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Research Article

Prediction Of Thermally Preheated Friction Stirs Welding Joint Of Aluminium Alloy By AI Technique

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ABSTRACT

Aluminium alloys are broadly used in aerospace industry, automotive industry, railways and in marine industry due to its resistance to corrosion, light weight and high strength to weight ratio. Welding strength on aluminium alloy has been always a puzzling by using conventional techniques. In this research, frictions stir welding technique is used to weld two plates of aluminum alloy 8011 having a cross section of 100 x 50 x 5 mm thick. These metals are welded under variation of three control parameters and remaining parameters is fixed. The three control parameters each are two levels has been design their combination for experiment. As per the experiment design work pieces are passed through FSW process and prepare specimen according to ASTM E8 specification. Specimen was tested for strength properties such as tensile strength respectively. The result of ultimate tensile strength and strength was predicted by Machine Learning Artificial Intelligent (MLAI) technique.

Keywords: Friction Stir welding (FSW), Aluminum alloy 8011, Tensile Strength, Charpy test.

1. Introduction

The ability to change properties in a very versatile manner is unique property of aluminum. The pure aluminum metal makes complicate alloys by changing properties. There are more than a couple of hundreds alloys of aluminum alloys and many are being modified from them internationally. Aluminum alloys have very low density compared to steel. Without an application of heat FSW immediately joint two metals and neglecting cooling phase from liquid to solid over fusion welding methods. Welding defects such as solute redistribution, porosity, solidification cracking and many more are not an issue during FSW. The ability of low concentration defects in FSW materials with low tolerant and variations in parameters. The schematic diagram of FSW process is shown in Fig 1.

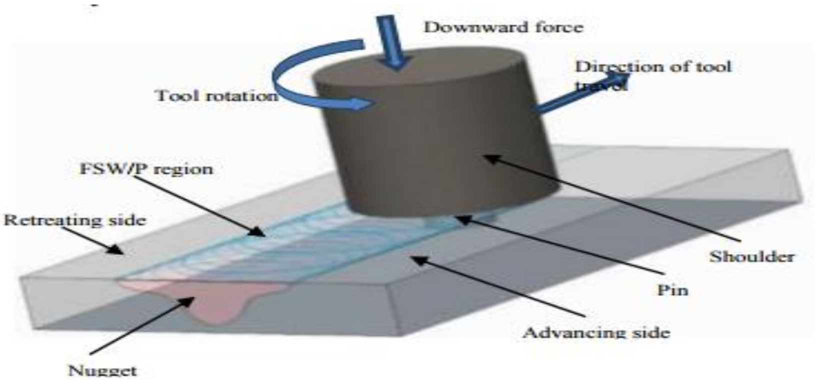


Fig. 1 Schematic Drawing of friction stir welding [8]

Observing the various research literatures it is found that the FSW tool rotation speed generate the temperature between the work-piece which offers flow the material in between them and make a bond without reaching its melting point. The frictional heat generated at the interface due to rubbing tool material on softens material, the soft metal gets extruded due to the compressive forces and the joint forms in the clear material, the relative motion of tool is stopped after passing through the material and compressive forces are increased to form a weld before the weld is allowed to cool. The extensive deformation during welding material is unable to accommodate due to insufficient weld temperatures, low rotational speeds or high traverse speeds. Low temperatures generation is due to minimum speed of tool rotation and so reduces the continuity of the bond between the materials from each side of the weld. Optimum stir welding for aluminum alloy is possible above 1000 RPM of FSW tool rotation but in case of steel material it is possible in minimum speed like 600RPM, it is due the grain size of material and many other properties were involved.

2. Review of Past Work

The performance evaluation of a physical vapour deposition coating on Cement Carbide Equipment FSW Friction Alloy Welding used friction welding equipment in the processing of TI alloy sheets [2]. A coating of AlCrN material was applied to the WC device to improve its wear resistance, thermal shock stability and hot hardness. Tool demotion was evaluated for micro core microscopy to allow electron core strength to observe the wear mechanism. The conventional joining process in FSW even further freezed, partly increased the melting point temperature on the metal. This friction temperature might also produce plasticity stage in metal, resulting in aggressive reintegration. The investigation found that overlaying had an effect on the degree of diet consequence of the two term substrate, the second would have a layer of overlaying and it was observed the interface in the zero set regions and overlaid the forward direction [5]. Composite coatings by refractories were provided utilising hard facing procedures to the surface of the FSW tool material. For coating and hard facing, carbide powders with other hard element were selected. The binder NiCrFeBSiC was chosen to make because of the self-fluxing alloy powder [13]. Friction stir welding observed austenitic chrome steel joints manufactured with the carbide hard facing on tool showed less reduction in toughness property when fabricated at 400 rpm and 110 mm/min rotating and welding rates, respectively. The strong structural, hardness, stability, fracture toughness, and oxidation resistance of hard faced composite tool could explain its exceptional hot shear wear resistance. Aluminum appeared to be a superior protected material, finding potential applications in the aerospace and defence industries, using friction stir welding (FSW) [6].

Due to the friction stir welding process in the spindle, the friction stir tool required to produce a large amount of heat, which greatly reduced thermal welding efficiency, and it caused the spindle bearings to have a destructive effect. Finite element analysis was used to suggest heat generation during FSW. It could be seen that three types of methods of stopping the flow of heat from the instrument to the spindle were studied [11]. The friction stirrer moved the joints on the 2 mm thick Ti-6Al-4V work-piece. The moving pin, which caused extensive harm to the instrument in the event of a process, was also thought to be a unique design [4].
Friction stir welding (FSW) devices processing different surface ephemeral temperatures were effectively measured at the top of the surface during the FSW, and the intermediate of the tester thickness, and the centre at the bottommost surface. In that case the results confirmed an unproductive value of the tool pin area, which was defect free in the FSW 7075-O process of the 7075-O Al alloy range, with a 50 mm / min welding speed at 500 rpm. The pin area was the high side of the result, resulting in higher tensile strength in the semi-circular pin, with a higher proportion (29.83%) of the pin side area generated at the FSW process joint with higher tensile strength .

3. Motivation of Work

Due to their high strength, low weight and ductility, of two similar aluminum alloys have found difficulty in welding. Thus a more efficient approach is required to serve the industry in a better way. The aluminum alloy 8011 is welded for commercially purpose because these alloys are difficult to weld in arc-fusion weld due to inherent porosity problem during arc welding. Particularly, it has been observed that holding time, temperature & cooling medium are the main factors which produce weld embrittlement. The main objective of present work is to minimize rotation of FSW tool with better response i;e tensile strength and charpy test of friction stir welded on aluminum alloy 8011 grade. The butt welded samples in particular were included for comparison purposes with the Self Reacting samples. With this information it should be able to provide input parameter to help reduce the likelihood of failures caused by this phenomenon and predict strong weld in terms of strength and toughness.

4. Methods and Material

Friction Stir Welding [20] tools consist of a shoulder and a probe which can be integral with the shoulder or as a separate insert possibly of a mild steel material. The design of the shoulder and of the probe is very important for the quality of the weld. The probe of the tool generates the heat and stirs the material being welded but the shoulder also plays an important part by providing additional frictional treatment as well as preventing the plasticized material from escaping from the weld region. Fig. 2 shows Friction Stir Welding tool. A specially designed mild steel welding tool is used for FSW process. The tool used in this study has a 20 mm shoulder diameter and a 4 mm long threaded pin with a diameter of 5 mm. FSW tool was prepared by pass of 300°C temperature with holding time 60 min and then it cool in water medium to increase the strength of pin probe.

Fig. 2 FSW tool

According to literature review welding speed, rotational speed and shoulder diameter is the major factor which affects the strength of welding joints, with these factors is taken fixed for welding because it is already predicted in past work. The rotational speed best performance level are 800 rpm, welding speed are in between 15 mm/min and the shoulder diameter are perform in 20 mm. The other parameters are focused in this work that is when temperature increases will reduce the grain size of material which increases the hardness of material [18-19]. Temperature of workpiece, holding time at that temperature and cooling medium apply will provide the better friction temperature between the wokpiece and job. This friction temperature helps to weld the joint. The variation of parameters used in this experimental work is temperature on work-piece, holding time & cooling medium air is 1 and water is 2. The different values of the controllable parameters and their levels are shown in Table 1.

Table 1 Process parameter

Factor	**Level 1**	**Level 2**
TEMPERATURE (Temp) (IN °C)	250	300
HOLDING TIME (HT) (IN MINUTE)	40	60
COOLING MEDIUM (CM)	1	2

Whare as
1 = Air
2 = Water

As per the full factorial design and level FSW process are passed to make welding join under the condition. The work-piece are prepared by passing through the different temperature with holding time in laboratory oven, after passing laboratory oven work-piece is passed through cooling medium according to the full factorial design.

Tensile Test

The tensile tests are done on the fabricated welds according to the standards given by the ASTM (American Society for Testing of Materials). The specimens are marked for identification: the center of the weld is identified and selected for the test specimen. The tensile test has been carried out in Universal Testing Machine (UTM) with applying load for tensile test is 40KN as shown in Fig 3. The specimen is loaded as per the standard, finally fails after necking and the ultimate tensile strength. Tensile Test specimens are cut as per standard dimension of ASTM E8 as shown in Fig 4.

Fig. 3 Tensile Testing Machine

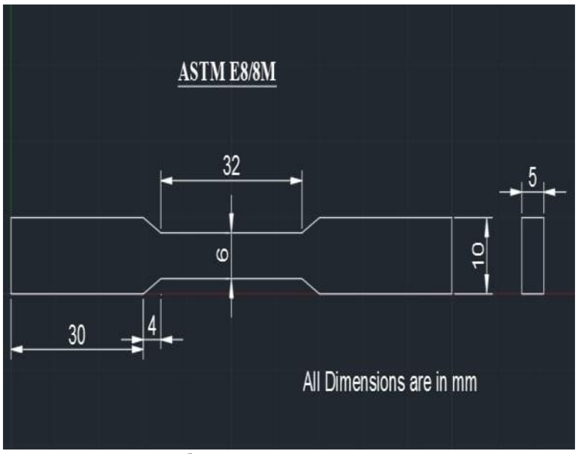


Fig 4 Tensile Test Specimen Dimension

5. Procedure

Initially prepare the machine for friction stir welding on aluminum alloy of grade 8011. For this experiment converts the vertical milling machine into the friction stir welding machine by changing the tool setup. In this experiments 5 mm sheet of aluminium alloy 8011 plates were used to join by Friction Stir Welding. The prepared work-pieces as per the combination of factors and level were passed through FSW machine with fixed speed of rotation and feed. The rotating tool was then plunged into the work piece till the shoulder touches the surface of work piece. Fixed feed are given to the work-piece along the centreline, the rotating tool produce the friction heat which allow the flow of metal between the work pieces to make weld joint as shown in Fig 6.

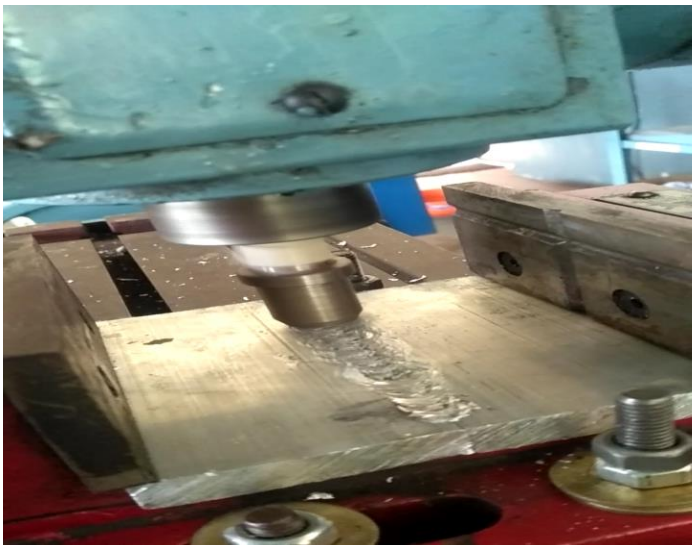


Fig. 6 FSW Process

Same process is repeated as per combination of factors and level and prepared 08 welding specimen. Following the ASTM standard prepare the specimen for tensile test and Charpy test which is tested in their respective equipment. The tensile test has been carried out in Universal Testing Machine (UTM). The specimen is loaded as per the standard. The specimen finally fails after necking and the ultimate tensile strength. Yield stress, and percentage of elongation have been evaluated. Responses data of tensile test were tabulated in table 3 and specimen are show in the Fig 7.

(a) (b)

Fig. 7 ASTM Standard Specimen

Table 3 Responses of Test

S. No.	Temp	HT	CM	Ultimate Tensile Strength (UTS) MPa
1	250	40	1	55
2		40	2	72
3		60	1	64
4		60	2	78
5	300	40	1	61
6		40	2	78
7		60	1	68
8		60	2	82

Responses of ultimate tensile test presented in Table 3. Final tensile test reactions showed that the water-treated cooling joint had higher tensile strength and made the best welding joint as it broke through the neck of the fourth and eighth specimens. Again work-piece material were passed under condition 300oC temperature with holding time 40 min and cooled with water, same as eighth workpiece material were also passed under condition 300 oC temperature but variation in holding time 60 min and cooled with water. After passing the condition it was welded by FSW which was a re-test of the best welding joint.

Micro Structure Study

This study is to make a view of the material properties in the grain growth at the welded area and the base metal. The microstructures were taken only for those samples which break from neck that is fourth and eighth specimen. The microstructures are shown in Fig 8. The results of the microstructure revealed in Table 4 shows the properties of the specimens at different regions like welded zone and the base metal. As seen in the microstructure specimen 4 have found cracks in welding zone where as these cracks are missing in specimen 8, it is clear that welding joint of specimen is more stronger the other welding and also it strength value is higher than the other welded metal.

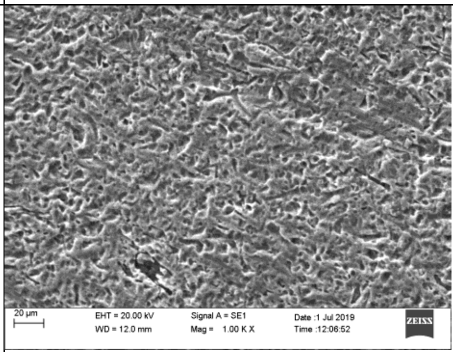
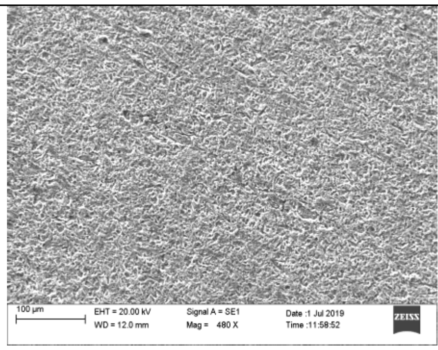
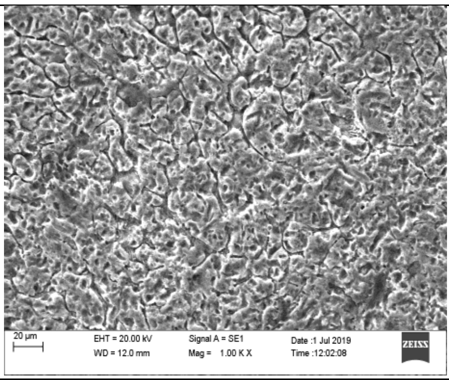
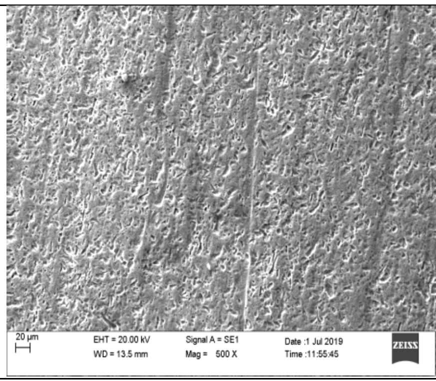
Sample	**Welded zone**	**Base metal**
Sample-8		
Sample-4		

Fig. 8 Micro structures of different specimens

Table 4 Micro structure Analysis

Specimen	**Area**	**Microstructure properties**
	Weld zone	This microstructure shows dendrites structure
specimen 8	Base metal	This microstructure shows light structure of austenite
	Weld zone	This microstructure shows dendrites structure
Specimen 4	Base metal	This microstructure shows light structure of austenite

6. Machine Learning Artificial intelligent

ML usually provides systems with the ability to learn and enhance from experience automatically without being specifically programmed and is generally referred to as the most popular latest technologies in the fourth industrial revolution Artificial intelligence (AI), particularly, machine learning (ML) have grown rapidly in recent years in the context of data analysis and computing that typically allows the applications to function in an intelligent manner [20]. Polynomial regression: Polynomial regression is a form of regression analysis in which the relationship between the independent variable x and the dependent variable y is not linear, but is the polynomial degree of nth in x [19]. The equation for polynomial regression is also derived from linear regression

$$Y = C_1 x + C_2 x + C_3 x + E \quad ....(1)$$

Here, Y is the predicted/target output, C_1, C_2, C_3, are the regression coefficients, x is an independent/ input variable and E is intercept. In simple words, it said that if data were not distributed linearly, instead it is then used multiple regressions to get desired output. After predicting the program response of UTS were shown in table 4.

Table 4 Predicted data by Python programming

S. No.	Temp	HT	CM	UTS
1	200	40	1	51.25
2	200	40	2	66.75
3	200	50	1	54.5
4	200	50	2	70
5	200	60	1	57.75
6	200	60	2	73.25

7	250	40	1	56.25
8	250	40	2	71.75
9	250	50	1	59.5
10	250	50	2	75
11	250	60	1	62.75
12	250	60	2	78.25
13	300	40	1	61.25
14	300	40	2	76.75
15	300	50	1	64.5
16	300	50	2	80
17	300	60	1	67.75
18	300	60	2	83.25

Predicted result were give maximum ultimate tensile stress 83.25 MPa under the condition of 300 oC temperature, 60 minute holding time and water cooling. It is further tested again which was observed 82 MPa for confirmatory test which is approximately close to predicted data.

7. Conclusion

Friction stir welding joint of Aluminum alloy 8011 are made successfully and their influence on mechanical properties of developed joints were investigate in terms of tensile strength. The tensile strength of welding joints extent depends on the all parameters that were temperature, holding time and cooling medium. As temperature increased, the hardness of material also increases depending on cooling medium which also affect the welding joint strength properties. Micro structure study verifies the strength of specimen 8 which have no cracks found in welded area due to change in grain sizes that were developed during welding process. Development of process parameter has to be predicting for strength and good impact bearable factor in future work. Machine learning artificial inteligent technique provides the prediction of UTS which was closest validate by confirmatory test.

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