Experimental Evolution and Analysis of Mechanical Behaviour of Frication Stir Processed Aluminium Alloys

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Abstract— A standout amongst other procedure for enhancing mechanical properties is the Friction stir processing (FSP) which is such a niece process system utilized for refinement of microstructure, generation of surface composite and improve the mechanical characteristics. In this work friction stir process was used to modify the mechanical properties using SiC as particulate reinforcement on the plate of AA6063 which result into a formation of complete surface structural composite. SiC with mesh size 400 was utilized as reinforcement particulate in FSP. For this purpose, two main parameters were selected i.e. tool revolution per minute of 1000, processing speed of 30 mm/min, and 10 KN of axial load. For achieving friction stir processing HSS tool was made with circular threaded pin having diameter of shoulder is 18 mm, length of pin is 5.8 mm and diameter of pin is 6 mm . Modified VM" Vertical milling machine "was used for friction stir processing with different percentage of SiC into the groove the capacity of the machine is 7.5 hp and speed range is about 300-3000 rpm. The surface composites are created by taking the percentage as respectively (Al/0.5 %SiC, Al/1 Vol. % SiC and Al/1.5 Vol. %SiC). The modification in the microstructure like grain size, compactness of SiC particulate and wetness of SiC into the parent metal was observed by using OM" Dewinter make inverted microscope and scanned electron microscopy (FLEX SEM 1000 VP-SEM). The micro hardness profile along the transverse direction of the FSPed specimen was analyzed by BLUE STAR make Vickers micro harness tester.

Keywords: Friction Stir Processing, Vertical Milling Machine, Vickers Micro harness Tester

I. INTRODUCTION

In 1980, the worldwide production of aluminum was 15 million. Then in 2005, the worldwide production of aluminum reached 30 million. So in last 30 years, the worldwide production of the aluminum has reached almost double of its production in 1980. Al alloys are widely used in various applications i.e. in automobile industry, aviation industry and others. Because Al has good mechanical properties like lowdensityi.e.2.7 g/cm3, less weight, high strength, low melting point etc. so it is used for efficiency enhancement in the aviation and automobile components. Pure aluminum has less strength and stiffness and strength. Properties of pure aluminum like strength, stiffness, hardness etc. can be enhanced by small addition of other elements i.e. silicon, magnesium, copper etc. These aluminum alloys are widely use in structural, automobile and aerospace applications. AA6063, a balanced mixture of manganese, iron, silicon magnesium, titanium, copper etc. is taken to study. FSP of AA6063 was studied as a feasible approach to improve the microstructural properties of the material by creating high strain rates and temperatures lower than the melting point by manufacturing a sophisticated, homogeneous grain structure. It is widely used in automobiles, aviation sector etc. Likely the most genuine shortcoming of aluminum from a building perspective is its moderately low modulus of versatility, around one third that of steel. A metal matrix composite AA8090-WC-ZrC was fabricated using stir casting method and its tribological behavior was investigated.[10]

A. Aluminum for Mechanical Application

For nonelectrical applications, most aluminum is utilized as a part of the type of alloys. These have substantially more prominent quality than unadulterated aluminum, yet hold the benefits of light weight, great conductivity, and consumption protection. While normally weaker than steel, some amalgams are currently accessible that have elastic properties that are better than those of the HSLA structural grades. Since composites can be as much as 30 times more grounded than unadulterated aluminum, originators can as often as possible streamline their outline and after that tailor the material to their particular necessities. The main objective of this study is to compare bone joints are made up of dissimilar biomaterials Femur bone is modelled in SOLIDWORKS and analyzed using ANSYS 13.0.[11]

B. Significant Properties of Aluminum Alloys

1) Simple to Fabricate.
2) It has high resistance to corrosion.
3) Better Electrical Conductivity. .
4) High Toughness at Cryogenic Temperature.
5) Reflectivity. Non-Toxicity Recyclability.

C. Classification of Aluminum Alloys

The aluminum alloys can be separated into two major group, wrought composites and cast combinations in view of the strategy for creation. Wrought composites are those that are molded as solids by plastic deformation, and are hence intended to have alluring framing trademark, for example, low yield quality, high pliability, great break protection, and great strain solidifying. Appealing highlights for the cast alloy, then again, incorporate low melting point, high smoothness, and easy to fabricate.

D. Wrought Aluminum Alloys

The Wrought aluminum alloys can be additionally categorized into two essential types: those that accomplish quality solid-solution strengthening and cold working and those that are reinforced by heat treatment (age hardening) records a portion of the normal wrought aluminum alloys in every family, utilizing the standard four- digit assignment framework for aluminums.

E. Cast Aluminum Alloys

Despite the fact that its low melting temperature tends to make it appropriate for casting, unadulterated aluminum is occasionally cast. Its significant shrinkage and hot splitting to. The main digit demonstrates the alloy group. Little measures defenselessness to hot splitting reason extensive trouble, and scrap is high. By including little measures of alloying components, notwithstanding, extremely appropriate casting characteristics are acquired and quality is expanded. Aluminum composites are cast in significant amount, and a considerable lot of the most mainstream combinations contain enough silicon to deliver the eutectic response, giving the materials low dissolving focuses, great ease, and high as-cast strength. Copper, zinc and magnesium are other well-known compound augmentations that allow the development of age hardening accelerates records a portion of the commercial aluminum cast combinations and utilizes the assignment arrangement of the Aluminum Association. The main digit demonstrates the alloy group. The second and third digits recognize the specific combination or aluminum purity, and the last digit, is isolated by a decimal point, which demonstrates the item frame (e.g., casting or ingot). An alteration of the first combination is shown by a letter before the numerical assignment.

II. EXPERIMENTAL WORK

A. Friction Stir Processed Super Plasticity in Aluminum Alloys

Researchers have investigated different aluminum compounds to accomplish super plasticity utilizing FSP because of their extensive variety of the applications. Writings in pertinence of FSP super plasticity in aluminum compounds are outlined in unthinkable frame for simple understanding as appeared.

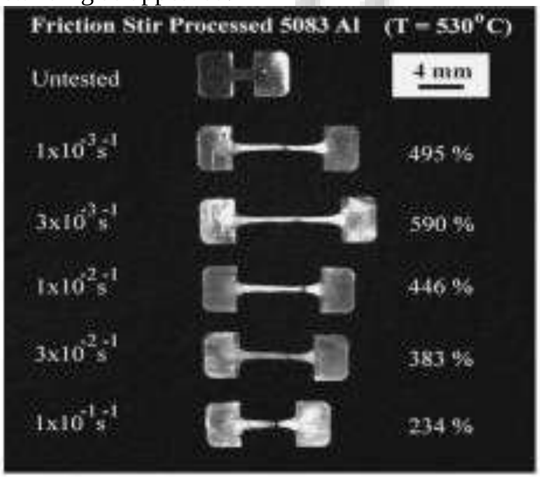

Fig. 1: Appearance of super plastically deformed tensile specimens of FSP AA 5083 with 6.5 µm grain size (Charit and Mishra, 2004[13])

B. Friction Stir Processing Microstructure Modification

Metal (2006a) [70] examined the impacts of FSP on the microstructural evolution of cast A356 Al combination.

In this examination single pass FSP was performed on 6.35mm thick plates. Distinctive tool rotational speeds (300,500,700,900rpm) and diverse navigate feeds (51,102,203 mm/min) were utilized to process the AL alloys.

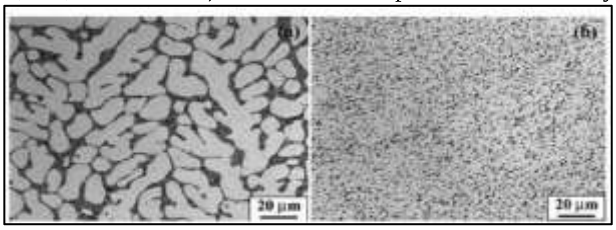

Fig. 2: Microstructure of cast A356 Al alloy

C. Thermal and Residual Stress Analysis

A significant impact on mechanical properties was observed in material after friction stir processing as far as thermal behavior and residual stresses are concerned .These micro structural changes and residual stresses in every region are strongly dependent to the local heating cycle experienced during processing. This is valid for FSP too. The issue in FSP, as with many developing advancements, is that the experimentation is costly in wording of time, materials, featuring and skill. The high cost of FSP machines what's more, tedious experimentations required the advancement of a numerical model to reenact this processing procedure.

D. Full Factorial Design for Thermal Analysis

Analysis was arranged utilizing design of experiments and directed under different processing conditions to quantify temperature and test perceptions (Roy 2001[96]). Full Factor approach was used for every possible combination of process parameters to optimize the favorable results and maximizing the probability of getting best results .For a full factorial design The number of possible designs is N = Lm ,where L = number of levels for each factor, m = number of factors.

E. Parameters and Its Combination Level

Processing speed and tool rotation plays a major role in the surface modification and enhancement in mechanical properties of the material. Different parameters like tilt angle, shoulder dia. and axial force were kept at steady state. For every parameter three levels were decided. Choose process parameters and its different levels are shown in Table 1

S.No	Parameter	Level I	Level II	Level III
1	Processing speed (mm/min)	45	95	124
2	Tool rotation (rpm)	500	1000	1500

Table 1: Selected process parameters

Nine experiments were selected as per full factorial design which is shown in Table 2

Process Parameters/Exp.Run	R1	R2	R3	R4	R5	R6	R7	R8	R9
Transverse Speed (rpm)	500	1000	1500	500	1000	1500	500	1000	1500
Welding Speed (mm/min)	124	124	124	95	95	95	45	45	45

Table 2: Total Experiment runs

F. *Material for FSP*

Aluminum alloys AA6063 was used for present investigation. This is generally utilized for air outline structures in defense aircrafts. The chemical composition the alloys 6063 was checked and shown in Table 3 (XRD analysis). The material in the form of flat plates was utilized for the experimentation.

Element	C	AL	Si	Mg	Cu	Fe	Cr	Ti	Zn
By wt		84.12	4.14	0.12	0.155	0.1	0.01	0.09	0.47

Table 3: Chemical composition of AA6063/SiC

III. RESULTS AND DISCUSSION

Processing trials were conducted at UIET, MDU, ROHTAK on an adjusted vertical milling machine driven by 7.5 kW motor (shown in Figure 1). Nine plates of size 100×50 × 6 mm were utilized for making FSPed specimens. Two plates and back plate were clipped on a fixture plate. Figure 2 Mod

Fig. 1: Vertical milling machine for fíiction stií píocessing.

Fig. 2: Chemical composition of HSS(heat tíeated) tool steel

A cylindrical tools was manufactured from hot worked HSS with a shoulder and a threaded pin of 18 mm and 5.8 mm the forces measured from the analyses were utilized for calculation of the heat input.

IV. SIMULATION OF THERMAL AND RESIDUAL STRESSES

To simulate the residual stress and thermal behavior of friction stir processed al alloy 6063A finite element model was developed using ANSYS SOFTWARE. Nine processing cases with three TR of 500, 1000 and 1500 rpm and three processing paces of 45, 95 and for nine processing cases, the predicted whole of124 mm/min were considered for experimentation as well as simulation. For nine processing cases, the predicted temperature observed during simulation at stir zone is almost equal to melting point of aluminum alloys AA6063. The distinction of the greatest temperature at a similar area (i.e. stir zone.) is under 100°C for the whole arrangement of parameters considered. Utilizing ANSYS model, the stress behavior in the processed plates were simulated to discover stress dissemination. The impact of tools discharge in the wake of processing was incorporated into the model. The longitudinal stress normal to the processing direction was anticipated utilizing the FEM model. Temperature recording and residual stress estimations were completed to check the validity of the FEM model produced for processed plate by FSP process. On-line temperature recording was performed for these nine processing trials utilizing thermocouples interfaced with LabVIEW programming through a suitable DAQ systemize to gauge the temperature information precisely. The predicted and experimental data were contrasted and discovered that they coordinated genuinely well. Residual stress estimation was done for nine specimens.

V. CONCLUSIONS

In the entire procedure, FSP was performed on Aluminum compound (6063) reinforced with Si with various rate by volume. At the point when the composite layer surface was outlined appropriately following conclusion were made as 1.The microstructural behavior demonstrates the dynamic recrystallization of the parent metal with well bonding of SiC particulate near the stir zone because of high heat input occurrence near the stir zone.2. Due to plastic flow occurrence near the heat affected zone and stir sone, asymmetric behavior of hardness was observed. Because of distortion energy present at the tool pin during FSP strain hardness could be increase. 3. It is observed that the grain size of the stir zone exhibits large size in comparison with other zones of friction stir processing.

VI. SCOPE FOR FUTURE WORK

1) All the components of force created during FSP can be measured and they can be incorporated into the model to calibrate the consequences of the limited component show.
2) To consider the impact of process parameters on impact strength can be evaluated.
3) Fatigue behavior can evaluated at different process parameters.
4) Material flow can be incorporated into the model to evaluate the residual stress design
5) TEM microstructure examination of the processed m might be completed to welcome the impact of process parameters on hasten disintegration.

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