Optimization of process parameters for producing AA 7075 surface hybrid composites

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Abstract—Aluminium 7075-grade alloy has higher strength compared to that of steel and has high corrosion resistance. It has high applications in light weight production. Friction stir processing (FSP) is the method used to change the properties of the AL7075 metal and it causes plastic deformation in the metal piece. Friction between the tool and work pieces softens the work piece. FSP encourages recrystallization phenomena due to high strain and heat input and refines the structure. Higher strain and lower heat input result in finer microstructure and enhance hardness value. In this project, AA7075 metal is chosen for analysis and five important process parameters where chosen to enhance the micro hardness and impact strength. In order to reduce no of experiments software analysis (Taguchi method) are carried out. The microstructure of the work piece with best combination of process parameters are captured to know the grain size and macro structure is captured for the same combination to know the defects in work piece, the hardness of AA7075 are tested using Vickers Hardness tester and impact strength tests are carried out. The hardness and the impact strength of the Friction Stir processed metal is higher than AA7075 base metal. After double pass these mechanical properties in Friction Stir processed metal is higher than the single pass metal and the results were discussed. This experiment shows that no of pass also influences mechanical property of metal

Index Terms— FSP of AA7075, Five process parameters, micro hardness, impact strength

1. INTRODUCTION

1.1 ALUMINIUM ALLOY

Aluminium alloys are very promising for structural applications in aerospace, military, and transportation industries due to their low density, high specific strength and resistance to corrosion, and especially regarding high energy cost. Aluminium alloys have been the primary material for the structural parts of aircraft for more than 80 years because of their well-known performance, well-established design methods, and manufacturing and reliable inspection techniques. Nearly for a decade composites have started to be used more widely in large commercial jet airliners for the fuselage, wing as well as other structural components in place of aluminium alloys due to their high specific properties, reduced weight and fatigue performance. Aluminium is a relatively low cost, a metal that can be heat treated and loaded to a relatively high level of stresses, and it is one of the most easily produced of the high-performance materials, which results in lower manufacturing and maintenance costs. However, the alloy shows limited micro hardness as well as poor impact strength even in the age-hardened condition. Therefore, it is necessary to enhance it for high strength and high wear-resistant applications, especially when the component is in contact with other parts.The micro hardness and impact strength can be improved through grain size refinement by several severe plastic deformation techniques. Aluminium alloys are categorized under two headings i.e. wrought alloys and cast alloys. Their light weight and high strength-to-weight ratio are the main reasons why cast iron and steel components are being increasingly replaced by aluminium alloys, particularly in the automotive industry.

The major problems existing in Al-based alloys are: they possess very low wear resistance and a moderate level of mechanical strength. Several techniques, such as alloying, age-hardening and particulate reinforcement have been evolved to enhance the mechanical strength of these alloys. Among these, particulate reinforcement is found to be the most suitable route to improve the wear resistance, mechanical strength and corrosion resistance of the Al alloys.

1.2 ALUMINIUM FOR MOTOR VEHICLE

Aluminium alloys for production, in particular, the bodywork of motor vehicles, have only recently been used. However, in a very short time, this type of material has gained very high popularity and presence in a large number of motor vehicle manufacturers, primarily because of its low mass and because it practically does not exhibit a tendency to corrosion. Aluminium bodywork has already reached mass production and uses in motor vehicles, although mostly on more expensive vehicle models.

However, the reduction of the mass of the vehicle continues, moving to a higher level, with the aim of increasing efficiency and reducing emissions of harmful combustion products during the exploitation of the vehicle. Aluminium alloys are now used not only for the bodywork of the vehicle but also for parts of the vehicle's steering and restraint system. Physical and mechanical properties impose special requirements before the required repair and maintenance procedures for those vehicle assemblies.

1.3 MICROSTRUCTURE

Microstructure analysis helps to find the dislocation of grain boundaries of metal composites added during FSP and find the intensity of stir zone, TMAZ, crystalline structure Agglomeration, Etched pit and Over etched pit produced in the base metal. In this work, the samples are analyzed in an optical microscope.

1.4 MACROSTRUCTURE

The impact is a very important phenomenon in governing the life of a structure. For example, in the case of an aircraft, the impact can take place by a bird hitting a plane while it is cruising, or during takeoff and landing the aircraft may be struck by debris that is present on the runway, and as well as other causes. It must also be calculated for in bridge construction where vehicles punch an impact load, etc.

1.5 MICROHARDNESS

The different compositions of metal composites have been added to AL-7075, the strength of the metal may vary. The Vicker’s hardness test is used to find the hardness of a given material. The Vickers microhardness values of the FSP regions was measured along and perpendicular to the processing direction using a load 10g with a dwell time of 10s

1.6 FRICTION STIR PROCESSING

Tabasi et al (2016), investigated that friction stir processing (FSP) is a method of changing the properties of metal through intense, localized plastic deformation. This deformation is produced by forcibly inserting a non-consumable tool into the work piece, and revolving the tool in a stirring motion as it is pushed laterally through the work piece. The precursor of this technique, friction stir welding, is used to join multiple pieces of metal without creating the heat affected zone typical of fusion welding. The FSP causes intense plastic deformation, material mixing, and thermal exposure. Resulting in significant micro structural refinement, densification, and homogeneity of the processed zone. When ideally implemented, this process mixes the material without changing the phase (by melting or otherwise) and creates a microstructure with fine, equiaxed grains.

This homogeneous grain structure, separated by high- angle boundaries, allows some aluminium alloys to take on super plastic properties. Friction stir processing also enhances the tensile strength and fatigue strength of the metal. FSP is considered to be a more experimental and analytical investigations are needed to advance the industrial utilization of FSP. The grain diffusion occurs on the base material improving properties of the first material while mixing with the material. This causes for the increase in base material properties.

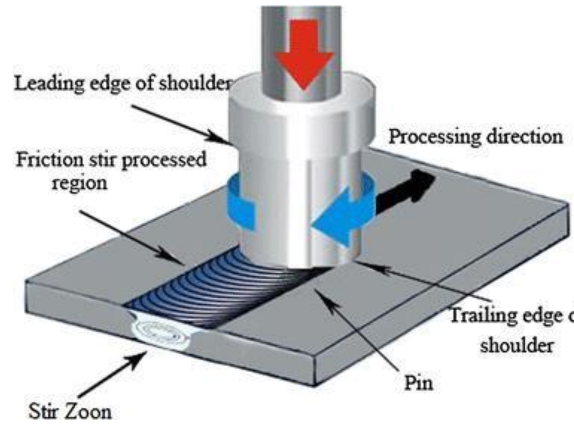

Fig. 1. Friction Stir Processing

Friction stir processing (FSP) as seen in Fig. 1,, which can significantly refine the structure and fabricate composites can be considered as a severe plastic deformation to modify the structure of materials. FSP requires a precise design of process parameters in order to achieve a defect-free work piece that is consistently reproducible. In addition, there are several FSP parameters that affect the structure and mechanical properties of Al. FSP encourages recrystallization phenomena due to high strain and heat input and refines the structure.

2. PROPOSED METHODOLOGY

The microstructure was analyzed using an optical microscope and the Vickers microhardness values of the FSP regions were measured perpendicular to the processing direction using a load 500g with a dwell time of 10s. The methodology of the proposed work is shown in Fig. 2.

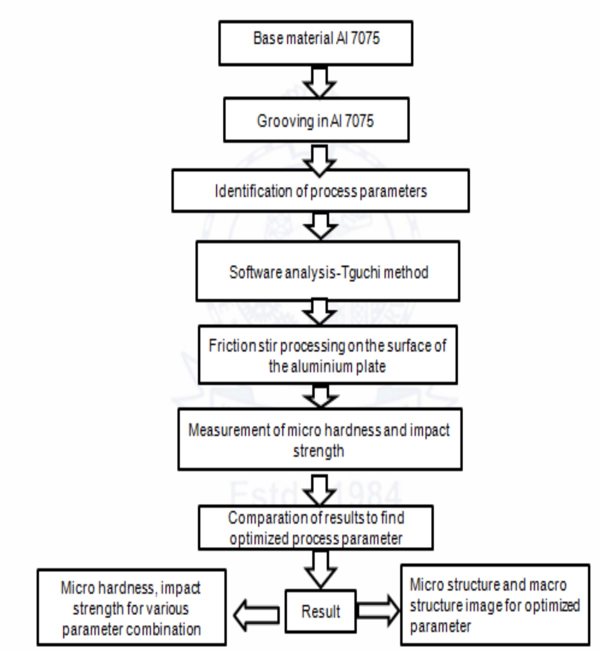

Fig. 2. Proposed Methodology

3. EXPERIMENTAL METHOD

3.1SELECTION OFMATERIAL

The work piece material used for present work was Al7075 aluminium plate of dimensions 143 x 50 x 8mm. Among many series of aluminium alloys, 7000 series that are made up of Al−Zn−Mg−Cu are widely used as structural materials due to their relatively low density, high strength, ductility, toughness and fatigue resistance. Specifically, 7075 Al alloy is an important material in many structures due to the high specific strength and also for high-temperature applications.

Table 1 Keller's reagent

Solution	Concentration
Distilled Water	95ml
Nitric acid	2.5ml
Hydrochloric acid	1.5ml
Hydrofluoric acid	1ml

3.2 FSP TOOL AND MACHININGPARAMETERS

The samples are friction stir processed on a vertical milling machine as shown in Fig. 3. FSP tool with the pin diameter 6mm,pinlength of 3mm and shoulder diameter of 25mm was used, which is shown in Fig. 4.

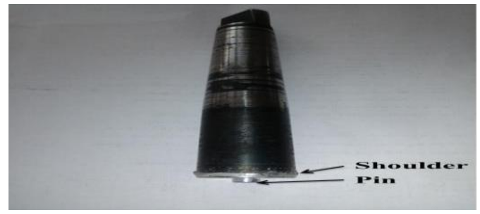

Fig. 3. FSP Tool

Fig. 4. Experimental setup of FSP

3.3MICROSTRUCTURE

3.3.1 Etchant Preparation

Etching is the process used to view the macroscopic and microscopic structure of any material very clearly. Different types of materials have different etchants. The etchant is prepared by mixing of acids in proper proportions. For Al 7075 etchant used is Keller's reagent.

3.4 OPTICAL MICROSCOPE

An optical microscope often referred as light microscope is a type of microscope that produces images of a sample by scanning the surface with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that contain information about the sample's surface topography,chemical composition, crystalline structure, stir zone, infrastructure, TMAZ zone and orientation of materials making up the sample.

The electron beam is scanned in a raster scan pattern, and the beam's position is combined with the detected signal to produce an image. Optical microscope can achieve resolution better than 1 nanometer. Areas ranging from approximately 1 to 5 microns in width can be imaged in a scanning mode using conventionalscanning techniques (magnification ranging from 20X to approximately 30,000X, the spatial resolution of 50 to 100nm).

Specimens can be observed after polishing with the emery sheet of 120 grades to 3000 grades and disc polishing want to do by adding alumina to get fine microstructure image. digital camera with a high resolution of 3.0nm. Magnification of this microscope is on the order of 3,00,000X magnification, where fine details of specimens can be observed. A modern microscope with a mercury bulb for fluorescence microscopy. The microscope has a digital camera and is attached to a computer. The Model-570 specimen chamber can accommodate up to 6-inches in diameter.

3.5 HARDNESS MEASUREMENTS

Microhardness measurement is done by Vickers hardness tester with diamond pyramid indenter having 136 degrees apex angle is used to study the hardness across the processed samplecoveringstirzone(SZ),thermomechanicallyaffectedzone(TMAZ)andbasemetal (BM). The load used was 10g with a dwell time of 10 seconds. Measurements are taken ata span of 1mm for the comparison of hardness at different regions of the processed sample. The Vickers microhardness machine is shown in Fig. 5.

Parameters in Vickers Microhardness test

Load = 500g
Dwell time = 10sec
Magnification = 400x
Indentation Type = Diamond indenter

Regression Equation for Single Pass

Hardness (VHN) = 116.50 + 0.00409 R.S - 0.0728 T.S - 0.02 T.A + 124.63 D- 0.000014 R.S*T.S - 0.000208 R.S*T.A + 0.00533 R.S*D + 0.1941 T.S*T.A - 1.430 T.S*D -35.88 T.A*D

Regression Equation for Double Pass

Hardness (VHN) = 122.95 + 0.00409 R.S - 0.0728 T.S - 0.02 T.A + 124.63 D- 0.000014 R.S*T.S - 0.000208 R.S*T.A + 0.00533 R.S*D + 0.1941 T.S*T.A - 1.430 T.S*D -35.88 T.A*D

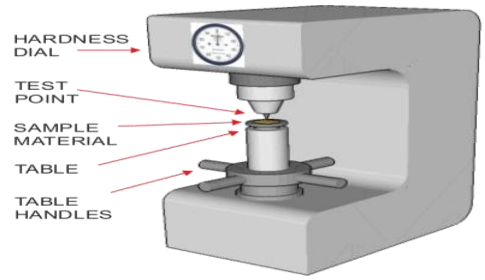

Fig. 5 Vickers microhardness

3.6 IMPACTSTRENGTH

Impact tests are used in studying the toughness of the material. A material's toughness is a factor of its ability to absorb energy during plastic deformation. Brittle materials have low toughness as a result of the small amount of plastic deformation that they can endure. Generally, at lower temperatures, the impact energy of a material is decreased. The size of the specimen may also affect the value of the Izod impact test because it may allow a different number of imperfections in the material, which can act as stress risers and lower the impactenergy.

Fig. 6 Impact strength tester

4. RESULTS AND DISCUSSION

4.1 PROCESSED SAMPLES

Fig. 7 shows the processed surfaces of the AA7075 alloy which are processed by FSP. The samples are devoid of any visible processing defects. The tool extends out and travels back to the origin before the start of consequent passes in friction stir processing

Fig. 7 Processed surfaces of the AA7075

4.2 MICRO STRUCTURAL STUDIES

Fig. 8 shows that the stir zone with finer grains and transition region between the stir zone and the TMAZ region. Because of the stirring action of the tool, the grains in the stir zone broke down and forms finer grains. In the Thermo mechanically affected zone (TMAZ), since the grains are exposed to longer temperature for elongated grains are formed in the region.

4.3 MACRO STRUCTURE STUDIES

Fig. 9 shows the length and width of the FSP processed area and the defects occurred are pinhole, warm hole and teardrop

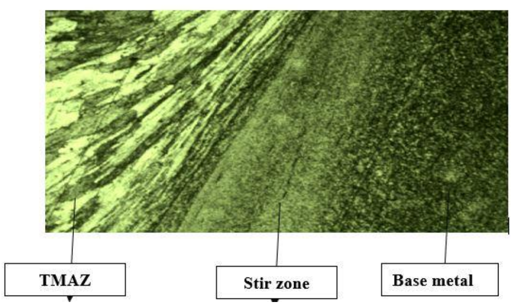

Fig. 8 Microstructure of FSP processed AA7075

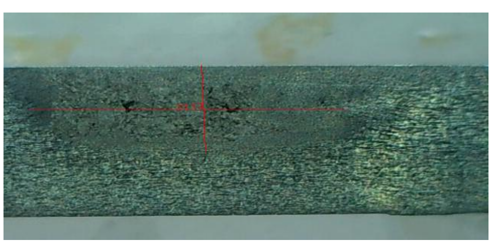

Fig. 9 Macrostructure of FSP processed AA7075

Taguchi Analysis: Hardness (VHN), Impact Strength (J) versus Pass, R.S, T.S, T.A, D

The results of Taguchi indicate that the no of pass has the highest effect on the microhardness and impact strength followed by the transverse speed, rotational speed, tool penetration depth and tilt angle respectively.

4.4 MICROHARDNESS

The maximummicrohardness of 151.12 was achieved when the number of passes, tool rotational speed, traverse speed, tilt angle and depth were selected as double pass, 2000 rpm, 56 mm/min, 3.0˚ and 0.1mm

5 CONCLUSION

The present study was aimed to identify the optimal and most influencing FSP parameters on hardness of Aluminium 7075 by conducting minimum number of experiments using Taguchi method. Various combinations of processing parameters were considered to evaluate the relative importance of parameters. Thus, from the above results no of pass is also an important factor in FSP process for improving mechanical properties. The hardness test showed higher hardness in stir zone and lower values in TMAZ. This is due to the formation of finer and coarser grains in stir zone and TMAZ respectively.Experimental result and software result for harness and impact strength are approximately same. This optimized value in combination with surface hybrid composites will result in enhancement of micro-hardness and impact strength in Al 7075 for various application.

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