Beijing Aeronautical Manufacturing Engineering Technology Research Institute (BAMTRI) and the Welding Institute (TWI) jointly signed the cooperative agreement on the FSW patent technology licensing, technology R&D, market development and other aspects. On this basis, China FSW center was established, marking the official opening of FSW technology in the Chinese market R&D and applications. Since the center established, some progress has made in the FSW equipment and process research and development.

As a new interdisciplinary technology, FSW can develop a variety of welding technologies such as girth welding, self-supporting double-sided welding, three-dimensional surface welding. After more than 10 years of development, China FSW Center has successfully developed a lot of FSW equipment, which has used the technology in Chinese aviation, aerospace, ships, etc. The center has gained considerable economic benefits, which not only provides a good solution for the welding of aluminum alloy, magnesium alloy, copper alloy and other materials, but also provides the FSW products for users, including astronautic cylinder structures, aeronautic thin-walled structures, the ship's wide strip plates and so on.

At present, there are many domestic research institutes carrying out experimental research, and there is a certain initial application in conventional aluminum alloy sheet and the profile of low connection requirements [9]. Central South University and other units have made a basic research on the friction stir welding of thick plates, and used 2000, 7000 series of high-strength aluminum alloy and super-hard aluminum alloy 7A52 to do FSW experiments. The experimental results are good.

IV. CONCLUSIONS

The mechanism study of FSW technology is always an important issue. Mechanical properties, failure mechanism, non-destructive testing and other research of the FSW joint are the basis of promoting the use of friction stir welding. Friction plug welding, friction spot welding and other technologies derive from the FSW technology. FSW technology is mainly used in aluminum alloy and other light metal materials, and FSW technology used in steel and other high melting point materials also gradually is laid out. The tool is the core of friction stir welding technology. Its development situation will directly affect the popularizations and applications of friction stir welding. It is important to develop a tool with sufficient strength and abrasion resistance for welding the materials which have higher melting point. In the future development, the increase of welding speed, surface welding will be the research direction of friction stir welding. In short, although the applications of FSW have just begun, and the theoretical research is slightly inadequate, the application range of FSW will become more extensive when the FSW technology continues to move forward.

ACKNOWLEDGEMENTS

The research is sponsored by the National Natural Science Foundation of China (No.51305254), and the Innovation Program of Shanghai Municipal Education Commission (No.13YZ108).

REFERENCES

[1]. Thomas W M, Nicholas E D, Needham J C, et al. Improvements relating to friction welding (TWI) [C]. European Patent Specification 0 615 480 B1.

[2]. Midling O T, Morley E J, Sandvik A. Friction stir welding (Norsk Hydro, rights transferred to TWI) [C]. European Patent Application 959 078 88.2.

[3]. Dawes C J, Thomas W M. Friction stir process welds aluminum alloys [J]. Welding Journal, 1996, 75(3): 41-45.

[4]. Luan Guohong, Chai Peng. Application Status and Development Trend of FSW[J]. Metal Working, 2008(24): 19-21.

[5]. Luan Guohong, Guo Delun, Guan Qiao, et al. Study on friction stir welding applied for aircraft manufacturing industry[J]. Aeronautical Manufacturing Technology, 2002(10): 43-46.

[6]. Liu Xiaowen, Yan Junhui, Du Suigeng. Friction stir welding technology of LY12 alloys[J]. Transactions of The China Welding Institution, 2001, 22(4): 55-57.

[7]. Wang Jianhua, Yao Shun, Wei Liangwu, et al. Thermal and thermo-mechanical modeling of friction stir welding[J]. Transactions of The China Welding Institution, 2000, 21(4): 61-64.

[8]. Huang Hua, Dong Shijie, Liu Jing. Application of friction stir welding in vehicle and watercraft manufacture[J]. Nonferrous Metal, 2006, 58(4): 22-25.

[9]. Zhang Tiancang, Guo Delun, Chen Qingang, et al. Aluminum alloys friction stir welding technology[J]. Chinese Journal of Mechanical Engineering, 2002, 38(2): 127-130.

[10]. Friction Stir Welding--the Most Revolutionary New Welding Technology. Exclusive Interview. Aeronautical Manufacturing Technology. 2003(11).

Hanwen Zhao received his BS degree from Hubei University of Engineering Science in 2013, China. He is currently a Master of mechanical engineering in Shanghai University of Engineering Science. His research interests include FSW, CAD/CAM/CNC, manufacturing automation and control. Liqiang Zhang received his PhD from Shanghai Jiaotong University in 2008, MS degree from Qingdao Technological University and BS degree from Shandong University, China. He is currently an associate professor of mechanical engineering in Shanghai University of Engineering Science. His research interests include CAD/CAM/CNC, manufacturing automation and control.

1Zhao Hanwen. "Friction Stir welding Technology." International Journal of Research in Engineering and Science (IJRES), vol. 05, no. 12, 2017, pp. 23–27.