Vibrational & wear analysis of friction stir processed aluminum alloy reinforced composite

Dissertation-II

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MECHANICAL ENGINEERING

By

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PUNJAB

CERTIFICATE

I hereby certify that the work being presented in the dissertation entitled "Vibrational & wear analysis of friction stir processed aluminum alloy reinforced composite" in partial fulfillment of the requirement of the award of the Degree of master of technology and submitted to the Department of Mechanical Engineering of Lovely Professional University, Phagwara, is an authentic record of my own work carried out under the supervision of (Rajeev Kumar, Assistant Professor) Department of Mechanical Engineering, Lovely Professional University. The matter embodied in this dissertation has not been submitted in part or full to any other University or Institute for the award of any degree.

(30-11-17)

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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(Harsh Sharma)

ABSTRACT

Friction stir processing is becoming an emerging method for the welding of two same or different materials and for enhancing the mechanical properties of materials nowadays. Many researchers worked in this filed for providing a valuable material to the society of manufacturing. This method is widely used in the manufacturing of aircrafts, aerospace and aeronautics. Although the development in this filed is still in progress. In this work a literature review related to the wear resistance analysis of friction stir processed aluminium alloy reinforced composite is carried out. The main concern of this work is to present a study of vibrations in the friction stir processing by means of some external methods or due to tool insertion. A survey that represents the effect of parameters such as tool speed, tool tilt and plunge depth on the properties of the reinforced material is presented. The mechanical properties of different available aluminium alloys is also focussed in this work.

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LIST OF ABBREVIATIONS

AC	Alternating Current
DC	Direct Current
TWI	The Welding Institute
FSW	Friction Stir Welding
FSP	Friction Stir Processing
TiC	Titanium Carbide
SiC	Silicon Carbide
WC	Tungsten Carbide
FSVW	Friction Stir Vibration Welding
CDRX	Continuous Dynamic Recrystallization
EBSDs	Electron Back Scattering Diffraction
TEM	Transmission Electron Microscopy
HAGBs	High Level of High Grain Boundaries
CMC	Copper Matrix Composite
AIN	Aluminium Nitride
FESEM	Field Emission Scanning Electron Microscopy
AMCs	Aluminium Matrix Composites
SEM	Scanning Electron Microscope
XRD	X-Ray Diffraction

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CHAPTER 1

INTRODUCTION

Welding

Welding is the process of joining two same or different materials with the help of a filler material. The filler material forms a pool of molten metal at the joint which after cooling weld the materials stronger than the base material. To perform welding pressure is also used along with heat or by itself. Welding is the method in which heat is supplied either by means of electricity or by gas torch. This method is most widely used for fabrication purpose and it is the most inexpensive process. For manufacturing of automobiles bodies, structural works, tanks various welding processes are used nowadays. That's why this process is also termed as a secondary manufacturing process. Welding is also used in the industries such as refineries and pipe line fabrications. This process is not only used for joining the two pieces it is also used in manufacturing a material with favourable mechanical as well as chemical properties. Basically, there are following types of welding processes used-

Arc welding

In arc welding a welding power supply and electrodes are required to join the materials. An electric arc is generated between electrode and the base material to melt metals at the welding point by using power supply either of alternating current (AC) or direct current (DC) and consumable and non-consumable electrodes. Some kind of shielding gases are also used to protect the weld region such as inert and semi-inert gases.

Gas welding

The gas welding is the process in which the metal is joined and cut by means of oxygen and fuel gases therefore it is also known as oxy-fuel welding and cutting. This process is less expensive and simple to employ. It is widely used for repair works and welding of pipes and tubes in industries.

Resistance welding

When two same or different metals are in contact the resistance is generated and a high current (1000-1000,000 A) is passed through the resistance which weld the metals together. In this process a pool of molten metal is formed at the weld area. The most commonly used resistance welding is spot welding.

Energy beam welding

Energy beam welding is basically of two types one is laser beam welding and the another is electron beam welding. The both processes are different on the basis of power supply, in laser beam welding a laser beam of high focus is used and in electron beam welding uses an electron beam to work under vacuum. The efficiency of both the process is excellent they can be used for welding in deep penetration and it also minimizes the size of the weld area. These processes can easily be automated.

Solid-state welding

In solid-state welding process the metals are joined in the similar way to the resistance welding but in this process the metal does not melt. Ultrasonic, explosion, friction, friction stir, magnetic pulse welding is some kind of solid-state welding. But instead of electric current vibrations, high pressure is used to provide the input.

1.1 Friction Stir Welding

The process of friction stir processing is invented and experimentally proved at The Welding Institute (TWI) in the UK in December 1991. It is a solid-state process in which a non-consumable tool is used to join two same or different materials without melting the workpiece material. In this process a rotating tool is used to produce heat by generating friction between the tool and the workpiece material. After that the tool is traversed perpendicular to the length of the workpiece and the tool mixes the two pieces of metals and forges them by mechanical pressure applied by the tool.

1.1.1 Parameters

For the application of FSW there are certain parameters to be examined. The most important parameters are listed below:

1.1.1.1 Tool Speed

In FSW the tool speed is the most important parameter because the tool turns on the joint to generate heat and then move on the length of the joint for transmitting that heat. The tool rotates with the speed of about 200 to 2000 RPM and a probe, called pin or nib is also tipped on the tool. The tool moves with the speed of about 10 to 500 mm/min. The speed of the tool is based on the application and the type of the material to be welded but a slow-moving tool cannot move incredibly fast across the joint line, for instance.

1.1.1.2 Tool Tilt

The welding process is majorly affected by the tool tilt angle. The general range of tilt is about 2 to 4 degrees so that the tool leans into the joint. The tool tilt has a minor effect on how easily the tool can move across the joint line because less pressure is put in the direction of the weld line.

1.1.1.3 Plunge Depth

The plunge depth is an important parameter to produce the necessary heat generation for plastic deformation of the material. Concentrated friction is generated when the tool moves along its path. The tool is inserted inside the metal up to a certain depth with particular plunge depth.

1.1.2 Tool Design

Tool design affects heat production, plastic flow, and requirement of power and uniformity of FSP joints. There are some important parameters related to geometry of tool like probe length and its shape, shoulder size as they influence heat generation and flow of plastic material. In FSP, tool is significant part and is comprises of shoulder and pin. Profile of pin plays important role in controlling speed of FSP process and in material flow. A lot of heat is generated by the shoulder and stops plasticized material from run away from work-piece, whereas tool pin and shoulder influence the flow of material. Friction stir joints are specified by nugget layer which is precise and shape of flow which is spherical; these shapes are totally dependent on the design of tool and some FSP parameters and conditions.
There are five types of profiles of pin such as straight cylindrical, threaded cylindrical, tapered cylindrical, triangular and square pin.

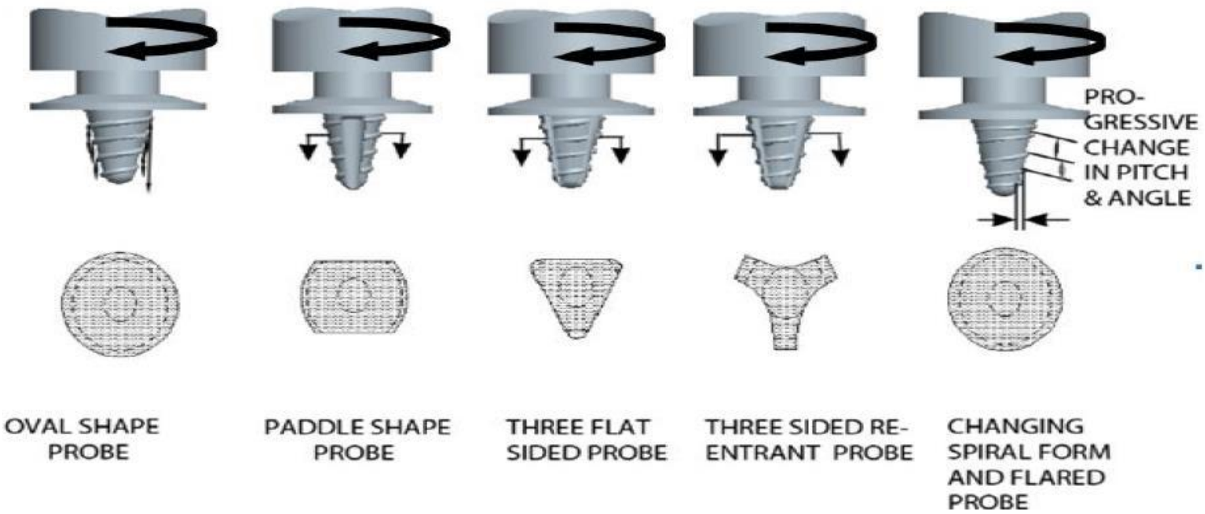

Figure 1 – *Schematic drawing of the FSW tool*

1.1.3 Applications

- FSW is used in manufacturing sheets of different materials such as AA 2519, AA 5083, AA7075 aluminium alloys, AZ61 magnesium alloys, nickel-aluminium bronze and 304 L stainless steel.
- Metallic parts produced by casting are inexpensive and contain many metallurgical flaws, hence FSW removes the various defects and homogenize it by stirring the cast metal part and reduce the grain size.
- Improvisation of the microstructural properties of metal objects.

- It is used in manufacturing of hulls, aluminium extrusions and offshore accommodations.
- It is used to manufacture the wings in aerospace industries.
- It is used to build railway tankers and container bodies.
- It is also employed in land transport such as automotive engine chassis, wheel rims, body frames and truck bodies etc.

1.2 Friction Stir Processing

To enhance the particular properties of a metal a method is introduced which is termed as friction stir processing(FSP). In this method, localized plastic deformation of the metal takes place due to inserting a non-consumable tool inside the certain depth of the workpiece and then the tool is provided a rotating motion while it is moving horizontally to the workpiece. This method is entirely different from traditional fusion welding it works on the principle of friction stir welding. By using FSW multiple metals are joined together without creating any heat affected zone. Various properties are enhanced by implementing FSP on the metal, such as the tensile strength and fatigue strength. Friction stir processing improves the microstructure of the fabricated metal with fine equiaxed grains. It also enhances the wear resistance and wear behaviour of the metal by avoiding metal-metal contact.

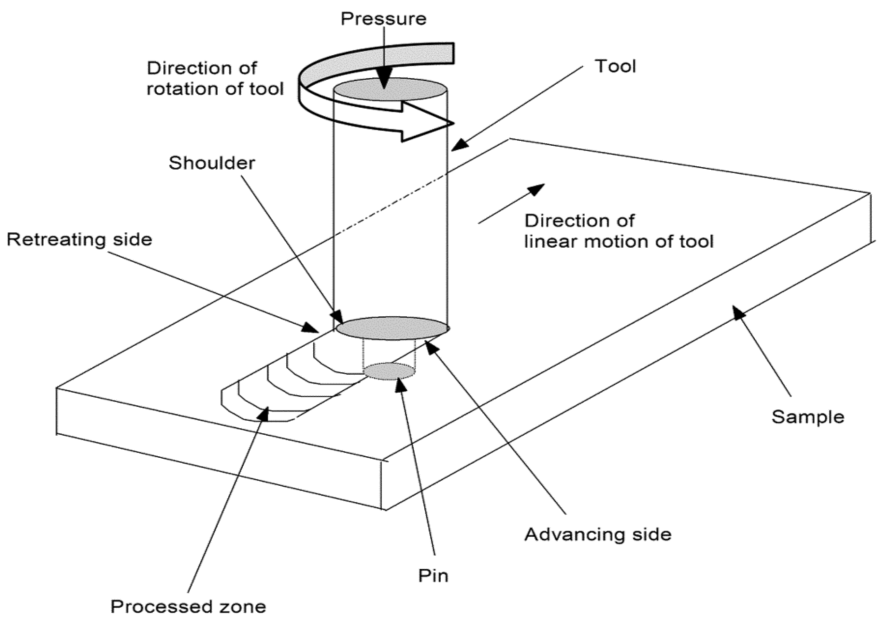

Figure 2 – *Friction stir processing*

1.2.1 Process

The friction stir processing follows a particular method of operation in this a rotating tool is moved through the traverse of the material to be welded in order to achieve the enhancement of certain properties by grain refinement. Firstly, the metal is fixed on the fixture with the help of clamps and tighten them and the tool is attached perpendicular to the traverse of the metal and allowed to carry number of passes through the length of the workpiece and change the mechanical properties of the metal. During this process, a significant grain refinement takes place due to intense plastic deformation. The main advantage of this process is that it changes the physical properties of the material without changing its physical state. Some materials may also achieve the condition of super-plasticity after friction stir processing. In this process the two same or different material are joined easily with a strong intermolecular bond. The enhancement of properties also takes place by mixing some ceramic particles in the geometry of the material. A groove is provided on the surface of the metal and the particles are filled inside the groove after then the process is carried out to attend a certain increase in the particular properties of the material. The ceramic particles basically used for processing are Al_2O_3(aluminium oxide), B_4C (boron carbide), TiC(titanium carbide), SiC(silicon carbide) and WC(tungsten carbide).

1.2.2 Applications of FSP

Where ever the two-different metal are need to joined, friction stir processing is used. The most basic use of FSP processed metal is in aerospace and automotive industries. By using this process, a new material is developed with improved resistance to wear, creep and fatigue. Examples of materials successfully processed using the friction stir technique include AA 2519, AA 5083 and AA 7075 aluminium alloys, AZ61 magnesium alloy, nickel- aluminium bronze and 304L stainless steel.

1.2.2.1 Casting

The materials manufactured through casting are quite inexpensive but often they are subjected to certain metallurgical defects such as flaws and porosity and microstructural defects also. But if the casted material is processed under friction stir processing the microstructure property get improved due to homogeneous distribution of the particles throughout the matrix and the grain size is reduced. The ductility and tensile strength is also improved.

1.2.2.2 Powder Metallurgy

The microstructural properties of powder metal objects are improved by using friction stir processing. The ductility, fatigue properties and fracture toughness of the workpiece is detriment on the surface of each granule of the aluminium oxide film in aluminium powder metal alloys. While conventional techniques for removing this film include forging and extrusion, friction stir processing is suited for situations where localized treatment is desired.

1.2.2.3 Fabrication of metal matrix composite (MMC)

Metal matrix composite are fabricated by means of friction stir processing at the nugget zone where we need the change of properties. There are so many composites fabricated by friction stir processing such as Al 5052/SiC. By using FSP nano-composites are also fabricated.

1.3 Friction Stir Vibration Welding

In the field of friction stir welding many researches are taken out to enhance the mechanical properties and super-plasticity nature of the material. After a certain development in field of FSP a new method is introduced in context with the FSP. In this method same as conventional FSP the workpiece is fitted on the surface of the fixture by using clamps and the tool moves perpendicular to the length of the workpiece and in addition to this ultrasonic vibration is induced in the system by using ultrasonic transducer. These vibrations distribute the ceramic particles homogeneously throughout the matrix without formation of any second phase particles. In conventional friction stir processing there is formation of intermetallic bi-layer which affect the properties of the workpiece, by using friction stir vibration welding this intermetallic bi-layer is converted into the mono-layer. In comparison to FSW the specimen fabricated by FSVW attend higher strength, hardness and ductility. The wear resistance is also increased by applying vibrations. The ultrasonic vibrations are provided by means of ultrasonic generator, the researchers found that the higher the power of vibration higher is the enhancement of the workpiece.

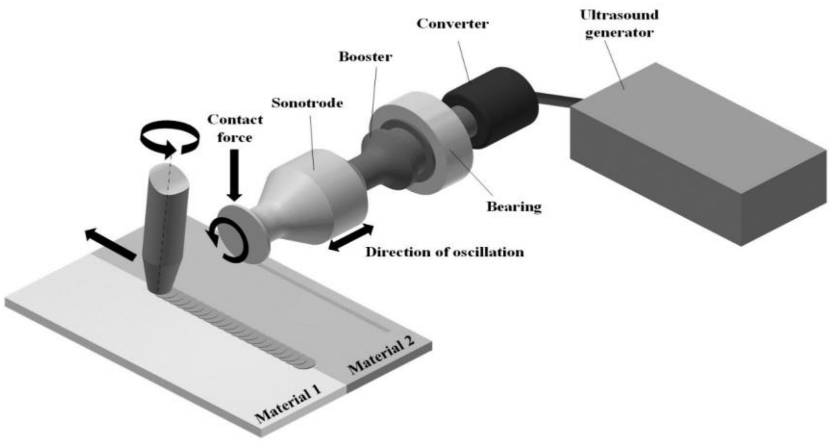

Figure 3 – *Friction stir vibration welding*

1.4 Aluminium Alloys

Aluminium with the aspect of growth in the welding fabrication industry, and its acceptance for many applications as an excellent alternative to steel. Understanding the aluminium, is to start the identification, requirement, designation system, many other aluminium alloys available and their characteristics.

Aluminium is extracted from the mineral bauxite by converting into aluminium oxide (alumina) by the Bayer Process. Using electrolytic cells and the Hall- Heroult Process, alumina is then converted to aluminium metal. Global demand for aluminium is about 29 million tons per year, of which about 22 million tons is new aluminium and 7 million tons is recycled aluminium scrap.

Property	Value
Atomic Number	13
Atomic Weight (g/mol)	26.98
Valency	3
Crystal Structure	FCC
Melting Point (°C)	660.2
Boiling Point (°C)	2480

Property	Value
Mean Specific Heat(0-100°C) (cal/g.°C) Thermal Conductivity (0-100°C) (cal/cms. °C)	0.219 0.57
Co-Efficient of Linear Expansion (0-100°C) (x10-6/°C)	23.5
Electrical Resistivity at 20°C (μΩ.cm)	2.69
Density (g/cm3)	2.6898
Modulus of Elasticity (GPa)	68.3
Poissons Ratio	0.34

Table 1 – *Typical properties of Aluminium*

Designations of Al-alloys

Copper, Zinc, Magnesium, Silicon, Manganese and Lithium are the metals mostly used for alloying with Aluminium. Small proportions of chromium, zirconium, titanium, bismuth, lead, and nickel are also made and iron is invariably present in small quantities.
There are about 300 wrought alloys with 50 in common use. They are universally accepted, originated from USA and normally identified by a four-figure system.

Alloy Series	Alloying Element
1XXX	Aluminum 99.000%
2XXX	Copper
3XXX	Manganese
4XXX	Silicon
5XXX	Magnesium
6XXX	Magnesium and Silicon
7XXX	Zinc
8XXX	Other Elements

Table 2 – *Designations for wrought aluminium alloys*

The 1st digit (Xxxx) indicates the principal alloying element, which is added to the aluminium alloy and is used to describe the aluminium alloy series, i.e., 1000 series, 2000 series, 3000 series, up to 8000 series.
The 2nd single digit (xXxx), if different from 0, indicates a modification of the specific alloy, and the 3rd and 4th digits (xxXX) are identified as arbitrary numbers given to a specific alloy in the series.
Cast alloys use similar designations with five-digit system.

Alloy Series	Alloying Element
1xx.x	Aluminum 99.000%
2xx.x	Copper
3xx.x	Silicon + Copper and/or Magnesium
4xx.x	Silicon
5xx.x	Magnesium
6xx.x	Unused Series
7xx.x	Zinc
8xx.x	Tin
9xx.x	Other elements

Table 3 – *Designations for Cast aluminium alloys*

The 2nd and 3rd digits (xXX.x) are identified as arbitrary numbers given to specific alloy in the series. The number after the decimal point indicates either the casting (.0) or an ingot (.1 or .2) of the alloy. Modification to a specific alloy is indicated by a capital letter prefix.

1.5 AA7075 Aluminium alloys

Zinc is the main alloying element in 7075 aluminium alloys. This alloy has a good fatigue strength and average machinability, its strength is also greater in comparison to many steels. These alloys have a better corrosion resistance than the 2000 alloys. The relatively high cost of these alloys limits its use.

1.5.1 Properties

- Aluminium 7075A has a density of 2.810 g/cm^3.
- Aluminium 7075-O (Un-heat-treated) has a tensile strength more than 280 MPa and yield strength more than 140 MPa. It has a failure elongation of 9-10%.
- The ultimate tensile strength of T6 temper 7075 is from 510-540 MPa, yield strength of about 430-480 MPa and failure elongation of 5-11%.
- The ultimate tensile strength of T651 temper 7075 is about 570 MPa, yield strength is about 500 MPa and elongation failure of 3-9%.
- T7 temper 7075 have 505 MPa ultimate tensile strength, 435 MPa yield strength and 13% failure elongation.

1.5.2 Applications

- 7075 alloys are used in marine, automotive and aviation due to their high strength to density ratio.
- It is also used in the manufacturing of bicycle components, rock climbing equipment, inline skating-frames and hang glider airframes.
- The chassis plates of hobby garde RC models are made from 7075 aluminium alloys.
- The weapons of American military are manufactured by 7075 basically M16 rifles.
- This alloy is also used for mould tool manufacturing due to its high strength, low density, thermal properties and its ability to be highly polished.

1.6 Wear Resistance

Friction stir processing enhanced various properties of the material, wear resistance is one of them. Wear is always an important context where metal-metal contact occurs. To reduce the wear various method are used but friction stir processing is one of the best method to reduce the wear. Many researchers worked in this field they perform various experiments on different material processed by FSP and analysed certain decrease in the wear. In FSP, by mixing some ceramic particles in the metal the wear gets reduced because the particles of that material get homogenously distributed throughout the metal matrix composite and start working as a solid lubricant and avoiding metal-metal contact. The wear behaviour is also improved using Friction stir processing by laminating the metal surface with a film of lubricant. Many researchers worked to enhance the wear resistance and wear behaviour of various materials by using different carbide particles and analysed that the wear properties of the fabricated material are excellent in comparison with the conventional friction stir processed material. Basically, pin on disc apparatus is used to measure the wear resistance of the fabricated workpiece.

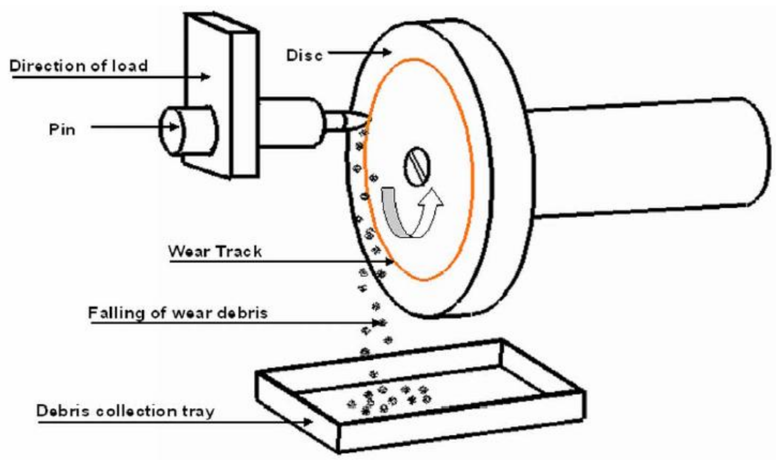

Figure 4 - *Pin on Disc apparatus*

1.7 Vibration analysis

Vibration is termed as a mechanical phenomenon where oscillations occur about a particular point. In some cases, this vibration is good but in some operations, it leads to failure and fracture of the system. The same is with the friction stir processing the vibrations have its own causes and prone. In FSP, when the tool is inserted inside the workpiece it exerts certain force perpendicular to the length of the workpiece. This force creates certain vibration in the workpiece the analyses of these vibrations is becoming important task to predict the properties of the workpiece. For measuring the vibrations of the system their various ways but we have to concern the temperature change during the process because at higher temperature some vibration measurement system losses their accuracy. Therefore, it is required to select the vibration system according to the context of friction stir processing and these vibration leads to certain effect on the mechanical properties of the fabricated material. Many researchers, investigated the effect of vibration on the properties of the workpiece and presented that with increasing value of vibrations the properties of the material are also increases. That`s why the analysis of these vibrations should carry out so that we can predict the changes in the material properties and enhance them for a better end result.

CHAPTER 2

LITERATURE REVIEW

Mostafa Akbari et.al [1] (2017) fabricated aluminium-base surface hybrid composites by using friction stir processing via the mixture of SiO_2 and Al_2O_3 particles on an Al- Si cast aluminium alloy. Scanning electron microscope is used to evaluate the distribution of particles in the stir zone. The reinforcing particles are uniformly distributed in the stir zone is concluded by the microstructures of the composites. The hardness test is used to measure the mechanical properties of each composite by indicating that increase in the relative content of SiO_2 resulting in a decrease in the average harness of the stir zone. The wear resistance is also investigated under normal load of 20 N, sliding speed of 1 m/s and distance of 4000 m respectively. The average hardness of the composite fabricated by the composition of 80% Al_2O_3 and 20% SiO_2 is about 83 HV which was nearly two times higher than that of the A356 base alloy (about 44 HV). The composite reinforced by 80% Al_2O_3 and 20% SiO_2 have a wear mass loss of about 4.2 mg which was significantly lower than that of A356 base alloy which was about 19 mg. The best suited composition for achieving higher wear resistance is 80% Al_2O_3 and 20% SiO_2.

Seyed Sajad Mirjavadi et.al [2] (2017) investigated the properties of AA5083 zirconia nanocomposites by the effect of friction stir processing with different number of passes. The tensile properties of AA5083 sheets was improved by using 2, 4, 6 and 8 passes consistently of multi-pass friction stir processing. The microstructure of the nanocomposites revealed that the reinforcement particles are uniformly distributed. Continuous dynamic recrystallization (CDRX) has occurred on the basis of EBSD (Electron back scattering diffraction) and TEM (Transmission electron microscopy) analysis of 8-pass FSPed nanocomposite, with fine equiaxis grains and high level of high grain boundaries (HAGBs). After multi-pass friction stir processing the wear rate of the fabricated materials decreases. Higher hardness and load bearing effect explains the wear rate of zirconia nanocomposites. The wear happened is abrasive wear, it is being concluded by observing the worn surface of the 8 pass FSPed material. The dominant wear mechanism is adhesive in nature with regard to base material. The 8-pass processed nanocomposite has higher coefficient of friction whereas the base material has lower coefficient of friction. The 8-pass processed nanocomposite and base material both have same fracture surface i.e, both showing networks of dimples and voids which are characteristics of ductile fracture.

S. Sarvanakumar et.al [3] (2017) To improve the wear resistance of copper surface aluminium nitride (AIN) is acapable ceramic particle. By using FSP Cu/AIN (0, 6, 12, 18 vol%) copper matrix composite CMCs was integrated on pure copper substrates. On the surface of the copper plates grooves are machined for compressing AIN particles. A set of fixed experimental conditions was used for FSP. Optical, scanning and transmission electron microscopy are used to evaluate the microstructural features. Pin-on disc apparatus is used to estimate the wear behaviour. In the surface composite the AIN particles are distributed homogeneously. AIN particles neither get clustered nor segregated. Around the depth of surface composite, the distribution was approximately constant. The AIN particles and the copper matrix have a good interfacial bonding. Due to FSP the shape and size of AIN particles not get affected. The dry sliding wear behaviour of the composite surface was described in detail.

C.N. Shyam Kumar et.al [4] (2016) fabricated a metal particle reinforced surface composites by consolidating tungsten particles in 5083 Al matrix using friction stir processing. FSP restrained the grain size and the particles were uniformly distributed in the matrix. The tungsten particle in their elemental form it confirmed that there was no any intermetallic peak showed by X-ray diffraction analysis. In comparison to the base and the friction stir processed alloy the composite surface layer displayed considerably higher wear resistance. At all the three loads the composite gone through adhesive and oxidative type of mild wear which was revealed by the worn surface analysis. In the base and FSPed samples to abrasive and delamination type of severe wear occurs.

Mohammad Narimani et.al [5] (2016) mono and hybrid surface composite layers of aluminium matrix containing B_4C and TiB_2 particles was produced by friction stir processing. The base material used for this purpose is AA6063. By using FSP, different fractions of milled B_4C and situ TiB_2 – 10 wt% Al composite powders produced by mechanical alloying were consolidated into the matrix. The study of microstructure and wear resistance of surface layers was carried out on the basis of different ratios of TiB_2 and B_4C reinforcing particles. Field emission scanning electron microscopy (FESEM) and optical microscopy was used to evaluate the microstructure of samples. The hardness was obtained by conducting the microhardness testing across the cross-sections of FSPed samples and the wear test as conducted on FSPed samples by using pin on disk apparatus. The results presented that in comparison with the FSPed AA6063 alloy the surface composite formed by incorporation of B_4C and TiB_2 reinforcing particles have higher hardness and wear resistance. As compared to other fractions, the sample containing 100% TiB_2 in its composite layer have the highest hardness and best wear behaviour.

R Palanivel et.al [6] (2016) hybrid aluminium matrix composites (AMCs) containing TiB_2 and BN particles was fabricated by using friction stir processing (FSP) on the base alloy AA6082 and also compared with AA6082, AA6082/TiB_2 AMC and AA6082/BN AMC. At certain parameters the FSP was carried out after computing the TiB_2 and BN particles into the groove. Optical, transmission electron and scanning electron microscopy was used to evaluate the microstructure of samples. Pin on disk apparatus was used to investigate the sliding wear behaviour. The particles are homogeneously distributed in the aluminium matrix irrespective of the region within the stir zone this was acknowledged by micrographs. In the hybrid AMC there was no segregation of two type particles. In the matrix, extensive grain refinement occurred that demonstrated the effective interfacial bonding between the particles. During FSP the BN particles were intact and the shape and morphology of the TiB_2 particles altered. The BN particles act as a solid lubricant and forms a tribo film on adding it in the AA6082 TiB_2 AMC and in result the wear resistance of the composite layer was enhanced. The iron content AMC was reduced by adding BN particles in the matrix and which was beneficial for a reduction in counter face wear.

N. Yuvaraj et.al [7] (2016) mono and hybrid surface composite layer of aluminium matrix (Al5083) containing B_4C and TiC was fabricated by friction stir processing. The microstructure is studied by scanning electron microscope (SEM) and XRD. Investigation of mechanical and tensile strength was carried out on the surface composite layer. Pin-on-disk apparatus sliding wear at the speed of 1 m/s and under the normal load ranging from 20 to 100 N in steps of 20 N. the result has been drawn from the study that the mechanical and wear resistance properties of the composite were higher than the base alloy. Among the processed composites, hardness and tensile strength was Al-B_4C composites. However, the hybrid composites (Al-B_4C-TiC) have exhibited significant increase in wear resistance. By conducting SEM studies, worn out surfaces and wear debris were analysed.

R. Jayaraman et.al [8] (2015) investigated the microstructure, microhardness and wear resistance of friction stir processed cast magnesium alloy. In the base metal and friction processed regions the amount of phases present was differentiated by using image analysis. In comparison to the base metal the FSPed region haver 64% increase in microhardness and that was indicated by hardness mapping. The base metal has increased wear resistance in comparison to the friction stir processed region that was evaluated by pin-on-disk testing. The improved microhardness and wear resistance of friction stir processed region was due to the fine grains with uniformly distributed second phase particles.

Yong Zhao et.al [9] (2015) fabricated 6061 aluminium alloy composite layers with B_4C particles by using friction stir processing. To evaluate the microstructure and the distribution of B_4C particles, optical microscopy, SEM and energy-dispersive X-ray analysis was used. The outcomes of micro hardness and wear resistance were performed in detail. B_4C particles were more uniformly distributed with the increasing number of FSP passes. In comparison to the base Al alloy the surface composite layer has significantly improved wear resistance and microhardness because of the consistent distribution of B_4C particles in the weld zone.

R. Sathiskumar et.al [10] (2014) fabricated a copper surface composite reinforced with variation in ceramic particles such as SiC, TiC, B_4C, WC and Al_2O_3. the effect of FSP parameters like the zone of the surface composite, microhardness, and wear rate on the properties of copper surface composites were analysed by developing empirical relationships. To reduction in the number of trials, a central composite rotatable design consisting of 4 aspects and 5 stages was used. Type of ceramic particle, groove width, traverse speed and tool rotational speed were considered as the factors. The developed experiential relationships were used to analyse the outcome of those factors on the properties of copper surface composites and accounted the microstructural characterization of the prepared surface composites. The surface composite fabricated by reinforcing of B_4C particles have greater microhardness and lesser wear rate.

H. Sarmadi et.al [11] (2013) Copper-Graphite composites were prepared with friction stir processing. To attend a uniform dispersion, 5 tools with dissimilar pin profile were used. The graphite particles dispersion is better in case of triangular pin tool showed through results. Repeating the procedure passes four more copper-graphite composites were developed with dissimilar graphite content by using triangular tool. Pin-on-disc apparatus was used to investigate the friction and wear performance of the composite. It was showed that the friction coefficients of composites were lesser than pure annealed copper and decreased with increase in graphite content. The graphite particle acts as a solid lubricant that decreases the metal-metal contact which consequently increase the friction coefficient. In increase of graphite content also decreases the wear loss of the composites.

Sima Ahmad Alidokht et.al [12] (2012) investigated the microstructure and wear resistance of cast A356 aluminium alloy treated by friction stir processing at different tool rotational speed. Wear behaviour was improved and the microstructure as significantly modified through friction stir processing. Significant amendment in size, morphology and spreading of Si particles, grain refinement and hardness enhancement attributed the wear resistance improvement. It was investigated that the more refine microstructure and consequently increased wear resistance were obtained at higher tool rotational speed.

C. Maxwell Rejil et.al [13] (2012) synthesized hybrid surface composite layers of AA6360/(TiC/B_4C) with different volume ratios of TiC and B_4C particles. On the surface of aluminium plate, a groove was cut of width 0.5 mm, depth 5.5 mm and length 100 mm and the particles were compacted in that groove. The parameters of FSP were set ton tool rotational speed of 1600 rpm, navigate speed of 60 mm/min and axial force of 8 KN. In opposite direction two passes were applied. Evaluation of microstructure and wear behaviour of the produced SCLs were carried out. In the SCLs the particles are homogeneously distributed. The result showed that AA6360.50%TiC+50% B_4C hybrid SCL have the lowest wear rate because of the formation of the thin tribo film.

S. Soleymani et.al [14] (2012) fabricated a surface hybrid Al-base composite reinforced with SiC and MoS_2 particles by using friction stir processing. The investigation of the microstructure, hardness and wear behaviour of the hybrid composite were carried out in comparison to the base metal and Al/SiC and Al/MoS_2 composites. The result presented that the particles are uniformly distributed throughout the welded zone and the surface processed layer and base metal have a good bonding between them. In comparison to the other samples the hybrid surface composite has highest wear resistance. During the dry sliding operating circumstances of samples, the dominant wear mechanism was also studied. It was presented that at the time of wear of the hybrid composite light delamination and light abrasion mechanism were functioned simultaneously. On fabricating the hybrid composite on the surface could expressively decrease the wear damages and improve the wear resistance of the alloy which was confirmed by wear mechanisms.

A.Shafiei-Zarghani et.al [15] (2011) fabricated a nano composite Aluminium/Aluminium oxide surface layer on an Aluminium alloy substrate by employing friction stir FSP. The Al_2O_3 constituent part were compressed into the groove made on the Al alloy substrate and were subjected to number of passes from one to four. The Al_2O_3 particles were uniformly distributed throughout the matrix with the increased no. of FSP passes. In addition, the surface nano-composite layers have decreased matrix grain size with increased number of FSP passes. On comparing the base alloy the nano- surface composite layer has improved microhardness value almost three times greater. In comparison to the base alloy the nano-surface composite layer has significant improved wear resistance. The result show that the superior wear resistance were obtained by the layer produced from nano-composite by four passes and due to this the microhardness have the greater value.

S. Fouladi, M. Abbasi [16] (2017) prepared a metal matrix composite of Al5052 alloy with SiO_2 particles. For improving the mechanical properties of the joint various methods are used but the problem is that the particles are not homogeneously distributed throughout the matrix by using friction stir welding (FSW). For welding purpose friction stir vibration welding was employed. During FSVW, the Al substrate vibrates normally to the welding line whereas into the weld SiO_2 particles were fused. The result presented that the specimens manufactured by FSV welding have attend higher strength, hardness and ductility with comparison to the conventional FSW specimens. The joint including second phase particles have to apply friction stir vibration welding.

X.Q.Lv, et. al. [17] (2017) fabricated Aluminium-Magnesium joints by using FSW and without ultrasonic vibrations and the intermetallic compound layers are investigated for both cases. An inter-metallic bi-layer of Al_3Mg_2+$Al_{12}Mg_{17}$ constituted in the joints fabricated through conventional Al/Mg weld. By applying ultrasonic vibrations, the bi-layers are reduced into mono-layer of reduced overall thickness. The result showed that the ultrasonic vibrations the tool offset also influenced the chemical composition of intermetallic compound layer. If the ultrasonic power was at 340 W, the intermetallic compound layer was completely removed. Mechanical testing proved that by using ultra-sonic vibrations showed enhanced morphology of fracture and ultimate tensile strength.

M. Rahmi, Mahmoud Abbasi [18] (2016) applied anew modified friction stir welding for synthesizing Al5052 alloy specimens. In this method a mechanical vibration was provided to the fixture which fixes the workpieces, in the direction normal to weld line in order to increase the straining of weld region material. The term provided to this new method was friction stir vibration welding (FSVW). The specimens manufactured by using FSW and FSVW were compared on the basis of microstructure and the mechanical properties. Metallography analysis showed that by applying FSVW, the size of rain decreases and rigidity of the welded joint increases. In comparison to the conventional FSW specimens the FSVW specimens attend higher strength and ductility values. During FSVW, it was because of more work hardening of plastcized material, so there were more generation and movement of dislocations that’s why the grain size decreases and mechanical properties improve.

Furthermore, with the increase in the frequency of vibration the mechanical properties enhanced.

Sachin Kumar [19] **(2016)** designed and fabricated an ultrasonic vibration setup for conducting a comparative study between conventional friction stir processing and ultrasonic assisted friction stir processing. In this study, the effect of ultrasonic vibrations on rotating speeds and traverse speeds are analysed by performing a series of experiments. The result showed that the material flow gets improved due to intense plastic deformation caused by the high heat generation in the stirred zone of FSP. It is analysed that the ultrasonic vibrations in FSP improved the tensile strength and hardness of the welded region. In case of ultrasonic vibration, the axial force and traverse force were also reduced.

L.Shi, C.S.Wu, X.C.Liu [20] **(2015)** in friction stir welding process, generation of heat, distribution of temperature and flow of material are analysed on the basis of effect of superimposed ultrasonic vibration by developing a mathematical model. The speed of weld, efficiency of welding and the welding eminence are improved by superimposing ultrasonic vibration in friction stir welding process due to improved material plastic flow. A comparative study was carried out between premeditated thermal cycles and thermos-mechanicaly affected zone margins of the experimentaly leisurely ones and the mathematical model.

CHAPTER 3

SCOPE OF THE STUDY

Friction stir processing is one of the major used process aimed at the production of defect free material with high strength and hardness values. The materials manufactured by using FSP is basically used in aero-space and automotive industries because their high strength to weight ratio.

In aerospace the material used should be hard enough to bear all the forces acting on it. Therefore, a particular method is applied for manufacturing the materials for aerospace to prevent it from fracture or any kind of failure. Nowadays almost all the automotive vehicles are manufactured by using metal matrix composite and FSP is the best way for fabricating the MMC.

In this research work the vibration in addition the wear resistance of the friction stir processed plate is being analysed.

CHAPTER 4

OBJECTIVES OF THE STUDY

The main focus of this research is to analyse the vibrations produced in the plate by insertion of tool and due to movement of the tool along the traverse path of the specimen. The effect of these vibrations on the properties of the material can also be predicted.

The other objective is to investigate the wear resistance of the friction stir processed plate and also define the behaviour of the wear. For this purpose, a pin on disc apparatus is used which clearly tells us about how much wear can takes place in the plate and the behaviour of that wear is also known to us.

Another objective of the study is to enhance the properties of the metal with the help of internal systems vibration rather than applying vibrations from outside.

CHAPTER 5

RESEARCH METHODOLOGY

Vibration and the wear resistance analysis is to be carried out on the basis of different friction stir processing parameters. In this methodology, the experimental setup has been discussed.

5.1 Experimental Setup

Basically, there are different components required to conduct the process of friction stir processing and analysing vibrations. All of them are listed below:

5.1.1 TAL V-350 CNC machine

For conducting the process of friction stir processing the requirement of readily available milling machine is important. In this work we will use TAL V-350 CNC vertical milling machine.

Figure 5 - *TAL V-350 CNC vertical milling machine*

Figure 6 – *Inner view of VMC*

5.1.2 Fixture

In FSP a fixture is used to mount the aluminium alloy plate on the bed of the vertical milling machine. The dimensions of the fixture are as follows:

Length – 40 cm

Breadth – 40 cm

Thickness – 3.8 cm

Material used cast Iron

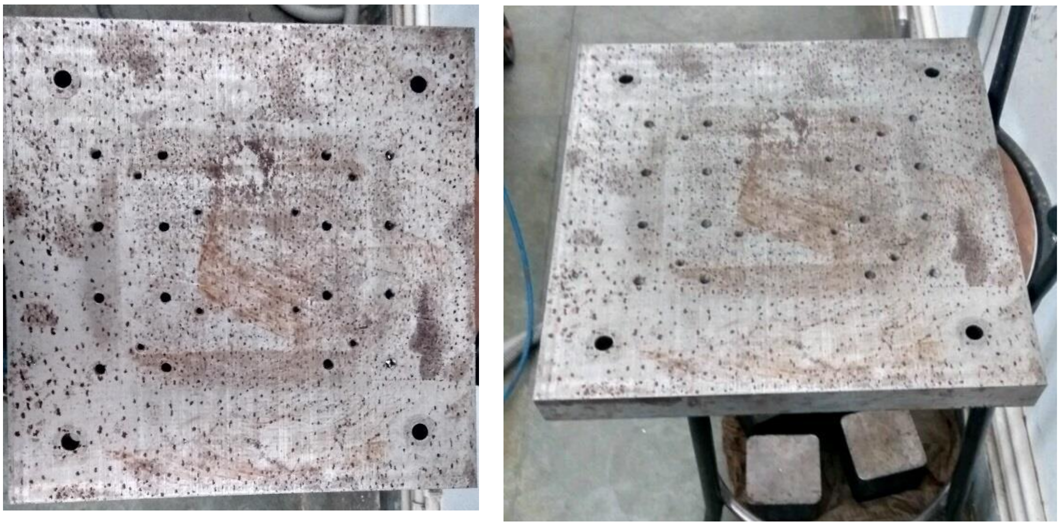

Figure 7 – *Design Fixture*

5.1.3 NI DAQ system

While conducting the process of FSP the vibration analysis is carried out by using a data acquisition system. This system measures the electrical signals of vibration and process them by using a computer software.

Figure 8 – *NI DAQ*

5.1.4 Accelerometer

Accelerometer is used to measure acceleration (rate of change of velocity). The vibration induced by the tool in the plate is measured by means of accelerometer. In this process we will use a triaxial kind of accelerometer which measures vibrations in all the three coordinates of the system.

Figure 9 – *Accelerometer*

CHAPTER 6

CONCLUSION

In this study the vibration analysis of aluminium alloy plate is carried out during friction stir processing and for this purpose particular components will be used. The wear resistance of the friction stir processed plate will also be done by using pin on disc tribometer.

The main focus of this study is to perform literature review about the work done in the field of FSP and to find the gap in between that works.

The vibration analysis helps in understanding the properties of the material enhanced due to vibrations.