"An experimental approach to study the effect of welding parameters on mechanical and microstructural properties of al 6061 alloys by friction stir welding"

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Abstract - Aluminum alloy 6061 is among the most desirable alloy for use in different industries because it is productively lightweight and demonstrates better mechanical and micro structural properties. In structural applications that require integration but are difficult to join using conventional welding procedures, aluminum alloy is used. The aerospace and automotive sectors have shown a great deal of interest in a sturdily joining procedure called friction stir welding because it can generate joints without flaws, especially for light .The purpose of this examining the influence of variables through an experiment on the characteristics of Aluminum alloy 6061. The chosen material was welded utilizing a combined with several variables, including tool shoulder diameter (18 mm and 20 mm), welding speed (20 mm/min), and tool rotating speed (1950 rpm and 3080 rpm). The link between UTS and weld pitch was found to be linear. At 3080 rpm, 40 mm/min, and a 20 mm tool shoulder diameter, The most amount possible of UTS, or 238.4 N/mm2, was attained. The study also showed that the link between grain size and weld pitch was inversely proportional.

Keywords—friction stir welding, tool rotation speed, welding speed, tensile strength, microhardness

I. INTRODUCTION

FSW is a type of joining technique that melts and plasticizes metal on both faces of a joint to create a robust, practical weld, according to a survey. A rotating cylindrical tool creates friction. The connecting does not contain filler metal. [Hirata et al., 2007]. For reordering the microstructure of metals and metal alloys, friction-generated heat is more successful than other methods to fuse weld.FSW can, however, be a slower approach. A revolving, non-consumable weld tool that advances the operation by slicing into the base material is used. A plasticized tubular shaft forms around the revolving pin as a result of friction heatthe plasticized material is pushed to the back of the pin by the welding tool's pressure, where it cools and solidifies.Due to its high heat conductivity, aluminum alloy is challenging to weld using conventional techniques, leading to flaws like porosity and cracks, among other things [Xu et al., 2013]. So, FSW is being used more and more. Since aluminum is challenging to weld using the arc process but is very easy to weld using FSW, the procedure is particularly well suited to butt and lap joints in aluminum. FSW is a new and highly appealing technology that can help you get around these problems. FSW uses less energy, reduces material waste, prevents radiation and hazardous gases from being produced. The FSW is a promising green and eco-friendly technology because of its energy efficiency, environmental friendliness, and adaptability.

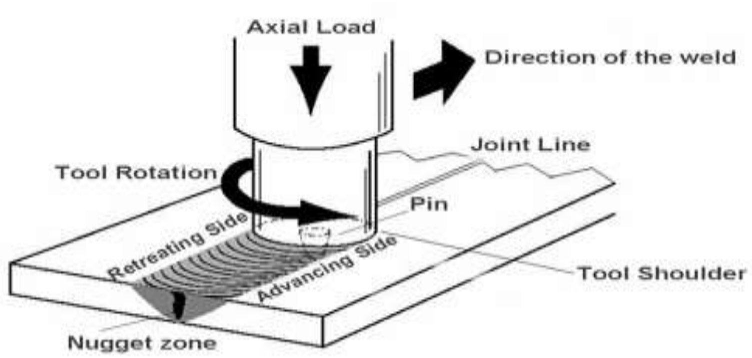

Figure-1. Illustrative of Friction Stir Welding

Alloy

Alloys in which aluminum (Al) predominates are called aluminum alloys. Different materials are used as alloying components. The two primary divisions are wrought alloys and casting alloys, which are further divided into heat and non-heat-treatable groupstwo primary categories.

Aluminum-based alloys have had a substantial impact on many different kinds of manufacturing industries. Aluminum-magnesium alloys have a tendency to be lighter than typical AL alloys and significantly less combustible than alloys with a high magnesium content. Alloys made of aluminum are categorized according to international standards. A four-digit number preceded by a code that represents the indication of temper can be used to identify these alloys. The first digit denotes the primary alloying element. Numero two symbolizes several alloy combinations. The last two numerals stand in for various alloy variations. The final correlation between the temper designation code and various strengthening techniques.

II. MATERIAL AND METHODS

Material

Magnesium and silicon,there are two primary alloying elements in the precipitation -hardening aluminum alloy 6061. Its original name was "Alloy 61S," and it has unique characteristics. This is one of the most preferred AL alloys for regular usage..

The Al6061 alloy used in the transportation sector is one popular alloy that could benefit from the usage of FSW joints [Krishnan, 2002]. This alloy is reasonably priced, has excellent strength, and is ductile. AI alloy is frequently MIG welded, laser welded, or riveted in industrial applications. However, these techniques might be expensive, ineffective, detrimental to macroscopic features, or add load. If the required study is done on FSW joints of Al6061, FSW offers a financially advantageous alternative.

As a result of the production of a transparent, protective layer of aluminum oxide, surfaces made of aluminum alloy will maintain their appearance of shine in a dry environment. When other metals and an aluminum alloy come into touch electrically that have larger negative corrosion potentials than aluminum, galvanic corrosion can happen in a moist environment.

To use friction stir welding to attain superior mechanical and microstructural properties, correct tool material selection and tool design are essential.

A productive manufacturing effort supported by AISI and SAE resulted in the development of a tool steel categorization system that categorizes the most popular tool steels into seven major groups. To link 6061 Al, it was necessary to select the proper steel with the proper distinctive features from among the range of available steels and alloys. Throughout the welding procedure, the tool's tip temperature may rise to 500° C, based on the kind of material that is being welded. The material for the tool must be strong, durable, and wear-resistant at high temperatures. Cold-work equipment for the current task, high carbon, high chromium hardened kind of steel's tool has been chosen due to its unique characteristics. The price and accessibility of this tool steel were other factors in the decision [Singh et al., 2013].

Method

This investigation's material was 210mm x 210mm x 6mm in size. However, for friction stir welding, the proper dimension for welding was 150mm x 75mm. To create eight frictions stir welded joints with various specifications, sixteen 152mm x 77mm plates were divided into sixteen parts. To ensure that interfaces are properly aligned, cut edges are then finalized with a filling process. Table No. 2 contains the parameters.

Table 2.Corresponding Specimen Number Specifications throughout the Study

Specimen No	Tool shoulder Diameter (mm)	Welding speed (mm/min)	Rotational speed(rpm)	Weld pitch (mm/min rpm)
1	18	20	1950	0.0102
2	18	40	1950	0.0205
3	18	20	3080	0.0064

4	18	40	3080	0.0129
5	20	20	1950	0.0102
6	20	40	1950	0.0205
7	20	20	3080	0.0064
8	20	40	3080	0.0129

III. RESULTS

The major finding of this experimental work, which looked at characteristics of FSW of AL 6061 alloy, is as follows:
It was discovered that base metal 6061 exhibited the best qualities for friction stir welding withtool shoulder diameter of 20 mm and a high weld pitch of 0.0129 mm/rpm, a noticeably high UTS value of 238.4 N/mm2 was produced. The right amount of heat generation, material movement, and grain refinement and ductility allowed for this to happen. The outcome of mechanical properties was observed with the various parameters which used in this experiment. A 3080 rpm tool rotation speed, 40 mm/min welding speed, and a 20 mm tool shoulder diameter were determined to produce the highest value of UTS. With a 1950 rpm tool rotation speed and an 18mm tool shoulder diameter, the lower UTS 230 value was attained.UTS rose as welding speed increased, resulting in a high stir rate and an expansion of the TMAZ and HAZ regions. The fault in tunnel was also discovered. The fragments of the specimens came from the area between TMAZ and SZ.The tunnel flaw and the intense spinning tool caused the impact strength's value to slightly fall. Brittleness and excessive heat input were noted in the specimen.

Welding settings have little impact on the reported impact strength. However, a little reduction in impact value was seen as rotational speed increased, likely as a result of the significant heat generation that result in a low level of brittleness.

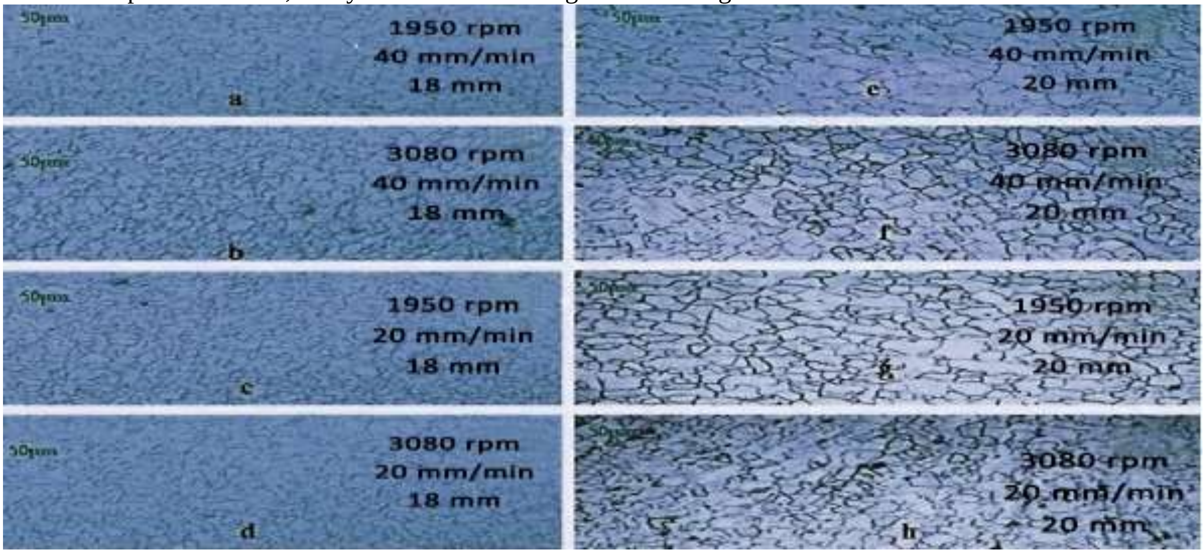

Figure-2. Microstructural Analysis

The SZ, TMAZ, HAZ, and base material, respectively, are four zones that make up the weld's microstructure. Due to the various variations in material strain rates, grain size does alter. The grain structure of the base material and the heat-affected zone was nearly identical. Microstructural investigation led researchers to the conclusion that the fine and equiaxed grain structure in SZ was a result of dynamic recrystallization. Due to limited heat input, grain size reduces as weld pitch increases.

Due to minimal heat generation and quick cooling, grain size grows as welding speed and rotational speed are increased. Due to high heat input, it was also noted that grain size increased as tool shoulder diameter rose.

Grain size influences microhardness. The value of micro hardness dropped as particle size rose. With a 20mm tool shoulder diameter and a tool's maximum rotating speed, 106.2Hv was measured. There had been enough stirring for this.

IV. REFERENCES

[1]. Afrin,N Chen ,D Cao,X and Jhazi M (2007), "Micro structure and tensile properties of Friction Stir Welded AZ31B magnesium alloy." Material Science and Engineering. Vol.472 pp 179-186

[2]. Babu, K; B; N; Kumar, A; P; Davidson, M; J; 2011 "A review of friction stir welding of AA6061 aluminum alloy", ARPN Journal of Engineering and Applied Sciences, Vol. 6, NO. 4, pp 61-63.

[3]. Barlas, Z., &Ozsarac, U. (2012). "Effects of FSW parameters on joint properties of AlMg3 alloy. Welding Journal," 91(1), 16S-22S.

[4]. Blignault, C. (2002). "Design, development and analysis of the friction stir welding process." MTME thesis, Faculty: Electrical, Industrial & Mechanical Engineering Port Elizabeth Technikon.

[5]. Casalino, G., Campanelli, S. and Mortello, M., (2014), "Influence of shoulder geometry and coating of the tool on the friction stir welding of aluminium alloy plates", Procedia Engineering, Vol. 69, pp., 1541-1548.

[6]. Cavaliere, P., Squillace, A. and Panella, F., (2008), "Effect of welding parameters on mechanical and microstructural properties of AA6082 joints produced by friction stir welding", Journal of Materials Processing Technology, Vol. 200, pp.,364-372.

[7]. Chen, H. B., Yan, K., Lin, T., Chen, S. B., Jiang, C. Y., & Zhao, Y. (2006). "The investigation of typical welding defects for 5456 aluminum alloy friction stir welds." Materials Science and Engineering: A, 433(1), 64-69.

[8]. Chowdhury , S. M., Chen, D. L., Bhole, S. D., & Cao, X. (2010), " Tensile properties of friction stir welded magnesium alloy, effect of pin thread orientation and weld pitch," Material science and Engineering, vol A527 pp 6064-6067.

[9]. Chowdhury, S. M., Chen, D. L., Bhole, S. D., & Cao, X. (2010), " Effect of pin tool thread orientation on fatigue strength of friction stir welded AZ31B-H24 Mg butt joints," Procedia Engineering vol. 2 pp 825-833.

[10]. Dinaharan, I., Kalaiselvan, K., Vijay, S.J. and Raja, P., (2012), "Effect of material location and tool rotational speed on microstructure and tensile strength of dissimilar friction stir welded aluminum alloys", Archives of Civil and Mechanical Engineering, Vol. 12, pp.,446-454.

[11]. Gibson, B.T., Lammlein. D.H., Prater, T.J., Longhurst, W.R., Cox, C.D., Ballun, M.C., Dharmaraj, K.J., Cook, G.E. and Strauss, A.M., (2014), "Friction stir welding: process. Automation and control", Journal of Manufacturing Processes, Vol. 16, pp.,56-73.

[12]. Hirata, T., Oguri, T., Hagino, H., Tanaka, T., Sung, W.C., Takigawa, Y. and Higashi, K., (2007), "Influence of friction stir welding parameters on grain size and formability in 5083 aluminum alloy", Materials Science and Engineering, Vol. 456, pp.,344-349.

[13]. Hou, X., Yang, X., Cui, L., & Zhou, G. (2014). "Influences of joint geometry on defects and mechanical properties of friction stir welded AA6061-T4 T-joints".Materials& Design, 53, 106-117.

[14]. Jedrasiak,P.,Shercliff, H. R.(2019) "Small strain finite element modelling of friction stir spot welding of Al and Mg alloys" Journal of Materials Processing Technology, 263, 207-222.

[15]. Hwang, Y. M., Kang, Z. W., Chiou, Y. C., & Hsu, H. H. (2008). "Experimental study on temperature distributions within the workpiece during friction stirs welding of aluminum alloys." International Journal of Machine Tools and Manufacture, 48(7), 778-787.

[16]. Khan, N. Z., Khan, Z. A., &Siddiquee, A. N. (2015). "Effect of Shoulder Diameter to Pin Diameter (D/d) Ratio on Tensile Strength of Friction Stir Welded 6063 Aluminium Alloy". Materials Today: Proceedings, 2(4), 1450-1457.

[17]. Klobar, D; Kosec, L; 2012. "Friction-stir welding of aluminium alloy",Material and Technology, 46(5), pp 483-488.

[18]. Kim, Y. G., Fujii, H., Tsumura, T., Komazaki, T., & Nakata, K. (2006). "Three defect types in friction stir welding of aluminum die casting alloy." Materials Science and Engineering: A, 415(1), 250-254.

[19]. Krishnan, K. N. (2002). The effect of post weld heat treatment on the properties of 6061 friction stir welded joints. Journal of Materials Science, 37(3), 473-480.

[20]. Kumbhar, N. T., &Bhanumurthy, K. (2008). "Friction stir welding of Al 6061 alloy." Asian J. Exp. Sci, 22(2), 63-74.

[21]. Lakshminarayanan, A. K., Balasubramanian, V., &Elangovan, K. (2009). "Effect of welding processes on tensile properties of AA6061 aluminium alloy joints." The International Journal of Advanced Manufacturing Technology, 40(3-4), 286-296.

[22]. Lee ,W.B. and Yeon, Y (2003), "Joint properties of Friction Stir welded AZ31B-H24 Mg alloy" Materials Science and Technology. Vol.19 pp 785-790.

[23]. Liu, G., Murr, L. E., Niou, C. S., McClure, J. C., & Vega, F. R. (1997). "Microstructural aspects of the friction-stir welding of 6061-T6 aluminum.Scriptamaterialia," 37(3), 355-361.

[24]. Malarbizhi, S and Balasubramanin, V (2012),"Influences of tool shoulder Diameter to plate thickness ratio (D/T) on stir zone formation and tensile properties of FSWed dissimilar joints of AA6061 aluminum and AZ31B Mg alloys" Materials and Design, vol. 40 pp 453-460.

[25]. Mishra, R.S. and Ma, Z.Y., (2005), "Friction stir welding and processing", Materials science and Engineering, Vol. 50, pp.,1-78.

[26]. N. ShanmugaSundaram , N. Murugan 2010 "Tensile behavior of dissimilar friction stir welded joints of aluminiumalloys",Materials and Design 31, pp 4184–4193.

[27]. Padmanaban,G and Balasubramanin (2008) , "Selection of FSW tool pin profile, shoulder diameter and material for joining AZ31B magnesium alloy .An experimental approach."Material and Design vol.30 pp 2647-2656.

[28]. PalaniveI, R; Koshy, P; Mathews, (2012) " Mechanical and microstructural behavior of friction stir welded dissimilar aluminum alloy", IEEE-International Conference On Advances In Engineering, Science And Management (ICAESM -2012), pp 7-12.

[29]. Palanivel, R., Mathews, P.K., Dinaharan, I. and Murugan, N., (2014), "Mechanical and metallurgical properties of dissimilar friction stir welded AA5083-H111 and AA6351-T6 aluminum alloys", Transactions of Nonferrous Metals Society of China, Vol. 24, pp.,58-65.

[30]. Pareek, M., Polar, A., Rumiche, F., &Indacochea, J. E. (2007). "Metallurgical evaluation of AZ31B-H24 magnesium alloy friction stir welds." Journal of materials engineering and performance, 16(5), 655-662.

[31]. Rajesh,N.,Hynes,Jesudoss.(2021). "An experimental insight of friction stirs welding of dissimilar AA6061/MG AZ 31 B joints". Journal Engineering

[32]. Manufacture Vol 236, 6-7

[33]. Rodriguez, R. I., Jordon, J. B., Allison, P. G., Rushing, T., & Garcia, L. (2015). "Microstructure and mechanical properties of dissimilar friction stir welding of 6061- to-7050 aluminum alloys". Mater Des, 83, 60-65.

[34]. Rose,AManiseka,K and Balasubramanian, V(2010) "Effect of axial force on microstructure and tensile properties of friction stir welded AZ61A magnesium alloy" Transaction of Non ferrous metals society of China. Vol. 2 pp 974-984.

[35]. Shen. Z., Yang, X., Yang, S., Zhang, Z., & Yin, Y. (2014). “Microstructure and mechanical properties of friction spot welded 6061-T4 aluminum alloy.” Materials & Design, 54, 766-778.
[36]. Singh,G and Singh,K(2011), “Effect of process parameters on microstructure and mechanical properties in friction stir welding of aluminum alloy ,” Indian institute of metals.
[37]. Singh, V. P., Patel, S.K., Ranjan, A., Kurichen, B.,(2020) “Recent Research Friction stir Welding of Aluminum- Magnesium Alloy: A Critical Review Progress in solid state” Journal of Materials Processing Technology, 9(3), 6217-6256.
[38]. Singh, I., Cheema, G. S., & Kang, A. S. (2014). “An experimental approach to study the effect of welding parameters on similar friction stir welded joints of AZ31B-O Mg alloy.” Procedia engineering, 97, 837-846.
[39]. Sivashanmugam, M; Ravikumar, S; Kumar, T; SeshagiriRao, V; Muruganandam, D; 2010 “ A Review on Friction Stir Welding for Aluminium Alloys”, IEEE, pp 216-221.
[40]. Technical Hand book on Friction Stir Welding
[41]. Threadgill, P. L., & Johnson, R. (2004). “The potential for friction stir welding in oil and gas applications.” In The Fourteenth International Offshore and Polar Engineering Conference. International Society of Offshore and Polar Engineers.
[42]. Xu, W., Liu, J., Zhu. H. and Fu, L., (2013), “Influence of welding parameters and tool pin profile on microstructure and mechanical properties along the thickness in a friction stir welded aluminum alloys”, Materials and Design, Vol. 47, pp.,599-606.
[43]. Zhang, H Lin, S.B. Wu, L and Ma L (2005), “Defect formation procedure and mathematic model for defect free Friction stir welding of magnesium alloy.” Material and Design vol. 27 pp 805-809.