REVIEW ON PARAMETRICAL PERFORMANCE INVESTIGATION IN UFSW

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Abstract: Underwater friction stir welding (UFSW) is one of the advanced technique of welding. In recent years, the research has become the primary aim in every field. In the present paper, brief explanation of introduction of the UFSW technique along with a review on the latest research has been made. The literature is based on the microstructures analysis, strength analysis, effects of parameters, optimum welding parameters, process modeling and computing techniques. The application of UFSW has also been discussed, along with a description advantages as well as limitation of UFSW technique.

Keywords - : Underwater friction stir welding, tensile strength, Microstructure, Corrosion evaluation, Normal friction stir welding

I. INTRODUCTION

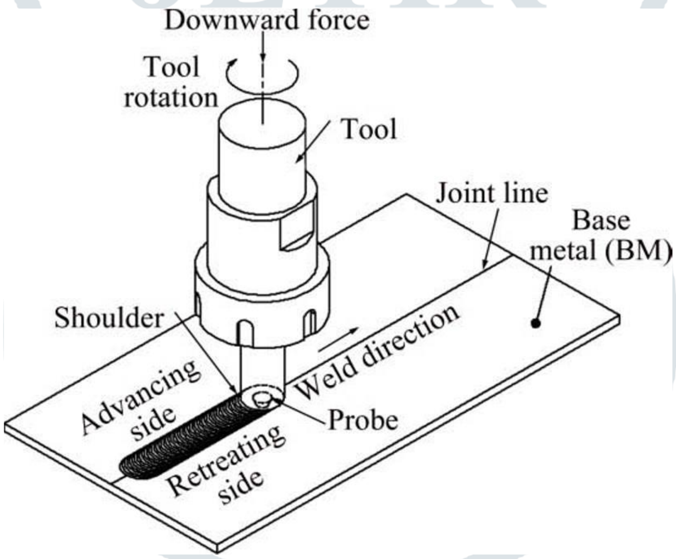

Fig 1 – Schematic diagram of FSW process

Friction stir welding (FSW) produces welds by using a rotating, non-consumable welding tool to locally soften a work piece, through heat produced by friction and plastic work, thereby allowing the tool to "stir" the joint surfaces. FSW is to create high-quality, high-strength joints with low distortion and is capable of fabricating either butt or lap joints, in a wide range of materials thickness and lengths. The process is carried out by plunging a rotating tool made of a wear-resistant and high temperature resistant material that is converting into the material to be joined and translating it along the desired weld line.

1.1 FSW in-Plate Zones

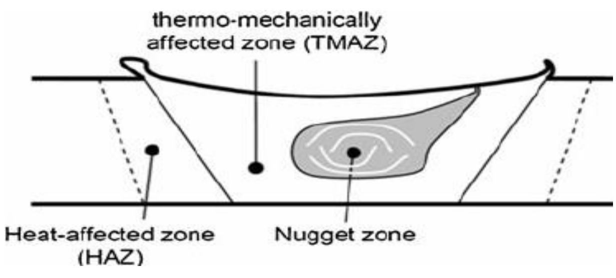

Fig 3 - Welded plate zones [13]

There are total three types of zones which are as follows.
(1) Nugget zone
(2) Thermo-mechanically affected zone (TMAZ)
(3) Heat- affected zone (HAZ)

A transverse section from a typical, conventional FSW joint is shown in figure. The weld is bounded on either side by unaltered, base metal (BM).Although BM near the weld zone does experience elevated temperature work piece in the as-received condition. Closer to the weld is the heat-affected zone (HAZ), which is heated sufficiently during welding to alter its properties without plastic deformation of the original grain structure. The alteration of properties in the HAZ may include changes in the strength, ductility, corrosion susceptibility, and toughness of the work piece, but typically will not include changes in grain size or chemical makeup. Heating in the HAZ is generally high enough in aluminum alloys to result in recovery of cold work and coarsening of precipitates, which is the root cause of changes in properties in this region.

1.2 Important Welding Parameters:

The parameters of FSW are as belows:
(1) Tool design
(2) Tool rotation speed
(3) Welding speed (Transverse speed)
(4) Tool tilt
(5) Plunge depth
(6) Axial force

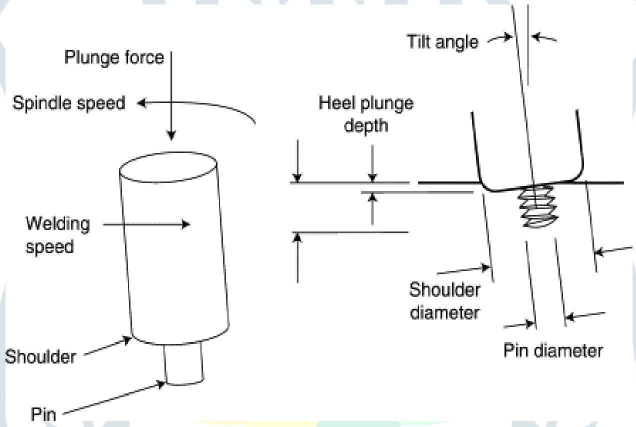

Fig - 3 Conventional FSW tool [13]

1.3 Underwater Friction Stir Welding

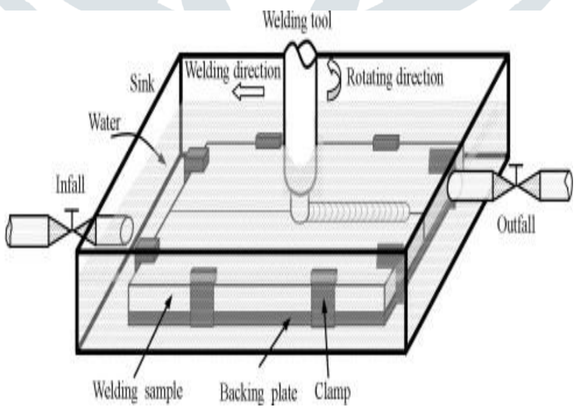

Fig - 4 Layout of UFSW[3]

In the UFSW, the samples are welded in water. It also minimizes various welding defects like porosity, shrinkage, splatter, embrittlement, solidification, cracking etc. UFSW is one of the advanced welding techniques in the present era. This process doesn't require shielding gas and filler material for welding which make this process cheaper. It consumes less energy and gives improved mechanical properties. It also provides well defined variation in grain size between different zones along the high quality weld joint produced.

1.4 Advantages of UFSW over NFSW

(1) Suitable for materials and alloys that are sensitive to overheating
(2) Development of peak temperature is lower, limiting the coarsening and precipitate dissolution
(3) Provide better mechanical properties of the work piece material.
(4) Prevents the oxidation and provides better surface texture.
(5) Less welding defects are observed
(6) Reduce the residual stresses and creates less distortion.
(7) Offers refined grain structure as compared to FSW

II. LITERATURE REVIEW

F. Heirani et. al.[1] focused on the effect of processing parameters on microstructure and mechanical behavior of underwater friction stir welding of Al5083 alloy and compared that result with the normal friction stir welding for same processing parameters. Total 5 numbers of samples (S1, S2, S3, S4, S5) have been taken for investigation. The result showed that the same welding parameters for the air and water cooled specimen(rotational speed of 600 rpm and welding speed of 30 mm/min). The hardness value was increased by 25 % in the stir zone. By comparing the air-cooled welded sample with water-cooled sample, the increase in the tensile strength of water-cooled specimens may be due to the increase of hardness in the stir zone caused by a fine grain structure.

S. Sinhmar et. al.[2]investigated on the microstructure corrosion behavior and mechanical properties of the friction stir welded joint of AA2014 in natural cooled and water cooled condition. 3.5% NaCl solution was used for the corrosion test. The thickness of plate is 6 mm. The processing parameters like rotational speed is 931 rpm, Traverse speed 41 mm/min, Pin length 5.8 mm and diameter for top is 6 mm and 4 mm for bottom part and tilt angle is 1.5^0. The flow rate of water during the water cooled FSW is 0.15 l/min. The result found that the corrosion resistance of water cooled joint was found higher than natural cooled FSW joints.

H .J. Zhang et.al.[3] discussed about the UFSW of 2219-T6 aluminium alloy at a fixed welding speed and various rotation speed in order to influence of rotation speed on the performance of underwater joints. The Value for the fixed welding speed is 100 mm/min and the range for the rotation speed is 600 rpm to 1400 rpm. With increasing rotation speed, the tensile strength first increases from 600 to 800 rpm and then reaches a plateau between 800 and 1200 rpm. At a higher rotation speed of 1400 rpm, the tensile strength sharply decreases due to the occurrence of void defect The result showed the when the rotation speed is too low or too high, the hardness is relatively low because of inadequate tool stirring or excess heat input.

P. Baille et. al.[4] studied about the comparison of the mechanical and microstructural properties produced during friction stir welding of S275 structural steel in air and water. The dimension for the plate measuring 2000 × 200 ×6 (mm).Travel speed 100 mm/min and rotation speed 200 rpm is chosen for the Air FSW and Travel speed 100 mm/min and 240 rpm rotation speed for the water FSW.It is concluded that there was no significant difference in the strength, hardness or fatigue life of the air and underwater specimen. Only charpy impact toughness was decreased for underwater specimen due to less angular grain structure.

F. Gharavi et. al.[5] focused on the corrosion behavior of friction stir lap welded AA6061-T6 aluminium alloy in sodium chloride + hydrogen peroxide solution. Welding conditions and process parameters used in this work: Rotation speed 1000 rpm, welding speed 60 mm/min, tool shoulder diameter 20 mm, pin diameter 8 mm, pin length 8 mm and tilt angle 3^0. The result suggested that the corrosion resistance in different weld region for the friction stir lap welding sample is poorer than that for the parent alloy.

S. Rajkumar et. al.[6] discuss about the predicting tensile strength, hardness and corrosion rate of friction stir welded AA6061-T6 aluminium alloy joints at different parameter and optimum welding condition was found to maximize the tensile strength and minimize the corrosion rate. The joint fabricated with a tool rotational speed of 1100 rpm recorded the highest tensile strength and hardness value of 121 HV in the stir zone region. Similarly the welding speed of 80 mm/min, axial force of 8 kN, shoulder diameter of 15 mm, pin diameter of 5 mm and tool hardness of 45 HRc, resulted in maximum strength properties compared to other process parameters. The corrosion rate can be reduced by minimum with acceptable mechanical properties if the optimal welding conditions are used.

S. Shanavas et. al.[7] studied the feasibility of underwater friction stir welding of AA5052 H32 aluminium alloy to improve the joint performance than normal friction stir welding. For the experiment, 6 mm cold rolled plates of high-strength aluminum-magnesium alloy AA 5052-H32 were used. The plates were cut in size of 100 × 50 × 6 mm. The samples were made by fixing the welding speed at 65 mm/min and rotation speed was in range of 500-900 rpm and at 700 mm/min travel speed, rotation speeds are 55, 65, 75 and 85 rpm. For experiment, 1.5^0 selected for tool tilting and 7 kN for axial force. It was observed that the tensile strength of underwater welded joints was higher than normal FSW joints except at 500 rpm. Maximum tensile strength of 208.9 MPa was obtained by underwater friction stir welding at 700 rpm tool rotational speed and welding speed of 65 mm/min. The optimum process parameters for maximum tensile strength by normal friction stir welding were compared with underwater friction stir welding. The result showed that the ultimate tensile strength obtained by UFSW about 2 % greater than that of normal FSW process.

H. Zhang et. al.[8] conducted underwater friction stir welding of 2219-T6 aluminium alloy to obtain the optimum welding condition and mathematical model was developed to optimize the welding parameters for maximum tensile strength. It has been stated that the tool geometry, rotation speed, welding speed and shoulder plunge depth are main factors that affect the mechanical properties of FSW joints. Rotation speed, welding speed and shoulder plunge depth are 900 rpm, 150 mm/min, 0.2 mm for low level, 1000 rpm, 200 mm/min, 0.3 mm for middle level and 1100 rpm, 250 mm/min, 0.4 mm for high level respectively. The result indicated that a maximum tensile strength of 360 MPa can be achieved through UFSW, higher than the maximum tensile strength obtained by normal condition. This Value is 6% higher than the maximum tensile strength obtained in normal FSW.

V. Balasubramanian et. al.[9] aimed to study the effect of welding processes such as GTAW, GMAW and FSW on mechanical properties of AA6061 aluminium alloy. Rotation speed 1200 rpm, welding speed 75 mm/min and 7 kN axial force is selected for this experiment. Threaded tool has been used whose shoulder diameter is 18 mm and pin diameter is 6 mm. Pin length is 5.5 mm. Of the three welded joints, the joints fabricated by FSW process exhibited higher strength values and the enhancement in strength value is approximately 34%compared to GMAW joints, and 15% compared to GTAW joints. From this investigation, they found that FSW joints of AA6061 showed superior mechanical properties compared with GTAW and GMAW joints due to formation of very fine, equiaxed microstructure in the weld zone.

L.Dumpala et. al.[10] focused on the study of mechanical properties of aluminium alloys on the normal friction stir welding and underwater friction stir welding for structural application. The experimentation temperature results are validated by utilizing deform-3D. Aluminum 6061, 6063 composites were utilized as a part of similar and dissimilar circumstances Experimentations are performed in two distinct conditions, i.e. NFSW and UFSW. The variable parameters are instrument turn speed 1200 and 1400 rpm, Tool feed rate is 22 and 44 mm/min, and tilt edge is 10^0. H13 chromium hot-work steel is utilized.

A. Heidarzadeh et. al.[11] focused on the tensile behavior of friction stir welded AA6061-T4 aluminium alloy joints. In this investigation, three welding parameters, five levels and 20 runs are used to develop for predicting the tensile properties. Variable rotational speeds are 763, 900, 1100, 1300, 1436 rpm, welding speed are 46, 60, 80, 100, 113 mm/min and axial force 5.32, 6, 7, 8, 8.68 kN. The result showed that the optimum parameters to get a maximum tensile strength were 920 rev/min, 78 mm/min and 7.2 kN, where the maximum of tensile elongation was obtained at 1300 rev/min, 60 mm/min and 8 kN.

III. SUMMARY OF LITERATURE REVIEW

No	Material	Thickness of Plate	Process parameters
1	AA5083	5 mm	Rotational speed : 600 – 1250 rpm Welding speed : 30-63 mm/min
2	AA2014	6 mm	Rotational speed : 931 rpm Welding speed : 41 mm/min Flow rate of water : 0.15 l/min Tilt angle : 1.5^0
3	AA2219-T6	7.5 mm	Welding speed : 100 mm/min Rotation speed : 600- 1200 rpm
4	S275 Structural steel	6 mm	Welding speed : 100 mm/min Rotation speed : 200 rpm (For NFSW) Rotation speed : 240 rpm (For UFSW)
5	AA6061-T6	5 mm	Rotation speed : 1000 rpm Welding speed : 60 mm/min Tilt angle : 3^0 Tool shoulder diameter : 20 mm Pin diameter & length : 8 mm
6	AA6061-T6	5 mm	Rotation speed : 862,1000,1100,1200,1337 rpm Welding speed: 32.43,60,80,100,127.5

			mm/min Axial force : 5.62, 6, 7, 8, 10.37 kN Shoulder dia. : 7.86, 12, 15, 18, 22.13 mm Pin dia. : 2.6, 4, 5, 6, 7.37 mm
7	AA5052 H32	6 mm	Rotation speed : 500 – 900 rpm & 55 – 85 rpm Welding speed : 700 mm/min & 65 mm/min Tool tilt angle : 1.5^0 Axial force : 7 Kn
8	AA2219-T6	7.5 mm	Rotation speed : 900,1000, 1100 rpm Welding speed : 150, 200, 250 mm/min Shoulder plunge depth : 0.2, 0.3, 0.4 mm Tool shoulder dia. : 12.5 mm Pin length : 7.4 mm
9	AA6061	6 mm	Rotation speed : 1200 rpm Welding speed : 75 mm/min Axial force : 7 kN Tool shoulder dia. : 18 mm Pin dia. : 6 mm
10	AA6061& AA6063	-	Rotation speed : 1200 rpm Welding speed : 22 mm/min & 44 mm/min
11	AA6061-T4	4 mm	Rotation speed : 763,900,1100,1300,1436 rpm Welding speed : 46, 60, 80, 100, 113 mm/min Axial force : 5.32, 6, 7, 8, 8.68 kN

IV. CONCLUSION

- Underwater friction stir welding is really advance and innovative technique of welding. In this present era, very few researchers have done the research on it. The scope of work is so high to research on this area for researchers as well as academicians.

- From the literature it has been found that the range for tool rotation speed and welding speed is between 600-1400 rpm and 20-100 mm/min.

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