Certain Investigation on the Failure of AA7075 Aluminum Alloy, Pure Aluminum Materials and Tools During the Process of Friction Stir Welding

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Abstract: Failure evaluation for base materials, namely AA7075 aluminum alloy and pure aluminum and tool material have been identified during the process of friction stir welding (FSW). Though the friction stir welding is considered as ideal for joining the nonferrous materials, it is difficult to avoid flaws in all materials particularly while using improper welding parameters. The flaws like insufficient penetration at the bottom of the weld and the pores are easily taken place when the materials are welded at a faster rate or welded with a small application of pressure. The present work aims to investigate the failure of base metal and tool material. Pure Aluminum metal and solution heat treated and artificially aged 7075 aluminum alloy has been friction stir welding and failures are investigated. A failure in the AA7075 alloy base metal is the result of welding with precipitate condition in which no fusion occurs in the base metal by using HSS tool. A failure in the pure Aluminum is due to lack of penetration of the tool and stirring effect. Welding with this condition leads to decrease the hardness and tensile strength. Torsion impact causes the failures in the tool materials.

Keywords: FSW, defects, FSW parameters, AA7075 alloy, a pure aluminu

I. INTRODUCTION

During the past decades, the solid state welding process, namely FSW has come into sight as new joining technique, mainly for welding high strength aluminum alloys. Because it is not so easy to weld these alloys by fusion welding process like GTAW, GMAW etc. Hence, The Welding Institute developed a new solid state welding process, namely FSW in 1991 [1].

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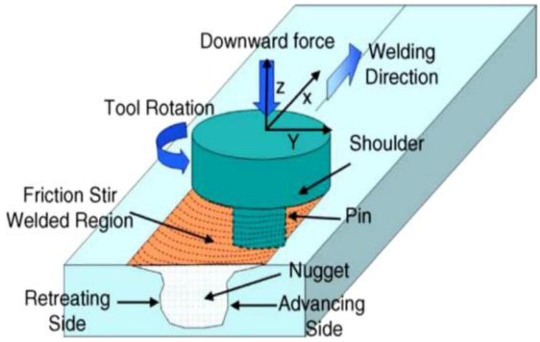

Fig.1 FSW [2]

The graphical representation of FSW is given in fig 1. The FSW is achieved by enforcing rotating tool into the base materials and pass in the length of the joint under suitable conditions. A heat will be generated in between the FSW tool and base materials which leads to plastic deformation. The heating between the tool and base material and the progress of material around the FSW tool pin leads to form the welded joint [3 and 4]. The progress of material around the FSW tool pin experience strong plastic deformation which results the formation of tiny grains, particularly at the center of the weld region [5]. This is known as a nugget. The FSW process parameters,viz, tool rotation / traverse speed, force, torque, tool material, tool design, workpiece material and thickness affect the progress of material around the FSW tool pin. Therefore, more attention should be given to those parameters to avoid such flaws in and around the nugget zone [6]. During frictional stir welding, the materials will be subjected to thermo-dynamical process like heating, cooling, deformation and progress of material. The FSW is a solid state welding process, joining takes place below the melting point, the defects like porosity, hot cracking will not appear. When the deformation resisting materials are joined by FSW, the sufficient quantity of heat energy will be supplied to facilitate the FSW process. But, this additional energy sometimes makes a situation to cause microstructural changes, viz, recystallization, grain orientation growth and coarsening. Hence, the FSW is susceptible to defect depends upon the process conditions (whether it is hot or cold) and also chemical composition [7]. Some defects like formation of voids or no proper bonding may take place due to insufficient material flow, which occurs because of cold processing conditions [8].

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On the other hand, the defects like flash formation, nugget collapse and reduction of joint strength may take place due to excessive material flow which occurs because of hot processing conditions [9]. Kissing bonds cracks may happen due to not having sufficient bonding of the materials [10].

The present work aims to investigate the failure of the base metal and tool material during friction stir welding.

II. EXPERIMENTAL WORK

The base material selected for this investigation is7075-T6 aluminum alloy and pure aluminum plate of 6 mm thickness, 50 mm wide and 100 mm length (Fig.2).

(a) pure aluminum

(b) AA7075 alloy

Fig. 2 Aluminum specimen

The pure aluminum contains 99.1% Al and AA7075 aluminum alloy having a composition of 5.6% Zn, 2.5 % Mg, 1.6% Cu, 0.23 Cr and rest Al. The milling machine was employed to carry out to make friction stir welded joint. The tool was made of Mild Steel (MS), Alloy steel EN31, High Carbon High Chromium (HCHCr) and High Speed Steel (HSS) with a shoulder diameter of 16 mm (Fig.3b). The HSS tool and pin has been is super finished just to know the friction effect. The pin is cylindrical, with a knurled tip; its dimensions were 6 mm diameter and 6 mm length. Dimension of the tool is shown in table 1.

Table 1 -Tool Dimensions

Tool	Shank diameter	Shoulder diameter	Pin diameter	Pin length
Size in mm	12	16	6	6

The tool surface was smooth in HSS and rough in HCHCr. The tool rotary motion and feed rate were 550 RPM and 200 mm / min selected throughout the experiments. In conventional welding the input parameter can be changed even after starting weld and can make a discontinuous weld. Whereas FSW once welding started, process parameter can be changed, but the process cannot be stopped. To maintain uniform thickness of friction stir zone, it is necessary to control the force depth of FSW tool. The force utilized in the current experiment is varied in pure aluminum to know the connection among welding parameter and flaws in the weld. The pressure is slightly less in one case and slight higher in another one.

In this present work, welding speed is constant throughout the process. The tool is rotating anticlockwise when it is viewed from top to make joints. After joining the specimen, characterization tests like Vickers micro hardness test, tensile test and Scanning Electron Microscope (SEM) were employed to measure hardness, tensile strength and reveal the microstructure respectively.

III. RESULTS AND DISCUSSIONS

Failure in the tool:

The failure in the hardened and tempered HCHCr tool pin occurs immediately after the stirring pin passed in the heat treatable aluminum alloy in the precipitated condition. The tool pin was broken and the broken tool pin of HCHCr lying inside the weld shows in fig.3a. Given relatively high pressure and speed leads to fail the base metal. Also, the failure takes place in the MS tool during friction stir welding (fig 3b and fig 3c).

Fig.3a

Fig.3b

Fig.3c

Fig. 3 Failure of base materials

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Failure in the base material

Fig.4 a (pure Al)

Fig. 4 b(A17075)

Fig.4 c (Al7075)

Fig. 4 d (Pure Al)

Fig. 4e (Al7075)

Fig. 4 d (Pure Al)

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Fig. 4 Failure of base materials

One type of failure takes place in pure aluminum is shown in fig.4a. This type of failure takes place when the base material AA7075 alloy is friction stirred with relatively very high smooth tool material like a fine finished HSS tool. The welding speed was 4 mm/Sec with the rotation speed at 550 RPM. This failure might have happened due to insufficient friction, heat and stirring effect to the base metal. Another failure of base materials is a rear end in failure as shown in fig.4b. This failure will happen owing to shortage of tool pin. The base material is prepared in such a way that it is 1 mm greater than the tool pin length. This rear end failure is owing to shortage of pin length, which fails to fuse the back side of the base metal. The hardened and tempered tool EN31 which is having a hard surface gives a relatively high friction and stirring effect. The heat generated by the tool must be maintained less than the eutectic temperature so that the formation of intermetallic compound can be avoided. Hence, the experiments were conducted with the feed rate of 3.4 mm/Sec and the rotary motion of the tool is 315 RPM. Based on the experimental it was found that pores are formed relatively high at about at one inch from starting point of weld (fig.4c). But, no pores were generated after some distance from the starting point with the same welding condition. At the beginning of weld there will be a discontinuity due to lack of heat generation and conduction in between the surface (fig.d). After some time heat will be stabilized and then there was a uniform bead. The Failure on the weld bead (fig. 4e) cannot be avoided one is burr on the base material surface. It is developed in between the end of the tool and top base material's surface. There is irregular formation of bead during welding of pure aluminum (fig.4f). The formation of such type of defect could be excessive stirring effected.

Though these defects happened during this welding, these flaws can be evaded if suitable welding parameters. Therefore, welding with appropriate parameters leads to flawless welded joints.

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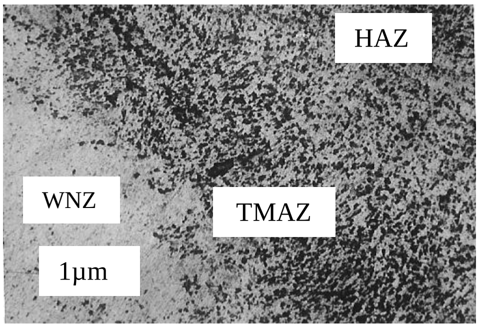
Microstructural examination



1μm

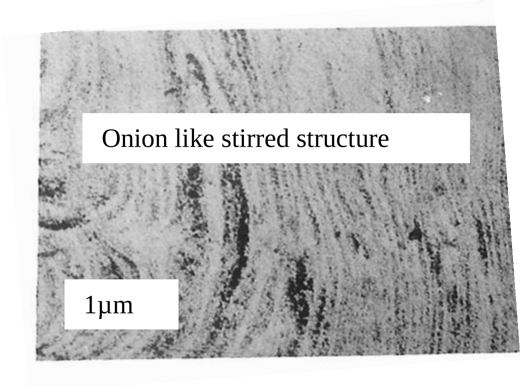


Fig.5 Microstructure of AA7075 alloy joint

The optical microscope with 100X magnification was employed to reveal the microstructure of welded joint (Fig. 5). The microstructure consists of different zones. The first important zone is the Weld nugget zone (WNZ) in which the tool pin deforms the base material plastically and dynamic recrystallization takes place. In this region, severe strain and high temperature promote fine dispersion, equiaxed grains. The next to the weld nugget zone is thermo-mechanically affected zone (TMAZ). This is the zone where the tool shoulder is directly in contact with the base material and the material is deformed plastically and at the same time dynamic recrystallization will not occur. Next to TMAZ is heat affected zone (HAZ). This zone generally does not experience any plastic deformation and undergo thermal treatment only. Finally, the unaffected zone is base metal (BM).

Another notable characteristic is the occurrence known as "onion rings". Onion rings are features of the microstructure represented in fig.5, where the process creates a noticeable circular geometry that resembles a sliced onion.

Hardness test

The Vickers micro hardness tester was used for measuring the micro hardness of welded samples. The values are plotted as shown in fig.6. The hardness of the welded region (TMAZ and WNZ) was decreased compared to other regions.

Hardness Vs Distance

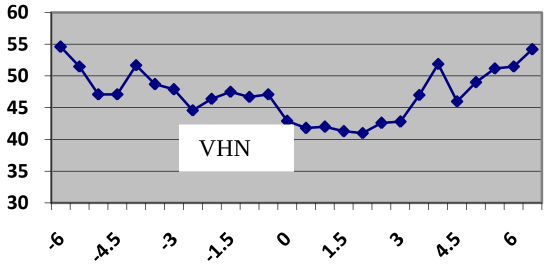


Fig. 6 Hardness distribution in various zones

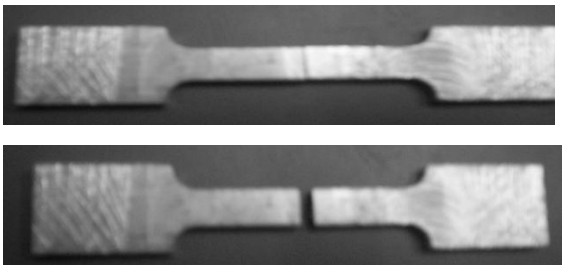
BM+HAZ TMAZ HAZ+BM
WNZ
TMAZ

Distance, mm

4.5 Tensile test

The transverse tensile test of pure aluminum base materials was performed according to ASTM standard (fig.7).

Fig. 7 Tensile test specimen before and after fracture



In friction stir welding, the strength of any area in the weld is determined primarily by micro-hardness and severity of defects in that area. The micro-hardness of pure aluminum alloy shows a weld zone "soft", where micro-hardness lowered than other zone and the presence of defects lead to lower tensile strength. The pure aluminium has a tensile strength of 173 MPa. After friction stir welding, the tensile strength was decreased to 110 MPa.

IV. CONCLUSION

The experiments conducted on pure aluminum alloy and solution treated and artificially aged 7075 alloy by FSW. Based on the experiments, it is concluded that:There was failure to bond the base metal in the precipitated heat treatable aluminum alloy (AA7075 alloy) due to the fine finished tool. Normally at the initial stage of welding about one inch, stirring is poor because heat obtained from stirring effect and after some length smooth weld bead produced up to the entire length. At the end there is an excess of stirring as a result of high heat input. And pores produced in the joints were comparatively higher in the initial stage than the end of the weld. Failure at the back end of the materials was due to the insufficient tool penetration. Tool material failure also considered in to account for failure analysis. Failure of the pin and the shank is owing to the torsional impact when it is welded the aluminium alloy at aged condition.

REFERENCES

1. Thomas, W.M., Nicholas, E.D., Needham, J.C., Murch, M.G., Temple Smith, P. and Dawes, C.J. Friction Stir Butt Welding. International Patent Application No. CT/GB92/02203, GB Patent Application No.9125978.8, UK Patent office, London, 1991.
2. S.Sheeba Rani, V.Gomathy and R.Geethamani, “Embedded design in synchronisation of alternator automation” in International Journal of Engineering and Technology(IJET) , Volume No.7, pp 460-463, April 2018
3. Grujicic, M., Arakere, G., Yalavarthy, H.V., He, T., Yen, C.F. and Cheeseman, B.A. Modeling of AA5083 material-microstructure evolution during butt friction stir welding. *Journal of Materials Engineering and Performance*, 19(5), 2010, pp.672–684.
4. Nandan, R., DebRoy, T. and Bhadeshia, H. Recent advances in friction stir welding process, weldment structure and properties. *Progress in Material Science*, 53(6), 2008, pp.980–1023.
5. Hassan, Kh.A.A., Prangnell, P.B., Norman, A.F., Price, D.A. and Williams, S.W. Effect of welding parameters on nugget zone microstructure and properties in high strength aluminium alloy friction stir welds. *Science and Technology of Welding and Joining*, 8 (4), 2003, pp.257-268
6. Crawford, R., Cook, G. E., Strauss, A. M., Hartman, D. A. and Stremler, M. A. Experimental defect analysis and force prediction simulation of high weld pitch friction stir welding. *Journal Science and Technology of Welding and Joining*, 11 (6), 2006, pp.657-665
7. Judy Schneider, Ronald Beshears. and Arthur C. Nunes. Interfacial sticking and slipping in the friction stir welding process. *Materials Science and Engineering A*, 435-436, 2006, pp.297-304
8. Elangovan, K. and Balasubramanian, V. Influence of pin and rotational speed of the tool on the formation of friction stri processing zone in AA2219 aluminium alloy. *Materials Science and Engineering*,459, 2007, pp.7-18
9. Kim, Y.G., Fujii, H., Tsumura, T., Komazaki, T. and Nakata, K. Three defect in friction stir welding of aluminum die casting alloy. *Materials Science and Engineering A*, 415, 2006, pp.250-254
10. Ruzek, R. and Kadlec, M. Friction stir welded structure: kissing bond defects. *International Journal of Terraspace Science and Engineering*, 6(2), 2014, pp.77-83