Investigation on Underwater Friction Stir Welding Of Al 6061 andAZ31

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ABSTRACT

Utilization of lightweight metals such as Magnesium (Mg), Aluminum (Al) and Titanium (Ti) to form weight saving structural components inaerospace and automotive vehicles can significantly benefit in improving fuelefficiency and reducing harmful emissions. The ability to producecomponents from different lightweight metal alloys and to integrate themtogether is an important technical challenge.To obtain defect free joining of dissimilar metals Al and Mg, studieshave utilized solid state welding techniques. Such as Ultrasonic Welding, Resistance Spot Welding, Linear Friction Welding, and Friction Stir Welding (FSW).The FSW process takes place below the melting temperature of the alloy, so several defects due to the solidification of the metals are avoided. However, some challenges still exist in the dissimilar friction stir welding of the Aluminum/Magnesium (Al/Mg) metallic couple. Among which the formation of the Al–Mg intermetallic compounds is the major problem.In order to control heat input and resulted morphological characteristics of brittle intermetallic compounds underwater Friction Stir Welding (ufsw) of 6061 Al alloy and AZ31 Mg alloy was carried out. In this study the morphology of Al-Mg weld interface will be studied to understand the effect of underwater Friction Stir Welding compared to conventional Friction Stir Welding. Process parameters such as rotational speed, traverse speed, tool pin profile are considered for this study.

Keywords---Aluminum Alloy, Dissimilar Alloy Joint, Friction Stir Welding, Magnesium Alloy, Underwater Friction Stir Welding

I. INTRODUCTION

As light alloys with low density, high special strength and good anti-corrosion properties aluminum and magnesium are widely used in transportation and electronic communication industries.In order to overcome all these drawbacks and defects solid state welding process, friction stir welding is developed, joining of metals done under the action of stirring. Though it has many advantages over fusion welding and other solid state welding, there exist some problems like formation of intermetallic compounds in their stir zone of dissimilar welds affects the mechanical properties of joints significantly. Higher heat generation. Hence in order to reduce heat input Control and formation of brittle intermetallic compound. The newly developed method called Underwater Friction Stir Welding is used and experimental work been done in this paper.

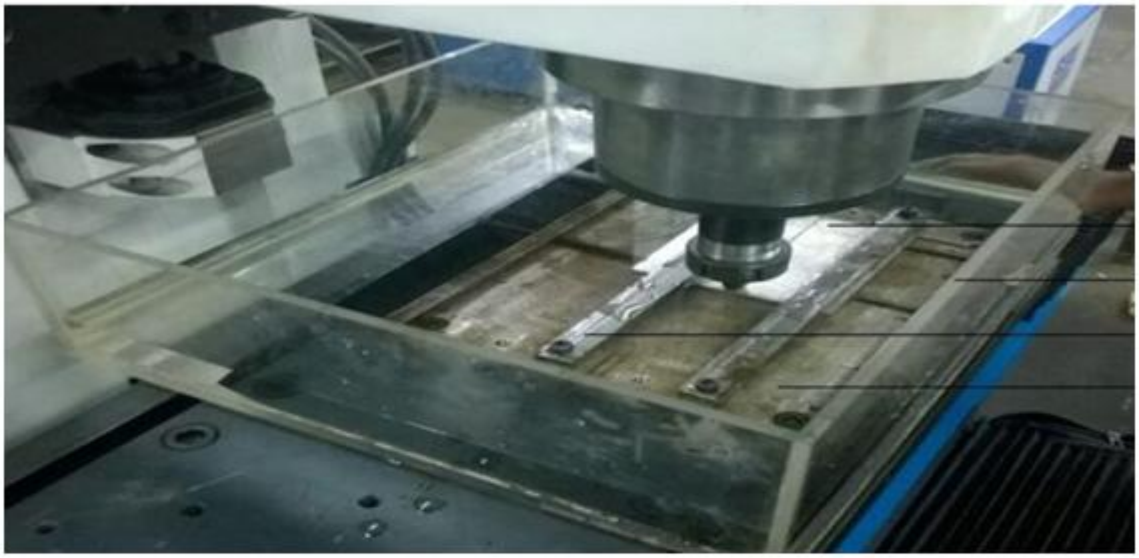

Fig.1. shows the underwater friction stir welding setup

II. EXPERIMENTAL SETUP AND PROCEDURE

Underwater friction stir welding (UFSW) is similar to friction stir welding (FSW) (i.e.) a cylindrical, shouldered tool with the profiled probe is rotated and slowly plunged into the joint line between the two pieces butted together.Frictional heat is generated between the wear resistant welding tool and the material of the work pieces. This heat causes the material to soften without reaching the melting point and allows traversing of the weld tool along the weld line.

For the experimental of SFSW on AA 6061-T6, the material selected for the fixture used, was mild steel (0.3 % C). AKRYLIK (Plexi-Glass) was chosen as the material of the tank. This material has been chosen for the sole purpose of the vicinity of the friction stir welding. This material also aids in the direct measure of the level of the water used in the tank. Fig.1. shows the experimental setup of underwater FSW. The fixture was fixed inside the tank by bolting it to the table, and the various samples were clamped on it. Water was poured at room temperature into the tank, so that the top surface of the samples was immersed in it.

The base metals (BM) utilized in the experiment was a Al 6061alloy and Mg AZ31 with the dimension of 100x50x8 mmand their chemical composition are listed in the Table 1 & 2.

Component	Amount (wt.%)
Aluminum	Balance
Magnesium	1.05
Silicon	0.65
Iron	0.23
Copper	0.24
Zinc	Max. 0.001
Manganese	.54

TABLE 1Chemical composition of Al 6061

Component	Amount (wt.%)
Magnesium	Balance
Aluminum	2.95
Silicon	0.05
Iron	0.003
Zinc	0.92
Nickel	0.001
Manganese	0.01

TABLE 2Chemical composition of AZ31

2.1. Selection of Process Parameters

The process parameters were selected for the friction stir welding. They are listed below

- Traverse rate in mm/min,
- Spindle rotational speed in rpm,
- Tool pin profile also considered as one of the input process parameters.

These process parameters are mostly contribute to heat input and subsequently influence the mechanical properties of the welded joints were selected in different levels. As per the standard orthogonal array table for the above parametric conditions L9 orthogonal array was selected. Table 1shows the process parameters corresponding to the nine experiments for both FSW in air and FSW in underwater setup totally eighteen experiments.

Welding Sequence	**RUN 1**	**RUN 2**	**RUN 3**	**RUN 4**	**RUN 5**	**RUN 6**	**RUN 7**	**RUN 8**	**RUN 9**
Spindle Speed(rpm)	1200	1400	1600	1200	1400	1600	1200	1400	1600
Welding Speed (mm/min)	250	500	750	250	500	750	250	500	750
Pin Profile	Cylinder	Cylinder	Cylinder	Square	Square	Square	tapper	tapper	tapper

TABLE 3 Welding Sequence and Process Parameters

The relationship between the welding speeds and the heat input during welding is complex but in general it can be said that increasing the rotation speed or decreasing the traverse speed will result in hotter weld. In order to produce successful weld it is necessary that the material surrounding the tool is hot enough to enable extensive plastic flow required and minimizes the force acting on the tool. If the material is too cold then voids or other flaws may be present in stir zone and the extreme cases the tool may break. Welding speed suitable for this experiment is selected between the range of 250(mm/min) – 750 (mm/min) as shown in the table 3.

The design of the tool is a critical factor as a good tool to improve both the quality of the weld and the maximum possible welding speed. It is desirable that the tool material is sufficiently strong, tough and hard wearing at the welding temperature. Further it should have good oxidation resistance and a low thermal conductivity to minimize heat loss and thermal damage to the machinery further up further up the drive train. The majorities of tools have concave shoulder profile acts as an

Escape volume for the material displaced by the pin, prevents material from extruding out of the sides of the shoulder and maintains downward pressure and hence forging of material behind the tool. From the previous studies the suitable tool dimensions and profile selected for experiment is are shown in Fig.2 & Fig.3.

- Conical pin profile
- Square pin profile
- Cylinder pin profile

Fig.2. shows the different tool profile used for the experiment

As per the sequence of parameters listed in the table 3 experiments been done in both FSW (air) and FSW (underwater) conditions.

III. RESULTS AND DISCUSSION

3.1Micro Hardness

The welded samples were polished using conventional polishing methods and chemically etched for Vickers micro hardness. Hardness was measured at different location of the joint line to understand the influence of process parameters. Their respective hardness values are listed on the table 4& 5

TABLE 4 Micro Hardness Results of FSW Air

Welding sequence	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7	RUN 8	RUN 9
Vickers Hardness (HV)	85.97	73.45	78.36	95.15	104.40	105.63	0.00	0.00	0.00

TABLE 5Micro Hardness Results of FSW Underwater

Welding sequence	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7	RUN 8	RUN 9
Vickers Hardness (HV)	103.40	108.26	112.20	120.1	126.53	116.26	95.13	87.22	90.93

In order to evidence softening or hardening effects induced by the FSW weldment done in air and underwater inter particle hardness measurements, with were made from the base material to the FSW zone on the different sections of welded plates. The micro hardness results of weldment of both the conditions are shown in the table 5 & 6.

The from the table 1 it clearly implies that the maximum micro hardness values are recorded at the RUN 6 of FSW experiment, (i.e.) at the spindle speed of 1600 rpm, welding speed of 750 mm/min, square tool pin profile. At the same with reference to table 2 comparatively the hardness values got increased especially at the spindle speed of 1400 rpm, welding speed of 500 mm/min, square tool pin profile, this is due to decrease in temperature during process, which results in finer grains resulting the increasing in hardness value.

3.2. Microstructure and Evaluation

The microstructure of the joints is examined at various location in and displacement to the FSW Zones. SEM images obtained at the weld region are shown in figure 5. It is clearly implies that the grain size of the weldment done in underwater is reduced when compared to the grain size of the weldment done in air. The fine equiaxed grains are seen in the FSW (UNDERWATER) implies that the decrease in grain size is due to reduction in temperature. Fine grain equiaxed grains are observed in RUNS observed during the weld done in Underwater. From the figure it clearly implies that the grain size of the weldment done by FSW air and Underwater is finer when compared to the grain size of base material which is due to the stirring done in reduced temperature.

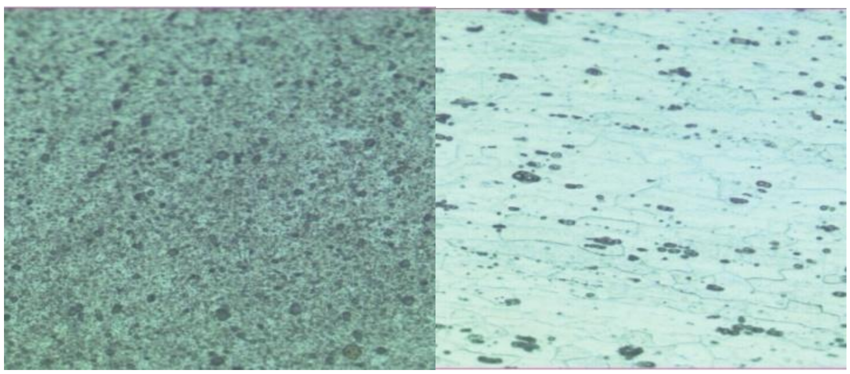

Fig.3. SEM Image of base material Al6061 and AZ31

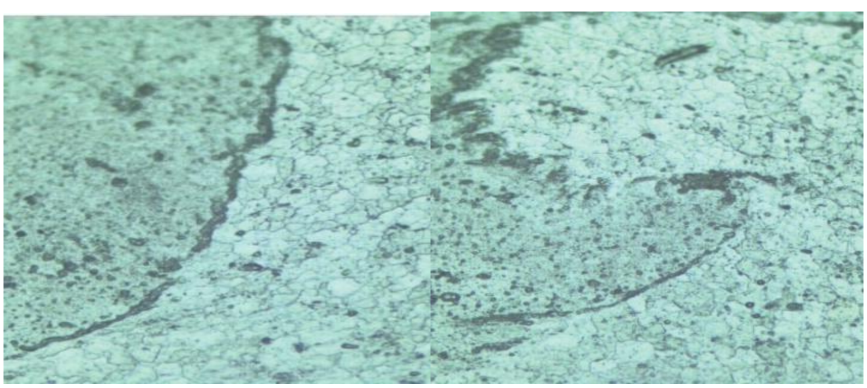

Fig.4. SEM Image of weldment done in air and underwater

IV. CONCLUSIONS

Butt joint configuration of Al6061 and AZ31 using FSW in air and in Underwater with three different process parameters of spindle rotation, welding speed and tool pin profile were welded successfully and the following conclusions were made.

- The results of the hardness test showed that the hardness were maximum in underwater FSW at the stir zone than other regions due to sudden cooling effect due to which the grains become finer resulting the increasing in hardness value.
- The microstructure of Friction Stir Welded samples done in underwater showed the distinct grain refinement seen between AS and RS of the weldment, which is possible due to the reduction in temperature during the welding process.
- From the above results it is clearly indicates the hardness depends on the size of the grain structure, lesser the grain size increases the hardness, thedecrease in grain size is due to the reduced temperature during the Underwater FSW process.

REFERENCES

[1]Banglong Fu, Guoliang Qin, Fei Li, Xiangmeng meng, Jianzhong Zhang, Chuansong W u , *Friction stir welding process of dissimilar metals of 6061-T6 aluminum alloy to AZ31B magnesium alloy, Material processing and technology, 218(2015).38-47*.

[2] Cao. X, Jahazi M, *Effect of welding speed on the quality of friction stir welded butt joints of a magnesium alloy, Material and Design, 30(2009).2033-2042.*

[3] Hui-jie ZHANG, Hui-jie LIU, Lei YU,*Thermal modeling of underwater friction stir welding of high strength aluminum alloy ,Transaction of Nonferrous Metals Society of china, 23(2013).1114-1122.*

[4]Venkateshwaran p, Reynolds A.P,*Factors affecting the properties of friction stir welds between aluminum and magnesium alloys , Material Science & Engineering, 54(2012).26-37.*

[5] Zhang H. j, Liu H.J, Yu L,*Microstructure and mechanical properties as a function of rotation speed in Underwater friction stir welded aluminum alloy joints, Materials and Design, 32(2012). 4402-4407.*

[6] Yong Zhao, Zhengping Lu, Keng Yan and Linzhao Huang,*Microstructural characterizations and mechanical properties in underwater friction stir welding of aluminum and magnesium alloy , Materials and Design, 65(2015).675-681.*

[7] Rao H. M, Ghaffari B, Yuan W, Jordan. J. B, Badrinarayan H,*Effect of process parameters on microstructure and mechanical behaviors of friction stir linear welded aluminum to magnesium , Materials science & Engineering, 651(2016).27-36.*

[8]Mirnov S, Onuma T, Sato Y. S, Kokawa H,*Microstructure evolution during friction stir welding of AZ31 magnesium alloy, ActaMaterialia, 100(2015).301-312.*

[9]Rathinasuriyan C, Senthil Kumar V.S, Avin Ganapathi Shanbhag,*Radiography and Corrosion Analysis of Sub-merged Friction Stir Welding of AA6061-T6 alloy, Procedia Engineering, 97(2014).810-818.*

[10]Mofid M.A, Abdollah-Zadeh A, MalekGhaini,*The effect of water cooling during dissimilar friction stir welding Al alloy and Mg alloy, Materials and Design, 36(2012).161-167.*