International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-8 Issue-4, April 2019

Experimental Investigation of the Mechanical Properties and Microstructure of AA 7075-T6 during Underwater Frictionstir Welding Process

Shahabuddin, V.K Dwivedi, Akash Sharma

Abstract: ***In this paper an experimental investigation on Aluminum Alloy AA 7075 –T6 during underwater friction stir welding is done and the effects of process parameters are analyzed and designed by using Taguchi's method as an optimization technique. Underwater friction stir welding (UWFSW) is a new approach which is similar as FSW (friction stir welding) but in this new approach of UWFSW the whole welding process is done under water i.e. the work piece and the tool is fully immersed under water. In this research paper mainly the three main process parameters are taken into major consideration for obtaining the optimized machining process parameters these three main process parameters are Tool Speed , Plunge Depth and Feed Rate. The Microstructure is analysis of different zone formed during the UWFSW process is also investigated. The run table for experimental run is generated by using Taguchi's L16 Orthogonal Array.***

Keywords: Mechanical properties, Aluminum Alloy, Underwater Friction Stir Welding, Microstructure

I. INTRODUCTION

Underwater friction stir welding is a latest technique which is widely acceptable in the industries like Aerospace and Shipbuilding for joining of different aluminum alloy series such as (6xxx,7xxx,8xxx) due to the light weight and high strength. It is very difficult to weld these alloys by using fusion method so, friction stir welding is introduced and it is widely taken into consideration for performing such welding process [1]. Here aluminum alloy AA7075-T6 is used for performing the experimental work. Aluminum alloy AA7075-T6 is having good mechanical properties, higher strength and lighter in weight and it is used for fabrication of different body parts of aero plane. UWFSW is a process in which the mechanical properties are improvised because of the water introduced as cooling medium which helps in cooling and due to which the overheating is minimized of HAZ(heat affected zone) which results in better mechanical properties[2,6,9]. In UWFSW the strength of the welding joint is increased as compared to the FSW (friction stir welding) process[10].

Manuscript published on 30 April 2019.
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Fig.1 Underwater friction stir welding process.

In Underwater friction stir welding the separate setup of fixture is used for performing such process. The fixture which is used so that the water can be filled and then the work piece is immersed in the water and the process is done of UWFSW.

II. LITERATURE REVIEW

Underwater Friction Stir welding (UWFSW) process is where the heat is generated by the stirring of the tool due to which the friction is produced and intense heat is generated.

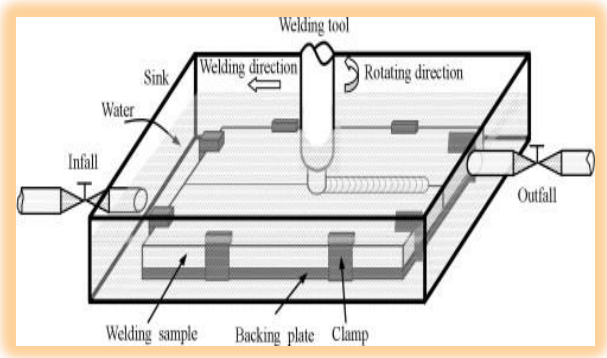

Fig.2 Underwater friction stir welding process.

In Under water friction stir welding process due to the flow of the water on the surface of work piece the heat input is controlled either in low,

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Medium or high level of heat input which results in increase of tensile strength as well improved microstructure of grain size[2].

The mechanical and microstructure is improved in under water friction stir welding. Toughness of the specimen is decreased due to the process which is taking place under water[3]. Intense heat generated during the underwater friction stir welding plays a vital role in formation of the fine grain in NZ (Nugget Zone) and also the Microstructure at TMAZ (Thermo-mechanically affected zone)[4].In Underwater friction stir welding process the mechanical properties and microstructure is found better as compared to simple FSW (friction Stir Welding) process. Under water friction stir process

Fig. 3 Vertical Milling Machine Used forUWFSW.

III. ALUMINUM ALLOY AA7075-T6

Aluminum alloy AA7075-T6 is widely used in various industries like Aviation, Automobile, and Shipbuilding etc. because it is having good mechanical properties, higher strength and lighter in weight therefore used for fabrication of different body parts of aero plane, ships building structures etc.

Mechanical and chemical compositions of Aluminum Alloy AA7075 (base metal) is given below in the table 1, 2.

Yield Strength(MPa)	527
Ultimate Strength(MPa)	571
Elongation %	12

Table.1 Mechanical properties of base metal

Element	Required wt%
Si	0.3
Fe	0.4
Cu	1.2-2.0
Mn	0.3
Mg	2.0-2.8
Cr	0.19-0.29
Al	87.1-91.4
Zn	5.0-6.2
Ti	0.3

Table 2. Chemical composition of AA7075-T6 according to spectrometer analysis (wt %)

IV. EXPERIMENTAL PROCEDURE

In Underwater Friction Stir Welding process the material used for performing experimentation is Aluminum Alloy AA7075-T6 because of its high strength and light weight and its wide acceptance throughout the industries for fabrication of light weight structures and different components.

The Tool in used in Underwater friction stir welding process (UWFSW) is made of H13 steel and also it is made by taking into consideration certain specified dimensions. Under water friction stir welding (UWFSW) process tool specifications plays very important role. Here the welding process is done by using H13 steel made tool whosechemicalcomposition is shown in Table 3. In this process, shoulder diameter 20mm and pin diameter of 4mm are used to experimental research work as shown in Figure 4, 5. A tool pin is very useful for filling the metal into the cavity. A tool with a tool plunge 0.20mm is used for performing the welding process on a vertical milling machine. Work piece firmly tighten on special designed fixture for underwater friction stir welding. First specimen is place on the fixture plate, and then water is dropped, until the specimen fully immerged into the water during the underwater stir friction welding process. While designing a tool there should be taken appropriate specification because the whole process rely on the tool, tool is plays major role in performing underwater friction Stir Welding Process (UWFSW). The different Process Parameters are shown below in Table.4.

Element	Required wt%
C	0.32
S	0.02
Mn	0.43
P	0.021
Si	1.05
Cr	4.98

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Table 3. Chemical composition of H-13 Tool Steel.

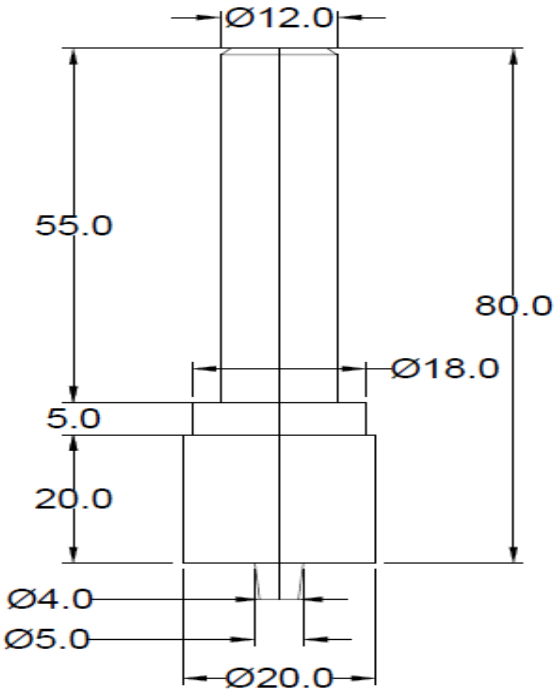

Fig.4 Tool Specifications

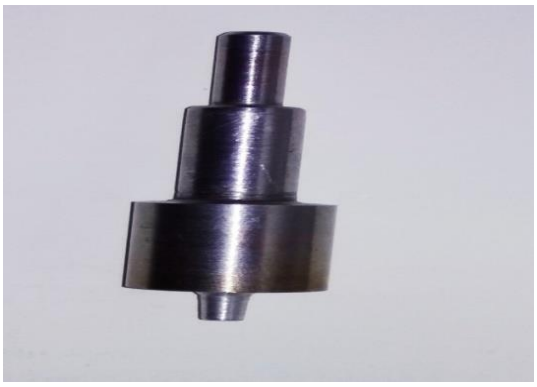

Fig.5 Tool used in UWFSW

Fig.6 Fixture setup used for UWFSW

Parameters	Levels (rpm)			
Tool rotation speed (N) (RPM)	900	1110	1200	1320
Welding speed(S) (mm/min)	55	60	65	70
Tool shoulder diameter(D) (mm)	20	20	20	20
Plunged depth(h) (mm)	0.10	0.12	0.15	0.20

Table.4 Process parameters used in UWFSW.

Design of experiments is used to performing Underwater friction stir welding (UWFSW) process so that better results can be achieved. A full factorial design was used to performed experiments. Three input parameters like tool shoulder diameter, welding speed and tool speed of the tool were selected as parameters in this research work to give better result when number of factor to 3 , with their levels shown in Table 5. Mostly experiments were conducted to find out the defect-free welding joints. In the present research work, full factorial arrays 3columns and 16 rows were selected as shown in Table 5. The tensile tests result were carried out in (IIT Delhi) at machine head speed of 2 mm/min. Weld joint specimens were prepared on double disc polished machine and different reagent were used for examined the microstructure through a metallurgical microscope (Jamia Millia Islamia, New Delhi). Scanning electron microscopy (SEM) was used to carrying out fracture features in (Jamia Millia Islamia, New Delhi 110025) of different specimens. A Vickers micro hardness testing machine (HM200, Mitutoyo, Kawasaki, Japan) was used for micro hardness measurement of the welded specimens by applying load of 2N and a delay time of 20s.Successive distance between two points was 0.5 mm.

S.No	Speed (rpm)	Plunge depth (mm)	Feed (mm/min)
1	900	0.10	55
2	900	0.12	60
3	900	0.15	65
4	900	0.20	70
5	1110	0.10	55
6	1110	0.12	60
7	1110	0.15	65
8	1110	0.20	70
9	1200	0.10	55
10	1200	0.12	60
11	1200	0.15	65
12	1200	0.20	70
13	1320	0.10	55
14	1320	0.12	60
15	1320	0.15	65
16	1320	0.20	70

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Table.5 L16 Orthogonal Array design of experiment (DOE)

In this research work, the different parameters were used for underwater friction stir welding (UWFSW) like that tool shoulder diameter, plunge depth and rotational speed. These parameters were varying by Taguchi L_{16} orthogonal array. Taguchi L16 array method was very suitable tool for engineering analysis with varying parameters at different levels to minimize the number of experiment trials.

V. TENSILE STRENGTH

In this research work, analysis of tensile strength is done due to effect of different parameters in underwater friction stir welding (UWFSW).Tensile strength is maximum at 1110rpm/min (410MPa) and minimum at 900rpm/min (334). Ultimate tensile strength (UTS) was observed by experimentally, Taguchi method was used to analysis with support of ANOVA for mode of fracture study. It is observed that third level of rotational tool speed (1110rpm), the second level of welding speed (70mm/min) and third level of tool shoulder diameter of 20mm (410MPa) gives higher tensile strength.

S.No	Speed (rpm)	Plunge depth (mm)	Feed (mm/min)	UTS (MPa)
1	900	0.10	55	334
2	900	0.12	60	332
3	900	0.15	65	362
4	900	0.20	70	397
5	1110	0.10	55	402
6	1110	0.12	60	410
7	1110	0.15	65	394
8	1110	0.20	70	409
9	1200	0.10	55	379
10	1200	0.12	60	399
11	1200	0.15	65	387
12	1200	0.20	70	382
13	1320	0.10	55	391
14	1320	0.12	60	389
15	1320	0.15	65	384
16	1320	0.20	70	394

Table 6. Tensile testing observation result for AA7075-T6 in UWFSW

VI. Microstructure evolved during underwater stir friction welding (UWSFW)

The microstructure zones to the underwater friction stir welding (UNFSW) were pointed out in all welded joints by using an optical microscope. The weld joint made at the 3120rpm and welding speed 70mm/min was analyzed for microstructure which as appearance has highest hardness and tensile strength. The grain size on nugget zone of AA7076-T6 on were better refined and continuous recrystallization due to the peak temperature. N. Martinez et al investigated that the heat and cooling rates influenced in the nugget in different zones. The top surface on the nugget having the better microstructure, fine grain and strengthening [5,7,8].

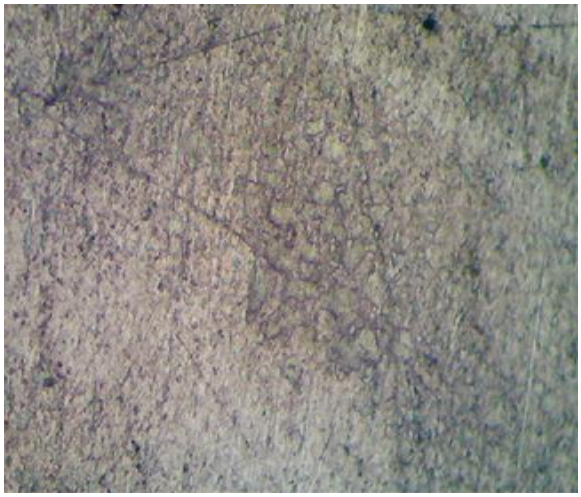

Figure.7 Microstructure of welding zone SZ

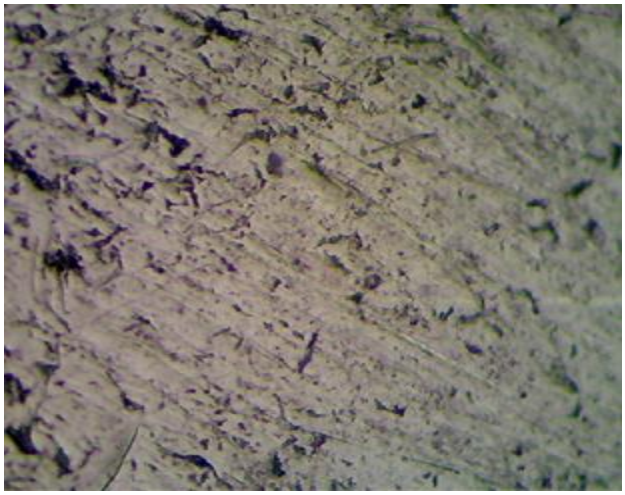

Figure.8 Microstructure of welding zone TMAZ

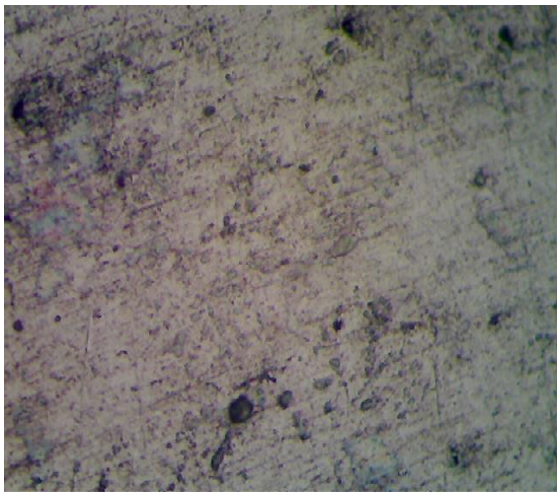

Figure.9 Microstructure of welding zone HAZ

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VII. RESULT ANALYSIS

Aluminum alloy AA7075-T6 is used in this research work and it is observed that the aluminum alloy AA7075-T6 have wide acceptance in industries like aerospace, shipbuilding etc. for light weight component manufacturing as well for structure building, because of its light weight and high strength. It is analyzed that the grain size of microstructure is improved and the tensile strength is increased due to the flow of water on the surface of work piece during UWFS (under water friction stir welding) because the heat input is controlled by using water. It is analyzed that the toughness of the specimen is decreased due to the underwater process. The microstructure of the three zones formed during UWFSW is analyzed and as a result it is observed that microstructure of all three zones during UWFSW is better than FSW (friction stir welding) process.

During experimental investigation it is analyzed that there is improvised mechanical properties due to the controlled heat in nugget.it is alsoanalyzed that the strength of the welded joint in UWFSW is more than the FSW process due to the low peak temperature. The microstructure analysis of UWFSW gives results as better tensile strength and hardness appearance as compared to the FSW process.it is observed that the top surface on the nugget is having better microstructure, fine grain and strength as per the microstructural analysis. In this paper the microstructural and mechanical properties are analyzed and discussed which results that both mechanical as well microstructure are found much better as compared to simple FSW(friction stir welding) process. In this paper by applying Taguchi's optimization technique it is observed that the better strength and fine microstructure is obtained at tool speed of 1320rpm, plunge depth of 0.2mm and welding speed of 70mm/min.

VIII. CONCLUSION

1. Successful UWFSW of AA7075-T6 used to tool speed of 1320 rpm; plunge depth 0.2mm and welding speed 70mm/min were found to be most appropriate weld joints.
2. Taguchi design method is very efficiently for optimizing welding parameters in performing the underwater friction stir welding.
3. Tensile strength and hardness of AA7075-T6 is more influenced by the welding speed.
4. Maximum hardness is obtained 148.7 HV and ultimate tensile strength 410MPa.
5. Strength improvement in UWFSW welded joint as compared to FSW due to low peak temperature.

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Akash Sharma, M.Tech (Production) Student, GLA University, Mathura (India) has earned his B.Tech (ME) from Uttarakhand Technical University, Dehradun and pursuing Masters in Technology from GLA University, Mathura (India). He is currently employed as a Scientist 'C' in Research and Calibration Division at FARE Labs Pvt. Ltd., Gurgaon, India. He has published 7 Research papers in International journal and Conference proceedings. He has presented Research papers in more than 10 National and International Conferences and attended various workshops. He is also having certification of AutoCAD from MSME (PPDC). He has keen interest in investigating the friction stir welding process and end milling process.

Dr. Vijay Kumar Dwivedi, Associate Professor, GLA University, Mathura (India) has earn his Ph.D. from Motilal Nehru National Institute of Technology, Allahabad and masters in engineering from Indian Institute of Technology, (ISM) Dhanbad. He has very vast research and teaching experience of more than 18 years. He has guided 3 Ph.D. and 10 Masters in the field of Mechanical Engineering. He has published more than 100 papers in International journals and conferences proceedings. He has filed two patents. He has keen interest in investigating the triobological issue in fluid film bearing, friction stir welding and thermal barriers coatings in engineering and applications.

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