Influence of Tool Geometry on Mechanical Properties of Underwater FSW Weld Joint

Komal V. Sangale[1], Prof. Kiran. N. Wakchaure[2]
[1, 2]SANJIVANI COLLEGE OF ENGINEERING KOPARGAON

Abstract- *The Normal Friction stir welding (NFSW) is the technology which is widely employed now a day. Basically it is a solid state joining process. This joining technique is energy efficient, environment friendly, and versatile. Though the joining takes place within the range of melting temperature of the material, the thermal cycle experienced by the thermo-mechanical-affected zone (TMAZ) and heat-affected zone (HAZ) influences on the internal structure of welded joint; which causes grain coarsening and precipitates dissolution in the age - hard enable aluminum alloys, which deteriorate the joint properties. To overcome this problem, underwater friction stir welding (UWFSW) process can be employed. This paper reviews the results of an experimentation in which the aluminum alloy AW6082-T6 was FSWelded, using threaded tool profile with different shoulder diameter & specified process parameters (rotational and travel speed). Mechanical properties of the test welds were assessed by means of tensile test. Macro and microstructure of the welds were examined by means of optical observations and Roughness weld of surface measurement.*

Keywords- Surface roughness, Tensile strength, tool geometry, UFSW.

I. INTRODUCTION

Friction stir welding has been in existence since the early 1990s and was developed mainly for the welding of aluminum alloys. Friction stir welding is a solid state joining process.

In friction stir welding, a rotating tool travels along the joint line, of material and accomplishes welding through mechanical stirring. The rotation of the tool heats up & melts the material in front of the tool is swept around and dumped at the rear side of tool, layer by layer. Aluminium alloy 6082 is a medium strength alloy with a very good corrosion resistance. It has the largest strength of the 6000 series alloys. Alloy 6082 is known as a structural alloy. In plate form, 6082 is the alloy most commonly used for machining .In aluminium alloy 6082-T6; T6 stands for solution heat treated and artificially aged.

The process and terminologies of friction stir welding are schematically explained in Fig 1.

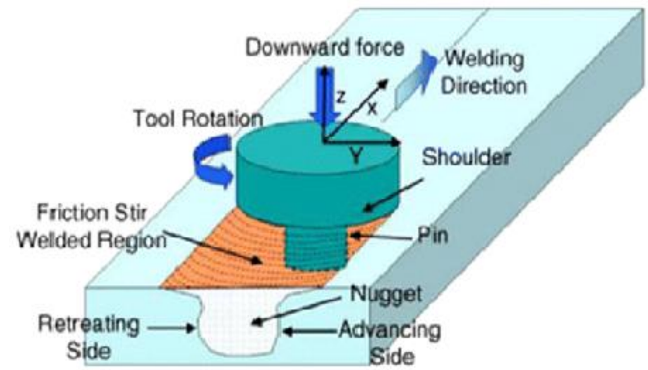


Fig. 1 Schematic of friction stir welding process and terminologies.

Underwater friction stir welding means the samples are welded of submerged totally in water or with water flowing across the surface in the welding process, which is a new variation to FSW.

II. LITERATUR SURVEY

Dr. D. Lingaraju et. al; investigated that the study of UFSW process is to understand the defect formation and the structure through which the mechanical properties of the welded joints can be improved and gives finally results a fine and efficient joint. The following review is given on comparison of different cooling media used in welding and its effect on weld joint.[1]

R.S. Mishra et.al (2005); has carried out descriptive study of FSW. In this review article,The descriptive study of FSW & FSP is carried out. Particularly focus was given to: (a) mechanism is effects on welded joint and micro structural refinement, and (b) effects of FSW/FSP parameters on resultant microstructure and final mechanical properties [2].

R.Rai, et al; here they review and examine number important points of FSW tools such as tool material selection, geometry and load bearing ability, mechanisms of tool degradation. They also found that friction stir welding (FSW) is a widely used solid state joining technology for soft materials such as aluminium alloys because it avoids many of the common problems of fusion welding [3].

S. Sree Sabari, et al. The experimental and numerical investigation on underwater friction stir welding (UFSW) and friction stir welding (NFSW) of armour grade, high strength AA2519-T87 aluminium alloy was conducted Under water friction stir welding (UFSW) is different from NFSW process which can reduce the heat input as well as can maintain it constant along the welded zone. The heat conduction and dissipation during UFSW controls the width of TMAZ and HAZ and also enhances the joint properties [4].

S. Sree Sabari, et al. in this study the effect of pin profile on the microstructure and mechanical properties of underwater FSwelded joint (of material AA2519-T87) are addressed. As per their study in FSW process rise in temperature at high rate is takes place which ultimately causes thermal effect on the HAZ & TMAZ which results in grain coarsening & precipitates separation which deteriorates the joint properties; hence to overcome this problem they employed underwater friction stir welding technology [5].

Mohammad Mohammadi-pour et. al; addressed on the effect of welding parameters on microstructure and tensile strength of joints welded by friction-stir welding (FSW). The influence of pin profile (threaded conical, non-threaded conical and triangular pin), tool rotational speed (800, 1000, 1250 and 1600 r_min-1) and welding speed (63, 80, 100 and 125 mm_min-1) on the mechanical and microstructural properties of joints welded in 5-mm 7075-T6 were found. The results shows that the pin profile has a important role in the shape and grain size of the weld nugget zone (WNZ) & moreover threaded pin is the most suitable for the FSW process because it produces fine grain size in WNZ this is stated by S. sabri et al and K. Kumar et al [6-7].

From the above literature review it is observed that Friction Stir welding is now widely used in the mechanical and manufacturing field; and the underwater friction stir welding (UFSW) process is having a latest research area. So many research has been done in UFSW but the effect of threaded tool profile with different diameter on the weld joint is unaddressed hence we have selected the same along with some specified process parameters for the further study.

III. EXPERIMENTATION

The base material used in this study is 6082-T6. Aluminium alloy 6082 is medium strength precipitation hardenable alloy which is used in aerospace industry for structural application. The chemical & mechanical properties of aluminium alloy are given in Table 1 and 2. The samples used are 150 mm in length 75 mm in width and 5mm thick. The specimens used are cut from 5mm thick sheets. Before testing the received material, samples are cut and prepared under the same conditions of the FSW samples to assure that only the effect of FSW is observed. The chemical composition of base material is tested in Nasik Engineering Cluster (NEC) laboratory. (Ambad MIDC, Nasik).

Table1. Chemical composition of Base Material A6082-T6

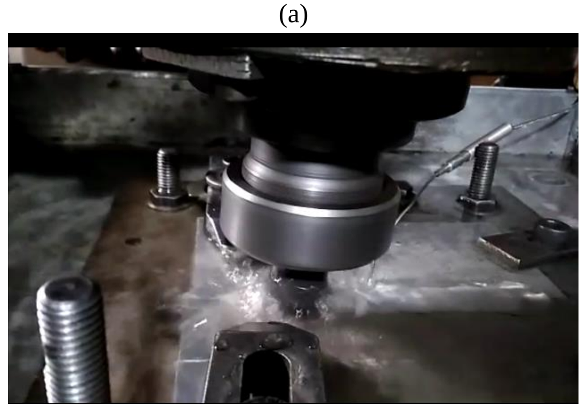
%Chemical Composition								
Mg	Mn	Zn	Fe	Cu	Si	Cr	Ti	Al
0.85	0.55	0.016	0.350	0.045	1.010	0.048	0.09	97.100

Fig. 1 (a), (b) Shows the experimental setup of Friction stir welding which is used for two conditions such as in air & an underwater. For the friction stir welding process, a Vertical milling machine of make: G-Dufour of 10HP power was used to carry out experimentation.

Table2. Mechanical properties A6082-T6

Mechanical Properties		
Tensile Strength	Yield Strength	Melting point
310Mpa	260 N/mm^2	660^0

(a)



(b)

Fig1. Experimental setup of FSW in (a) air (b) FSW underwater.

Here in Table 2. the process parameters and some welding conditions used for FSW & UFSW are shown. On the basis of this conditions and parameters some trials are taken on the plates (of base material A6082-T6). Tool used for welding is Threaded cylindrical type of different diameter & of H13 material.

Table 2 Process parameters and welding conditions for FSW & UFSW.

Process & Tool Parameters	Units	Notation	Values
Rotation speed	Rpm	N	910
Feed rate	mm/min	F	22
Tilt angle	Deg	A	2
Shoulder diameter	Mm	D	18
Pin dia.	mm	d	6

We have taken 6 readings in which 3 are in air and 3 an underwater. Hence Fig.2 below shows Friction Stir Welded joint in air and an underwater respectively.

After formation of weld joints some tests are carried out for the results such as micro structural test, tensile & elongation test, roughness test etc.

In of Micro-structural testing; Optical micrographs of FS weld joint at the SZ-TMAZ interface, the samples were chemically etched at ambient temperature for about six minutes with an extended Flick reagent consisting of 1.5 parts of HCl, one part of HF and nine parts of H_2O. FSW introduced varying micro structural refinement in the SZ of the weld joint. Higher fraction of HAZ formed in the bottom region of the SZ that resulted in fine grains formation.

For mechanical testing of welded joints, tensile tests are used. The testing is performed with the standard testing machines and test pieces. For the tensile tests, ASTM E8 or 1608: 2005 standards were used and testing is performed at a ambient temperature. Samples which are cropped from welded work pieces were taken from normal direction.

Roughness value of welded region has checked by using Roughness tester instrument of (Make: Mitutoyo). It covers 4.80 mm average distance to check the roughness value of surface. Fig.3 shows roughness testing instrument.

Fig.3 Roughness testing instrument

IV. RESULTS & DISCUSSION

1. Microstructure

Fig.4 shows microstructure view of both normal FSW (air) welded joint & underwater FSW joint. In which different zones are specified. It can be observed that numerous recrystallizations have occurred during the FSW as well as UFSW process [5].

FSW introduced varying micro structural refinement in the SZ of the weld joint. Higher fraction of HAZ formed in the bottom region of the SZ that resulted in fine grains with an average size of 2 μm. In the top region of the SZ, the additional heat provided by FSW tool shoulder provided coarse grains with an average size of 6 μm. And in case of UFSW average grain size observed was 5-6 μm.

The heat availability in UWFSW in various regions is lower than the FSW joints [5]. Basically in FSW process rise in temperature at high rate is takes place which ultimately causes thermal effect on the HAZ & TMAZ which results in grain coarsening & precipitates separation which deteriorates the joint properties [4]. Fig. 5 shows the micro structures of welded region in Heat Affected Zone.

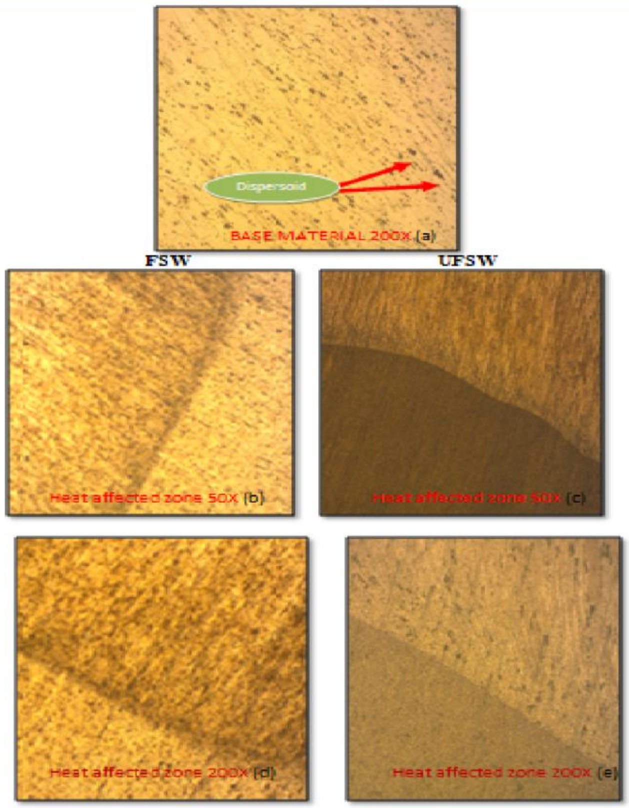


Fig.4 Representative micro structures of the FSW aluminium alloys: UFSW of (a) Microstructure of base material, (b) HAZ 50X in air and (c) HAZ 50X underwater; (d) HAZ 200X in air, (e) HAZ 200X underwater.

Air cooling medium reveals marginally larger grains and wider stir zone than the joint fabricated using Water cooling medium [5].

2. Tensile test

The unwelded parent metal showed tensile strength of 310Mpa with elongation 10%. The UFSW joint shows tensile strength 227 N/mm^2 which is 73%, and elongation shown 6. And FSW joint shows tensile strength 243 N/mm^2 which is 79% and elongation shown 8% which is less than parent material. And tensile strength obtained in case of UFSW is higher than the normal FSW joint. Fig 5 shows the result obtained for tensile strength and elongation. During tensile loading, the strain gets localized at the softer TMAZ among the various regions of weld joint. Because of the strain localization, both FSW and UWFSW joints exhibit lower elongation than the parent metal this is stated by S. Sree sabri et al [4].

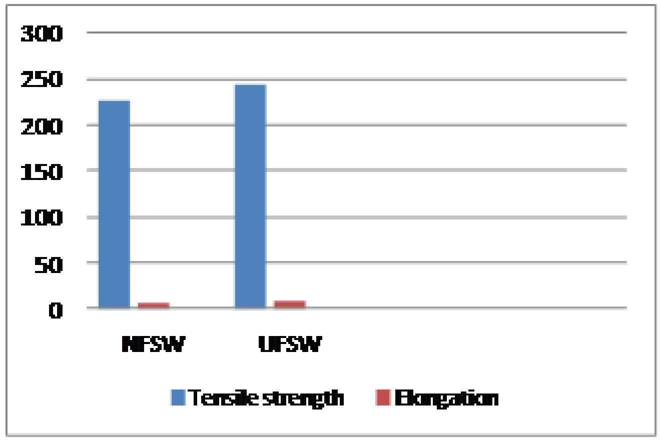


Fig.5Tensile Strength & elongation for both normal & underwater FSW.

3. Surface Roughness

Following are roughness values of welded joint in air as well as under water. Average roughness values in case of UFSW are found higher than that of FSW.

Due to high heat distribution in nugget zone in normal FSW joint shows smooth surface finish compare to underwater FSW joint.

Table4. Roughness value of weld joint in air & under water

	Roughness value (Ra)				Avg Ra
Air	8.686	5.676	5.338	3.995	5.923
Under water	6.062	6.247	4.820	4.548	7.697

V. CONCLUSION

The experimental investigation on underwater friction stir welding (UWFSW) and friction stir welding (FSW) of high strength AA6082-T6 aluminium alloy was conducted and following important conclusions are derived:

1. The coarsening and dissolution of precipitates resulted in TMAZ as the weaker zone. Thermal gradient along the welded joint is controlled by the water cooling and hence TMAZ & HAZ are reduced which ultimately increases the tensile properties.
2. Tensile strength observed in UFSW is larger than in FSW which is 243 N/mm^2.

3. Elongation observed in case of FSW is less than UFSW i.e 6 & 8% respectively; and elongation observed in both cases is lower than parent metal due to strain localization.
4. Normal FSW joint shows smoother surface than that of UFSW joint.

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