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Effect of Under Surface Cooling on Tensile Strength of Friction Stir Processed Aluminium Alloy 6082

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Abstract **- Friction stir welding (FSW) is a new upgraded version of friction welding. This technology is used worldwide especially in automobile and aerospace industries due to some of its advantages over conventional fusion welding techniques. Friction stir processing (FSP) has recently emerged as a new technique for microstructural surface modification of various materials or for changing the properties of metal by producing intense localized plastic deformation in the material. Friction stir processing is proved to be a viable tool for improving the mechanical properties of materials. This technique works on the principles of FSW. The plastic deformation is produced by same way as in FSW by inserting a non-consumable shouldered pin tool in the work piece and by providing lateral movement to the tool. FSP also used as a method for depositing materials like tool steels, stainless steels and hard facings materials to improve the quality of an underlying metallic base material.**

Simultaneous cooling of the specimen during FSP is a new approach to further improve the microstructural properties. The results of tensile testing show that the tensile strength can be improved with simultaneous under-surface cooling in FSP.

Keywords: **Friction stir processing (FSP), tensile strength, under surface cooling, aluminum alloy6082.**

I.INTRODUCTION

Friction stir processing (FSP) is a solid-state metal working technique based on the ethics of friction stir welding (FSW)[1].Friction stir processing is a shortest route; solid-state processing technique with one-Stage processing that achieves microstructural refinement. Moreover the microstructure and mechanical properties of the managed zone can be accurately controlled by optimizing the tool design, FSP factors and active cooling/heating[2].Friction stir processing is used as post processing method for improving the surface quality and reducing porosity [3]. During FSP, the work piece involves intense plastic deformation at elevated temperature. Which lead to fine-grained microstructures. The fine grained micro-structure often resulted in excellent mechanical properties in non-heat-treatable aluminium alloys[4, 5]. More grain refinement can be achieved by minimising the grain growth [6].In FSP a rotating tool with pin and shoulder is inserted in a single piece of material for localised microstructure modification [1, 7, 8].Friction stir welding joints developed with and without in-process cooling showed lower tensile strength and percentage elongation than the base metal [9]. The hardness of the material can be improved by underwater FSW[10].

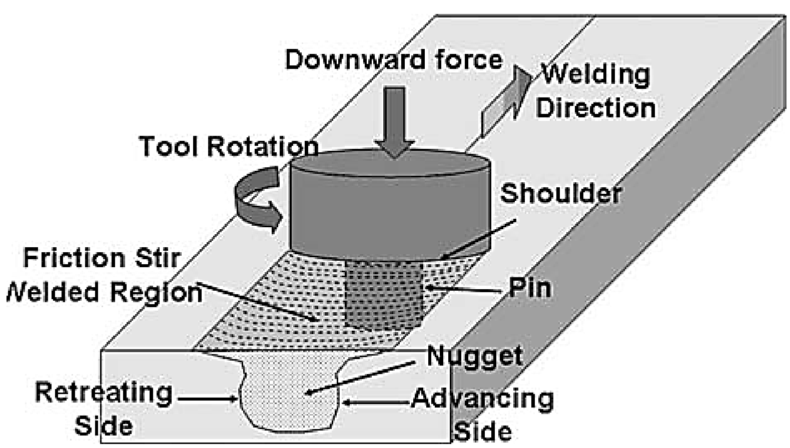

Fig.1.1: Set up of a FSW Process [7].

II.EXPERIMENTAL PROCEDURE

The work material used for this study was aluminum alloy (AA 6082). Aluminum 6082 from 6xxx series was selected for this investigation. 6xxx series was considered as it is highly used in aerospace industry due to their good strength to weight ratio, mechanical and corrosion resistant properties. Aluminum 6082 has excellent corrosion resistant properties. The chemical composition of AA 6082 alloy was tested on a global discharge spectrometer (Model: GDS 500A, Lecco, USA) and its composition is shown in Table 1.1.

TABLE 1.1: COMPOSITION OF WORK MATERIAL (% WEIGHT)[11].

Aluminium Alloy	Mn	Si	Mg	Cu	Zn	Fe	Al
6082	0.57	1.23	0.48	0.028	0.030	0.13	97.3

The material used as processing tool for this investigation was High Carbon High Chromium Steel rod of diameter 20 mm. The chemical composition of the tool material is given in Table 1.2.

TABLE 1.2: COMPOSITION OF TOOL MATERIAL (WEIGHT PERCENTAGE)[11].

Tool Material	C	Mn	Si	Cr	Mo	P	S	Fe
High Carbon High Chromium Steel	2.1	0.45	0.51	11.2	0.016	0.024	0.031	Balance

The fixture already used elsewhere [11] for holding the base plate during FSP was designed in house and fabricated at Dhiman Industries, Bathinda. The fixture consisted of a rectangular base of dimensions 150mm x 100mm x 26mm. The material of the fixture was mild steel. Galleries were made of dimensions 70 x 10mm using arc welding. Using vertical milling machine a pocket of 100mm x50mm was made with the help of end mill cutter. Two nipples were made by machining and were attached at the inlet and at outlet of fixture. The whole of the fixture shown in Fig.1.2, was fixed on the bed of milling machine with the help of sliding screw arrangements.

Fig. 1.2: Fixture clamped on the bed of CNC vertical milling machine[11].

The equipment used for FSP was a CNC vertical milling machine as shown in Fig.1.3 (already used in [11]). It was available at Research and Development Institute, Ludhiana, Punjab. The tool holder and the table of the machine were pneumatically controlled. The detailed specifications of the CNC vertical milling machine are presented in Table 1.3. The processing tool was griped in the collet of the vertical spindle of the milling machine that can move up and down. The automatic feed can be given to the table of the vertical milling machine in X, Y, Z direction. The processing tool was then rotated to a prescribed speed with respect to the normal of the work piece. First of all a hole was made in the work piece using drilling operation. The tool was then slowly plunged into the work piece material, until the shoulder of the tool touched the bottom surface of the material. A downward force was applied to maintain the contact between the work piece and the tool shoulder. Then a transverse force was applied in the processing direction by giving automatic feed to the work table along the length. Upon reaching the end of the last round of path defined, the tool was withdrawn[11].

TABLE 1.3: SPECIFICATIONS OF CNC VERTICAL MILLING MACHINE USED FOR FSP[11].

Make	Millitronics Partner, USA
Model	MDU 1500
CNC Control	FANUC O-i MATE MD
Motor Power	15/18 KW Gear Head Spindle
Maximum Load	600 Nm
Tool RPM	20 - 4500 RPM
Table Size	800 mm x 600 mm
X, Y, Z Movements	58”, 27”, 24”

Fig. 1.3: Vertical milling machine used for FSP[11].

III.PREPARATION OF SAMPLES FOR TESTING

Six mm thick plate of AA 6082 was cut in rectangular shape at slow speed with cooling, in order to avoid excessive temperature rise, so that the grain structure of the materials may not damage. After which, finishing of samples was done. The size of rectangular pieces was 100 mm x 50 mm x 6 mm. After FSP, the specimens were finished with the help of file. Then these specimens were cut into small pieces with the help of slitting wheel to perform the various tests. Some material from the top side had been discarded to obtain properly processed portion for the testing. The tensile samples were machined of properly. The standard American Society for Testing of Materials (ASTM E8M-04)[9] guidelines was followed for preparing the tensile test specimens and the dimensions of tensile test specimen are shown in Fig. 1.4.

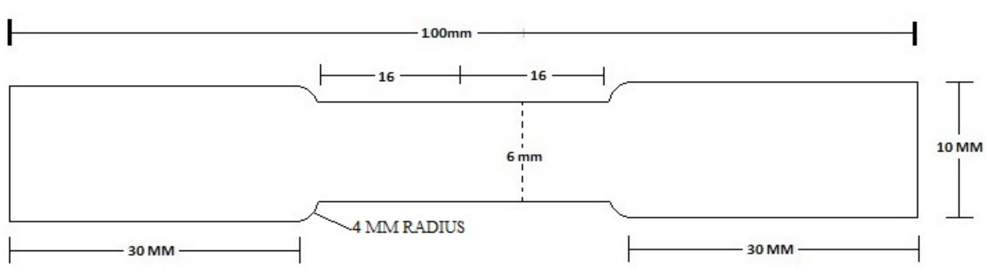

Fig. 1.4: Dimensions of tensile test specimen (in mm)

Total Length of Specimen	= 100 mm
Reduced Section Length	= 32 mm
Length of Grip Section	= 30 mm
Width of Grip section	= 10 mm
Gauge Length	= 16 mm
Thickness of specimen	= 6 mm
Center Width of Specimen	= 6 mm
Fillet Radius	= 4 mm

IV.RESULTS AND DISCUSSION

Results of Tensile Test:

The average values of tensile strength are listed in Table. 1.3. These average values are calculated from total three values and the values are plotted in the form of bar charts in Fig. 1.5.

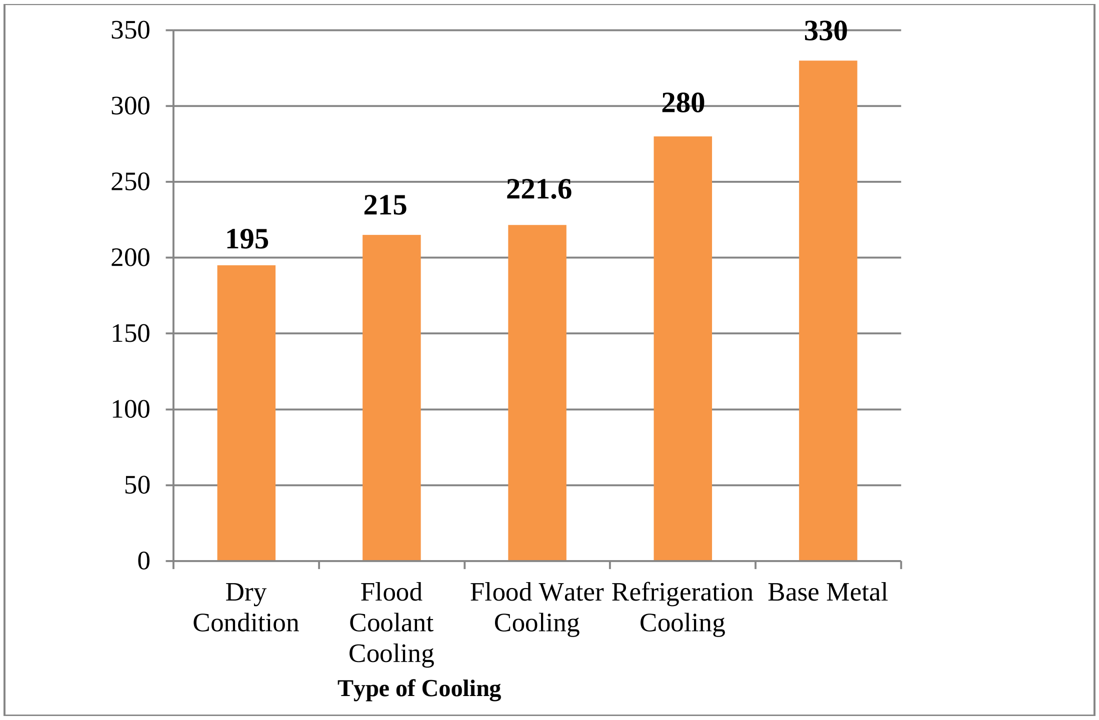

Fig. 1.5: Effect of cooling conditions on the Tensile strength of FSPed samples

From the results of tensile testing it has been found that with increase of hardness value under various cooling conditions its tensile strength also increase accordingly. It has been observed that value of tensile strength in the FSPed zone is lower than that of the base metal. The value of tensile strength obtained from the base metal was 330 MPa. The least value of tensile strength 195 MPa was obtained from the sample processed with dry condition. During flood coolant cooling and flood water cooling conditions the value of tensile strength was215 MPa and 221.6MPa respectively which is higher than that of dry condition and is lesser than that of refrigeration cooling whose tensile strength is 280 MPa. From all the conditions it is clear that tensile strength varies directly according to hardness. Tensile strength value is higher in case of refrigeration cooling as in this case large quantity of heat can be dissipated from bottom surface also along with top surface. Where as in case of other type of cooling conditions the heat dissipated will be from top surface.

Advantage of FSW is that the heat absorption effect of water can be utilized by immersing the whole work piece in water environment during the welding process. A large quantity of heat can be dissipated not only from the top surface but also from the lateral and bottom surface of the work piece. Consequently, the properties of all the locations of specimen can be effectively strengthened under this integral water cooling effect. Leading to an improvement in tensile strength of underwater joint [3, 12].

The maximum tensile strength of underwater joints is higher than that of the normal joints, further confirming the positive effect of water cooling on strength improvement for FSW of heat treatable aluminum alloys [10]

V.CONCLUSIONS

The conclusions drawn from the present investigation are as follow:

1. The result confirmed that that the value of tensile strength is improving with the effect of cooling. Dry condition produces less tensile strength than that of any other type of cooling.
2. It has been observed that no cracks and voids are present in the processed part. A small amount of porosity is present in some of the samples.

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