INVESTIGATION OF MECHANICAL AND WEAR PROPERTIES OF A FRICTION STIR PROCESSED ALUMINUM ALLOY REINFORCED COMPOSITE IN A CORROSIVE ENVIRONMENT

Dissertation-1

Submitted in partial fulfillment of the requirements for the award of the degree

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MECHANICAL ENGINEERING

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Certificate

I hereby certify that the project work entitled ”Investigation of mechanical and wear properties of a friction stir processed aluminum alloy reinforced composite in a corrosive environment” 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 (Mr. Jaswinder Singh, 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.

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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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The external viva-voce examination of the student was held on successfully

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Signature of Examiner

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CHAPTER 1

INTRODUCTION

1.1 Welding

It is a joining process of materials performed by application of heat by using the pressure or without using the pressure. Some joining process will use filler material. Welding is broadly utilized in almost all engineering science applications, from small level industry to large level industry and from smaller to larger machines, welding is applied almost everywhere. Construction, ships, huge boats, bridges, gigantic buildings, roadways, railways, aircraft, pipe lines and vessels constructions depend a lot on welding technology.

1.2 Welding Process classification

Welding categorized, based on state of the materials in the time welding process they are

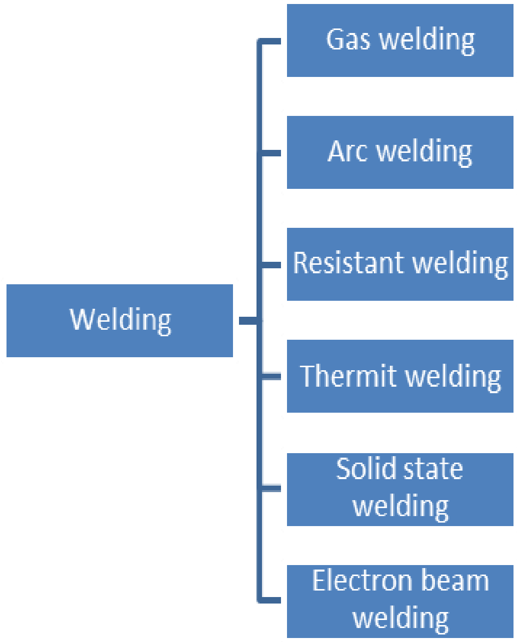
1.2.1 Solid state or Plastic welding

– in this welding, material joining will occur by using pressure, but base metal will not melt during welding. Filler materials are not required

1.2.1Fusion welding

- In this welding, material joining will be done by melting two materials at the joint and allow them to solidify. Filler material additions are possible in this process.

Welding categorized based on types source of heat used



Some commonly used welding methods are described below.

Oxy Fuel Gas Weld	In this welding, gas flame is used for the generation of heat which will melt the base filler metal. This results in formation of welding of two materials. Fuel gas can be either acetylene or hydrogen which will be mixed with oxygen in a proper proportions
Arc welding	It is the generally utilized welding. In this welding the heat source is an electric arc created by an electrode which is connected to a power source. It's an fusion welding.
Resistance welding	In this welding the joining of materials is the result of heat generation from the resistance of the work piece for the flow of an electrical current.
Cold welding	It's a solid welding process. By using pressure at normal temperature produces material joining with huge deformation on weld.
Diffusion welding	This process occur in solid state. When a rightly prepared surface kept in contact by predetermined condition of pressure, times and high temperature.
Thermite welding	This process will make use of molten metal to get permanently join

	the materials. This process involves heating the material by an exothermic reaction of thermite and it requires no extrinsic source of heat or current.
Electron beam welding	In this welding concentrated beam is used to obtain heat for joining material. Concentrated beam which composed of high velocity electrons will imping on the surface which need to be joined.
Electro slag welding	Welding process will join the metals by the using a molten slag that melts the filler material and work to be welded
Laser beam welding	In this method, materials are joined permanently by a concentrated coherent light beam which will imping to the surface to be joined.
Explosive welding	In this solid state process the joining is accomplished by high velocity motion of material parts to be joined which originated by a controlled detonation.
Ultrasonic welding:	In this welding process the joining is accomplished by the use of High Frequency Vibratory Energies as the work material are kept together under a particular pressure.

1.3 Friction stir welding

This was discovered and proven experimentally at The Welding Institute in the United Kingdom in the year of 1991 December. It is a solid state combining process where a non-consumable tool is utilized to combine two material.

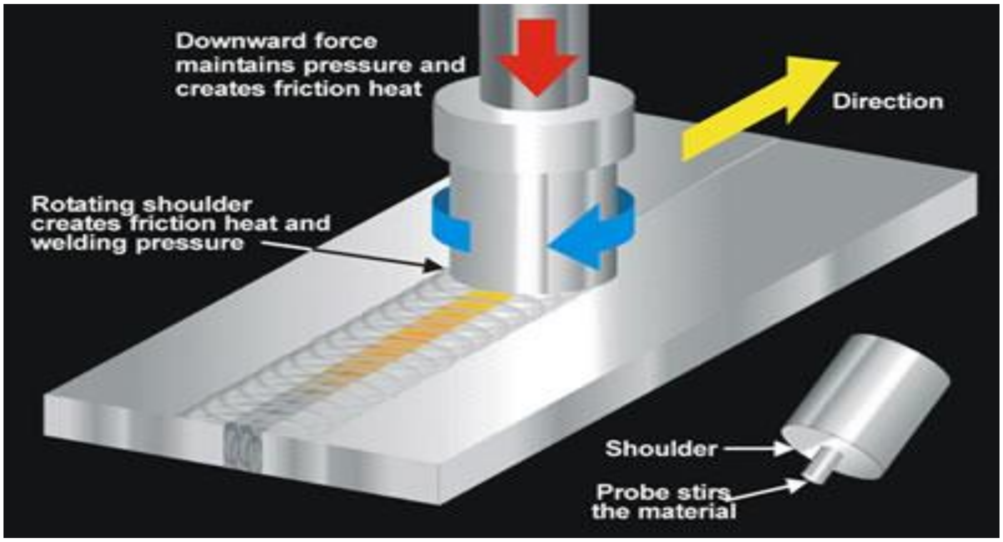


Fig 1: Friction stir processing [F1]

Material won't melt during FSW. Heat is created by friction between the tool and the work, which soften region near to the tool. When the tool passes along joint surface , it mechanically mix the two work pieces, and forges hot and soften metal by using mechanical pressure of the tool. This process of tool passing along the joint line of a plasticized shaft of metal result in a severe solid deformation and dynamic recrystallization. It is mainly used on extruded or wrought aluminum and especially for structure which requires very high strength of weld. FSW is also seen shipbuilding, and aerospace etc., it is a feasible technique for joining aluminum alloy that are impracticable by fusion weld.

1.4 Friction stir processing

It is modified from FSW. FSP use the same procedure of FSW, Whereas FSP is for modifying the local microstructures and FSW is for combine material together. FSP is to modify the internal material structure resulting in desired mechanical properties .FSP a multipurpose method, because it has extensive applications like processing, fabrication and materials synthesis. FSP a method of altering the material properties through severe, localized plastic deformation. This mutilation on the material is produced by energetically inserting a tool which is non-consumable, and rotating the tool in a motion as it is pushed alongside through the material.

1.5 Mechanism of FSP

A cylindrical tool with a shoulder and pin will spin and plunged into the selected area of material. When the tool moves downward to the work, the rotating pin comes in contact with the work surface there would be a generation friction heats which will soften a small portion of metal. When tool shoulder comes in contact with the work surface, tool rotation creates more friction heat and plasticize a larger work portion surrounded by the inserted tool pin. This shoulder of tool provides a force which will tend metal to flow upward caused by pin. The tool traverses along the area need to be processed and continues with overlapping pass, until the whole selected work area get processed to a fine grain size. Heat generated during FSP does not extent the melting degree so this process is considered to be a solid state process

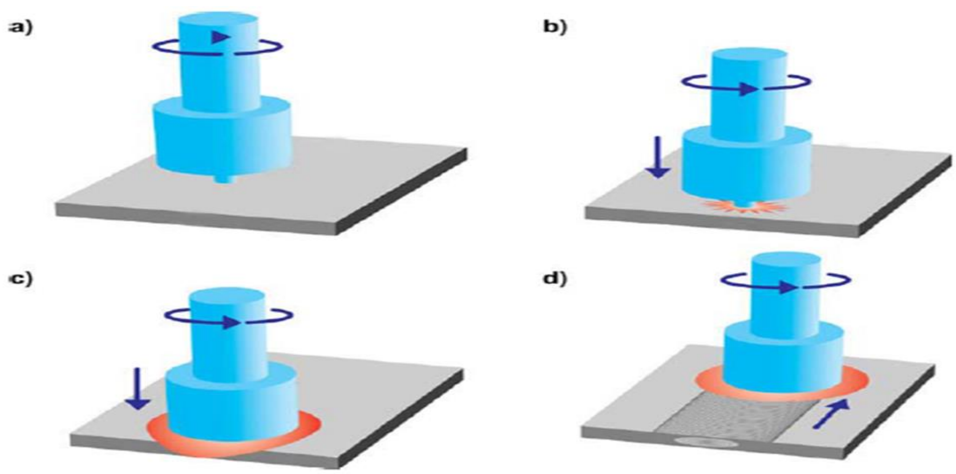


Fig 2: Friction stir processing [F2]

a. before the contact of rotating tool with the metal
b. after the contact of the tool pin with work which generate heat
c. when the tool shoulder come into contact and restricts the penetration and enlarges the stir zone
d. Plate moves with relation to the tool and produces a fully crystallized fine grain.

1.6 Tool used in FSP

Tool has smaller diameter pin and larger diameter shoulder. The shoulder radius and length of probe controls depth of penetration

1.6.1 Fixed tool

This tool has single piece consisting both shoulder and pin. This tool can only process or weld a metal with a fixed thickness due to fixed length of probe .If the pin wears highly or break, the entire tool need to be replaced

1.6.2 Adjustable tool

Adjustable tool has two pieces which are independent, that is a separable shoulder and pin to permits adjustment of pin length during FSP or FSW. The shoulder and pin can be made by using different materials and we can easily replace the probe when it’s get worn or damaged. And also adjustable pin length will allow processing and welding of changing and multiple thickness material, and fulfillment of the strategies for filling the defect, left toward the finish of friction stir process such as exit hole. Both tool that is fixed and adjustable often need backing anvil.

1.6.3 Self-reacting

The spool type tool which is made with three pieces: They are top shoulder, probe and bottom shoulder. This kind of tool can weld or process on multiple thickness joints by utilizing the adjustable pin length. Backing anvil inessential but this tool can work only perpendicular to work surface. In contrast, the other one that is fixed and adjustable can tilted laterally and longitudinally

1.7 Tool materials

A tool material characteristic is critical for FSP. Tool material depends on the work piece material and the required tool life

The tool material should consider following properties:

- Good strength, creep resistance and dimensional stability
- Thermal fatigue strength to withstand repeated heating and cooling cycles
- Doesn’t produce harmful reactions with the work piece material
- Fracture toughness to oppose damage during dwelling and plunging
- Low thermal coefficient expansion to decrease thermal stresses

1.8 Advantages of friction stir processing

- Cost and time of production is less compared to other heat treatment process
- microstructural purification, densifying and homogenizing can be done in single pass of FSP

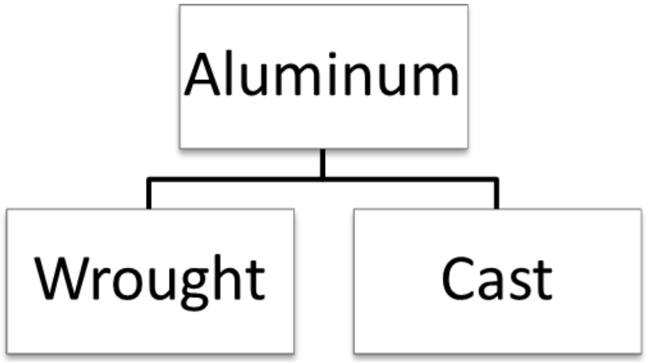
- The input heat is created by friction and plastic deformation.so it is a green and energy efficient method.
- FSP process doesn't produce any hurtful gas or radiation and noise.
- Employing FSP method doesn't alter the shape and size of material and keeps them intact.
- FSP process can be conducted by using any available machines such as conventional milling or non-traditional machine and there is no need of any special facilities and equipment's, so it is a tolerable method.

1.9 Aluminum alloys

Aluminum alloys in which aluminum is predominant constituent and Main alloying elements are magnesium, tin, zinc , silicon ,copper and manganese

Property	**Value**
Atomic Number	13
Atomic Weight (g / mol)	26.98
Valency	3
Melting Point (°C)	660.2
Boiling point (°C)	2480
Crystal Structure	FCC
Co-Efficient of Linear Expansion (0-100°C) (x10-6/°C)	23.5

1.10 Types of aluminum alloys



Categories of aluminum alloy

Types of aluminum alloys , their differences, applications and characteristics.

1.10.1 1xxx Series - Non-heat treatable. With UTS of 11 to 27 ksi. This series often referred as the natural aluminum series because it's 99% composition is aluminum. They have weld ability. However, due to their smaller melting point, they required certain considerations for producing welding procedures. When considered for fabrications, these alloys opted mainly for their higher corrosion resistance such as in chemical tanks and for their superior electrical conductivity as in bar of bus applications. These alloy have poor mechanical properties. These alloys are often weldable with 4xxx series filler or matching filler materials dependents on performance requirements and applications

.**1.10.2 2xxx Series** – Heat treatable, with UTS of 28 to 62 ksi .This series are alloyed by copper (copper percentage in between 0.7% to 6.7%), these alloy has higher strength, some good performance alloys are extensively used for aircraft and aerospace. They have excellent strengths over a broad range of temperatures. Some alloys considered as non weldable by using arc welding process. Because of its ability to stress corrosion and hot cracking; whereas, other alloys get arc welded favorably with the correct procedures of welding.

1.10.3 3xxx Series – non heat treatable, with UTS of 16 to 40 ksi. These are alloyed by manganese alloys .manganese percentage between 0.05% to 1.8%.it has average strength, appreciable corrosion resistance and formability and are acceptable for usage in high temperatures. They are the main component for heat exchangers in the automobiles and power plant. It can be welded by using 1xxx, and 5xxx series filler.

1.10.4 4xxx Series – heat treatable and non-heat treatable with a ultimate tensile strength of 25 to 55 ksi. These are alloyed by silicon. silicon percentage between 0.6% to 21.5%.

Silicon addition into aluminum will lower its melting point and fluidity will increase when molten. These characteristics are required for filler materials used for both fusion welding and brazing. And this alloys are highly acceptable as filler materials. Silicon, alone in aluminum is cannot be heat treated.

1.10.5 5xxx Series – non-heat treatable with UTS of 18 to 51 ksi. These are alloyed by magnesium (magnesium percentage of 0.2 to 6.2%) It has highest strength of among non-heat treatable alloys. And also this series is easily weldable and due to this reasons broadly used for shipbuilding, pressure tanks, and buildings. The magnesium based alloy can welded with filler, by considering magnesium content of base metal, applications and service environment of the welded component.

1.10.6 6xxx Series – it is heat treatable, with UTS of 18 to 58 ksi. Magnesium and silicon as foreign particle in aluminum (magnesium and silicon percentage of 1.0%) These are found broadly in welding fabrication industries, used majorly in the form of extrusions. Presence of magnesium and silicon to aluminum create a compound which has capability to turn solution heat treated for the improved strength. This are naturally crack sensitive, and due to this reasons, cannot be arc welded without filler material. The addition of correct amount of filler materials during arc welding process is unavoidable in order to provide dilution of the materials, there by prevents hot crack problem. They can be welded by both 4xxx and 5xxx fillers which dependents on the applications.

1.10.7 7xxx Series Alloys – it is heat treatable with ultimate tensile strength of 32 to 88 ksi. These are alloyed with zinc (zinc additions ranging from 0.8 to 12.0%) and it comprises some of the highest strength aluminum alloys. Those alloys are often used in high performance applications such as aircrafts, aerospace's, and competitive sporting equipment's. Like the 2xxx series of aluminum alloys, this series incorporates alloys which are considered unsuitable candidate for the arc welding, and others which are often arc welded very successfully.

1.11 Aluminum 7075

Is an alloy, with zinc as the predominant alloying element in aluminum. It has good strength considering many steels and also has appreciable fatigue strength and normal machinability. But lower corrosion resistance than most of aluminum alloys, It is created in different tempers, 7075-0, 7075-T651 and 7075-T6. Japanese company developed 7075 first time in secret in 1943.

1.12 Application of Aluminum 7075

- High strength to density ratio makes 7075 usage in transportation, including marines, automotive and aviation's.
- Using 7075 aluminum in components of bicycle, Rock climber equipment, skating frame and airframes are common. Hobby grade models commonly uses 7075 and 6061 for the chassis plates.
- Manufacturing of the M16 shooter gun of American military. In particular high quality M16 gun lower and upper receivers and extension tubes are commonly from 7075-T6 alloy. Many militaries are using precision rifles made by using 7075.
- It is commonly utilized in shafts for the lacrosse sticks.
- Due to its appreciable strength, lower density, thermal properties and its ability to get polished, 7075 is broadly used in mold manufacturing.

1.13 Corrosion

Is a damaging phenomenon occurs in materials, mainly on metals by a chemical reaction with their environmental conditions. The corrosion resistance of metals and alloys is the basic property with which these metals and alloys react with a given environmental condition. It is a natural mechanism which helps to reduce the binding process in metals.

Fig 3: Corrosion [F3]

It can occurs in different forms. Initially, it attacks slowly on the overall surface of metal which decreases the thickness of the metal. Secondly, rather than the overall surface attack, it can affect isolated areas that may cause the localized corrosions. Further, it also takes place on weak part of the metals due to variation in resistance to corrosion. Environmental conditions effects corrosion by means of change in the rate of flow, fluctuation in temperature and other thing that would influence the amount of reaction. According to the simple terminology, The corrosion phenomena involves in the reaction of materials with environmental conditions.

"Corrosion is an permanent intermediate reaction of materials (metals, ceramics and alloys) in its atmospheric conditions which helps in termination of solution into the surface of the material in a surrounding conditions. Rarely, corrosion provides an outcome which will affects the occurrence of damages on the materials."[W1]

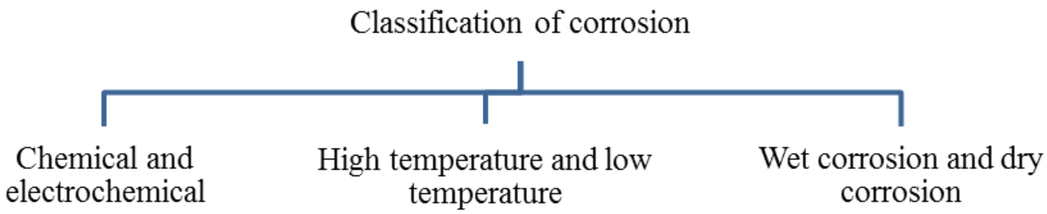
1.14 Consequences of corrosion

Failure can occur in different forms and the replacements occur may be expensive, and also it may cause reduction and destroy the materials in small amount. Some of the major consequences due to corrosion is described as below:

- Reduction in mechanical properties and structural defects may occurs due to the reduction in the weight and size of material.
- People may harmed due to operational breakdowns.
- there may be reduce in value of goods because of deterioration in appearance
- The holes may occur on the materials like pipe and vessel

1.15 Classification of corrosion:

Corrosion can be classified into various categories on the basis of material, environment, and the morphology of destruction of corrosion.



1.16 Corrosion mechanism in aluminum

1.16.1 Pitting

Fig 4: Pitting in aluminum

It is the most common corrosion which found in aluminum. Aluminum are affected in a various degrees which depends on composition, thermal treatment history and atmospheric conditions. It is a galvanic reaction between elements in the alloy, generally, aluminum which is simple and no other foreign components then it has higher resistance to pitting. The penetration rate usually diminishes with time. Pit depth is generally in 0 to 5mm. If metal is adequate then perforation cannot occur for a limited time. Reason behind the slowing reaction is that pit get filled by the hydrated aluminum oxides, a gel like product that occupies +/- 20 times of the volume of the pit. Due to small quantity of metal is removed, mechanical properties will not affect significantly. The products of corrosion will generate a white bloom near the pit.

1.16.2 Galvanic Corrosion

Natural reaction between metals in contact in the presence of electrolyte. Aluminium is a more anodic and more active material than the most. When aluminum contact with more cathodic material (that is, metals rather than zinc, magnesium and cadmium) in electrolyte presence electrolyte. The corrosion rate can be determined by potential difference of aluminum and specific metal by consideration of the ratio of areas, and the characteristics of electrolyte in the operating environment. Aluminum is also tremendously anodic to the active carbon

1.16.3 Inter-granular corrosion

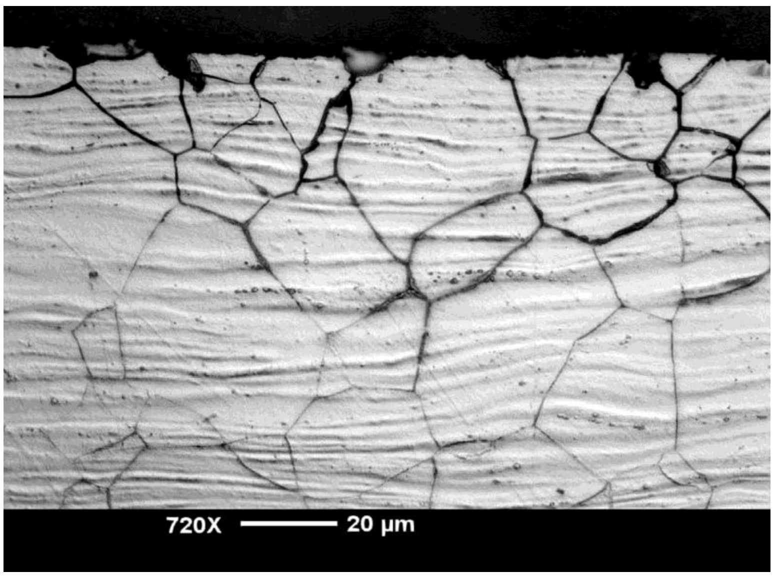


Fig 5: Inter-granular corrosion in aluminum [F5]

it is less noticeable than galvanic or pitting corrosion, since it is confined to a very small grain boundary regions of the alloying elements. And those boundaries are either depleted or enriched.

1.16.4 Exfoliation

Fig 6: Exfoliation [F6]

It's a corrosion form which disperse at the same time along several grain boundaries parallel to the metals surface. The residual metal between the corrosion paths will opens like leaves of a book. Due to this, exfoliation corrosion is quickly identified. From the service viewpoint exfoliation corrosions must be considered as serious, as it lead to reduce in thickness and strength, which can cause to a failure

1.16.5 Stress Corrosion

Stress corrosion is considered as the most serious form of attack, because if not recognized, lead to sudden failure of the component. Visually it is difficult to see. Its may only show cracks, and there being a little or no corrosion product. From a service point of view, focus should be on the high strength .It is mainly occurs on aluminum 7XXX series ,aluminum 2024, the medium strength Al Zn Mg alloys and the high Magnesium alloys.

1.16.6 Poultice Corrosion

Any absorbent materials, (such as sawdust, asbestos, papers, soils and similar materials), which contact with aluminum and becomes soggy due to condensation or water trap tend to create stagnant water. The aluminium may corrode. Good design can avoid the usage of such materials in contact with aluminum under moist conditions. Unfortunately as it is not possible to predict the moist conditions during service, absorbent gasket are not recommended.

1.16.7 Crevice Corrosion

This corrosion is an anaerobic, localized corrosion in the gaps which is smaller than about 1mm. Meniscus force of water will draw and prevent drying and the required exposure of oxygen. As a result of differential aeration, corrosion occurs in an accelerated rate in the form of etches and pits at patches within a crevice between the two surface.

One of the common examples of crevice corrosion is water staining of aluminum sheet and extruded products. A grey or black stained patch develops when water gets trapped between adjacent surfaces during storage. In a small time water staining does not decrease the structural properties of the material whereas, it is of practical importance where surface appearance is important. Subsequent surface treatment won't hide water staining.

1.16.8 Filiform Corrosion

This is an under film corrosion which affects coated surfaces. As powder coating is hygroscopic, continuous exposure to humidity can be results in attack on the aluminum substrate. Due to this in high humid conditions a two coat system is preferred with the first coat being either anodizing or a suitable epoxy coating.

1.16.9 Bacterial Corrosion

In aluminium, mainly this occurs when water is stagnant in un drained constructions which never dry. In the presence of oxygen the aerobic bacteria's form sulfides resulting in corrosion. Without the presence of oxygen, anaerobic bacteria's also common. Layers of anaerobic bacteria's can present in the inner part of the corrosion deposits, while the outer parts are inhabited by aerobic bacteria's. Bacterial colonies and deposits can form concentration cells, causing and enhancing galvanic corrosion. Bacterial corrosion may also appear in a form of pitting corrosion

CHAPTER 2

2.1 Literature review

Reviewing the works on particular field in which area of notice is important so that no other papers or thesis has done on the same field. This would be benefited in reduction of determination, concentration, period and other expenses on the work. It would also provide us good knowledge in generating original work data which would further provide the details regarding the material and research work which is beneficial from the industrial points of view. By analyzing the problem which would provide an objective related to our experiment.

Johannes et al [2007] studied the results of overlapping passes of friction stir processing on super plasticity in 7075 Aluminum alloys. Aluminum sheets were subjected to friction stir processing by nine overlapped passes. The investigation on microstructure revealed that after FSP the grains became finer and pure. And also tests were conducted to investigate the result of strain rate on forming and tensile strength. The tensile test said that overlapped FSP exhibited superplastic behavior, but the as received sample did not exhibit superplastic behavior. [1]

Ma et al [2008] investigated friction stir processing of 7075Aluminium rolled plates with different processing parameters. The microstructural investigations revealed that FSP resulted fine-grained. They noticed that heat treating the FSP processed work plate at 490 °C for one hour resulted in high temperatures fine grain structures were stable. Superplastic investigations at the temperature range of 420-530C and strain rate range of 1×10^{-3}–1×10^{-1} s^{-1} carried out and demonstrated reduce in size of this grains resulted significantly which enhance super plasticity and there is a shift to higher strain rate. Ma et al. concluded that the mechanism which responsible for superplastic that is behavior of the Friction Stir processed 7075 Al was the grain boundary sliding.[2]

V. J. Badheka et al.2016 fabricated surface composite of Al 7075 by Boron carbide particles as a parent metal and powder particles respectively and they fabricated and investigated on multiple material by various combination of friction stir processing parameter that is traverse speed , rotational speed and number of passes. They evaluated microstructure by using image analyzer and found some defend in FSP zone.[3]

Tewari et al. [4] Studied SiC specific orientation change by the friction stir processing on A6061. They took high-resolution surface image for the detailed image of microstructural of SiC/A6061of the composite materials before and after single friction stir processing step. The SiC reinforcement particles were found to have anisotropic shape. The scanning electron microscopic image of the composite shows a morphological feature. From the particle orientation image, they found some favorable orientations for SiC particles after extrusion process. The preferred orientation can modified during traverse of the friction stir tool. [4]

Shafiei Zarghani et al.carried out friction stir processing of Nano Al2O3 into AA6082 aluminum alloy for creating particulate composite surface layer .The Al2O3 particles have average size of about 50 nm. They achieved favorable bonding of surface composite and aluminum substrate which has defect free interface.

They examined Mechanical properties including micro hardness and Wear .Their results revealed increment in FSP passes results in proper dispersion of Nano sized reinforcement particles. They founded that surface hardness become three times compared to base alloy. And also found significant increment of wear resistance in the Nano composite surfaced Aluminum compared to the base Al alloy. The wear rate is reduced to one third that base aluminum alloy. [5]

Sunil Sinhmar et al. carried out an investigation on tensile properties, hardness and microstructure in Friction Stir Processing of AA 7039 Alloy. They analyzed that the friction stir processing make reduction in UTS and yield strength. And also observed that the ductility of friction stir processed material was seen significantly higher than unprocessed base metal.

Hardness measured by using Vickers's hardness tester. Hardness testing on different pass of FSP were carried. The hardness for stir zone is found to be less than normal base alloy. The decrease in hardness after friction stir processing of AA 7039 results in reversion that is dissolution of hardening MgZn2 precipitates and recrystallization. [6]

Don hyun choi et al [2012] Conducted experiment of effect of SiC powder particles on Aluminum 6061–T4 parent metal by using method of friction stir processing. They evaluated microstructure of friction stir processed 6061-T4 . SiC particles were dispersed uniformly in parent metal. Also SiC particles enabled grain refinement of the matrix using FSP. The average grain size of zone with the SiC particles was smaller than zone without SiC particles. [7]

Barucha et al [2016] Studied effect of number of passes on the microstructure and mechanical properties on friction stir processed alloy that is Al-7Si-3Cu. Evaluated metallographic examinations, Tensile test and hardness value of the Friction Stir Processed work were carried out and found that Triple pass. FSP altered micro structural refinement, and homogeneity of Si particles. Found hardness in the friction stir processed region incremented with number of passes. and The tensile strength of triple pass friction stir processed material is 2.25 times as cast alloy. [8]

Yong liu et al. 2014[9] worked on the friction and wear characteristics of FSP composite of 6061 Aluminum as parent metal and boron carbide as reinforcement. Evaluated the load applied, sliding velocity, sliding time reach critical values, the friction coefficient and mass loss increase significantly. critical delamination of wear when sliding for two hours with applied load 30N. Fretting happens when sliding velocity reach 240 r/min. After treated at 550 ºC/1 hour and then aged at 180 ºC/15 hours, the composite gains the highest wear resistance phases in matrix and the strong bonding of parent alloy and B_4C particles. [9]

M. Salehi et al [2012] worked to find optimum process parameters for creating 6061 aluminum alloy parent metal where SiC as reinforcement by friction stir processing and a Experiment design applied to determine factors which influence ultimate tensile strength of the Nano composites which produced by friction stir processing. Effect of four parameters, including transverse speed, tool penetration depth and pin profile and their Ultimate Tensile Strength was investigated. By Taguchi method, the optimum of process parameters were determined. Analysis of variance relieved that the rotational speed is the most influential parameter. UTS for threaded pin is larger than that for square pin. Also higher the rotational speed and lower the transverse speed results in higher the Ultimate tensile strength. [10]

M.Bahramia et al [2015] They evaluated microstructures and mechanical properties in aluminum 7075 as parent material and SiC as reinforcement. And their matrix composite was fabricated by friction stir processing. relation of particle size and tool parameters on processing was studied by distributing SiC in metal matrix. And also they evaluated microstructure, micro hardness and wear behavior of specimens. His experimental results revealed that increment in FSP passes, and decrement in size of SiC powder improved hardness as well wear properties. [11]

Xing Hao and Bao Lin. [2017] worked on FSP to create ultrafine grained microstructure on AZ61 magnesium alloy. These ultrafine grain were also proved by micro hardness test. The hardness value of stir zone approaches Hv120-130, which is significantly higher than that of AZ61 base alloys. All these results shows that under a certain cooling rate, ultra-fine AZ61 alloy with enhanced mechanical properties will be obtained by FSP through dynamic recrystallization. [12]

I.S.Lee et al [2011] They first produced metal matrix composite by using Powder metallurgy after that they used FSP. They used atomized aluminum powder and silicon powder. Mixture of Aluminum and Silicon powders with particular compositions get compacted to create a billet. Billet was sintered and by using milling machine they carry out FSP. The work sample were examined by using scanning electron microscope. Tensile standard specimen were machined from zone of FSP billet which kept tensile axis alongside to the traverse direction of tool. The strain were calculated using an extensometer which is clipped to the gauge length. The FSP specimens have a better finer SiC particles which is uniformly dispersed into Aluminum matrix. [13]

Y.mazaheri et al [2011]worked to produce surface nano composite A356/Al2O3 by friction stir processing method. The specimens used was A356-T6. Residual machining chips A356 and micro and nano sized α-Al2O3 powders with 99.9% purity used for creating

A356/Al2O3 composite powders. Rotation, feed and tilt of tool were 1600rpm, 200mm/min and 2^{o}. Micro hardness and indentation tests used to evaluate the specimen. They found that the uniform dispersal of Al2O3 grains into A356 matrix using FSP process that will enhance mechanical properties of matrix. [14]

Adem Kurt et al [2010] worked on Surface alteration of aluminum by friction stir process. , SiC powder were dispersed by using Friction Stir Processing into aluminum cold rolled plate 1050 aluminum alloy to create particulate surface layer. Samples were evaluated with and without powders. Microstructural observations carried by using optical microscopy. Hardness and bending also evaluated. Increasing rotating as well traverse rate results in more uniform dispersal of SiC particles. They observed that hardness of processed surfaces made better three times as compared to base aluminum. Bending strength of created metal matrix composite was higher than simply processed specimen and base metal. [15]

B. Zahmatkesh et al [2010] Studied microstructural and wear behavior of friction stir processed Aluminum 2024-T4.Evaluation of microstructures of work samples by using optical microscopy. Hardness and wear resistance were evaluated. Dry sliding wear test were conducted by utilizing translating wear test. The results revealed Friction stir processing was favorable concerning improvement in hardness and wear resistance. FSP were lessened wear rate. [16]

Lingyu Guo et al [2015] conducted experiments to improve Corrosion and Wear Resistance of aluminum 6061 by using friction stir processing with Fe78Si9B13 Glass Particles. The AA6061-T6 aluminum and annealed Fe78Si9B13 particles were processed by friction stir processing. The coefficient of thermal expansion for FSP specimen increment at first with temperature and afterward diminish as the temperature is further increased. The corrosion and wear resistance of FSP material have been improved. They state that lubrication impact by Fe78Si9B13 particles results in improving wear resistance. [17]

Dakarapu Santha Rao et al [2016] Evaluated Wear and Corrosion Properties of Aluminum 6061 alloy fortified with TiB2 particles Produced by FSP Technique . The main aim is to produce MMCs with low cost in an effective way . They produced AA6061/TiB2 MMCs with various volume divisions of ceramic by using friction stir processing. By using pin on disc method dry sliding wear of composites was investigated. The corrosion of specimens was analyzed by using salt spray method. They found that wear and corrosion resistance was incremented with increment of reinforcement up to 8% of composite. [18]

Karthikeyan et al [2009] Investigated friction stir processing which can eliminate casting imperfections locally by characterizing microstructures in which that can improves mechanical properties of specimen. They used base material as cast aluminum alloy of 2285. They used three feed rates with two rotational speeds .On processing, hey were observed that increase in mechanical properties such as tensile, yield strengths and ductility FSP material. [19]

Kwon et al [2003] He used FSP technique on 1050 aluminum alloy. They have evaluated the relation between mechanical properties, hardness and tensile strength with two rotational speed. They found that they have indirect relation with tool rotational speed. The outcomes denote there is an increment up to 37% and 46% in hardness and in tensile strength respectively for processed specimen. The hardness in the forward side was higher when compared with the backward side. The research indicates that Friction stir processing approach is highly usable when there is a need for enhancement in mechanical properties of grain refinement. [20]

2.2 Research gap

After a comprehensive study of the existing literature review a number of gaps have been observed in friction stir processing of aluminum alloy 7075 by using boron carbide as reinforcement. By studying and analysis of literature review reveals that the researches worked mostly on varying one parameter at a time and no consideration has been given on interaction impact of two or more parameters.

- There is a need of study on change in mechanical properties of corroded friction stir processed al 7075 and non-corroded friction stir processed al 7075
- There is a gap of investigations on change in wear resistance of corroded friction stir processed al 7075 and non-corroded friction stir processed al 7075
- Very less research done on impact of corrosion on mechanical properties of FSP material
- Very less research works on impact of friction stir processing of boron carbide in aluminum 7075
- Very less research done on impact of corrosion on wear properties of FSP material.

2.3 Objectives

- Increment of corrosion resistance of aluminum 7075 by using FSP
- Investigate effect of mechanical properties on friction stir processed 7075 aluminum alloy in corrosive environment
- Investigate effect of wear properties on friction stir processed 7075 aluminum alloy in corrosive environment
- Effects of friction stir processing of boron carbide in 7075 aluminum
- The outcome of adjusted parameter on surface quality will be researched

2.4 Scope of studies

As indicated by the specified points of interest of friction stir process, it is an exceptionally productive and versatile process and will be supplanted by the standard property alteration strategies. Yet it is still new. Since it isn't utilized in the manner, there is a need to upgrade the learning in on various states of process. 7075 Aluminum alloys have been broadly utilized as basic materials in aeronautical and aircraft skins due to their attractive thorough properties, it has a favorable mechanical properties, but this aluminum had less corrosion resistance, and there is a need of high corrosion resistance to the aerospace due to its exposure to saline humidity. So there is a scope on increment of aluminum 7075 by using friction stir processing

CHAPTER 3

EXPERIMENTAL SETUP

3.1 Material

We consider Al 7075 of dimension 180 *160*5 mm for samples.

3.1.1 Aluminum 7075

The first aluminum 7075 was produced in secret by a Japanese company called Sumitomo Metal in 1943. 7075 aluminum is an Aluminum alloy in which zinc is the primary alloying element. It has good strength equivalent to many steels, and has better fatigue strength but average machinability. Main problem of this alloy is lower corrosion resistance.

3.1.2 Chemical composition of Aluminum 7075

Element	Al	Zn	Mg	Cu	Cr	others
Content %	90	5.6	2.5	1.6	0.23	0.07

3.1.3 Physical properties of Aluminum 7075

Property	**Value**
Density (lb/in^3)	0.101
Specific Gravity	2.81
Melting point (degree F)	900
Modulus of elasticity tension	10.4
Modulus of elasticity torsion	3.8
Ultimate tensile strength	140 - 580

3.2 Tool

In friction stir processing, there is a need to design a suitable and accurate tool. In this case we choose a tool which is made by a H13 steel. This selection will causes an improvement in strength and wear resistance during thermal processes. After employing FSP the mechanical properties of tool may get changed

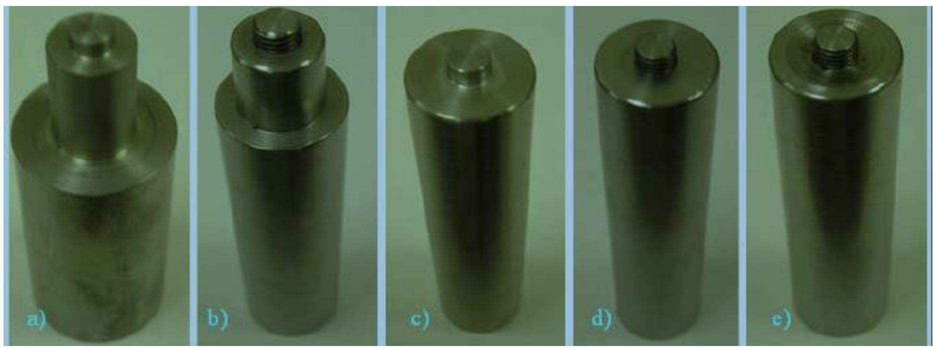
.

Fig 7: Different types of tool configuration [7]

3.3 Experimental Tests

3.3.1 Hardness Test

For hardness test we will use Vickers hardness tester. Various combinations of rotational speed, feed rate were used on samples and their test will be employed on all samples and different zones to have accurate experimental results. Test will be like first the diamond or indenter will be depressed into the surface of the material at a particular value of a load and the size of the impression is measured by utilizing a calibrated microscope.

Formula for Vickers hardness

HV = 1.854F/d2

Average d = d1+d2

3.3.2 Tensile Test

We are planning to use ASEME9 standard for tensile testing. For this test there is a specific standard dimension of specimen. So we will cut stir zone according to that dimension and subject to tensile test. Sand papers were used to polish the samples prior to test. The cut samples for tensile test have been shown below.

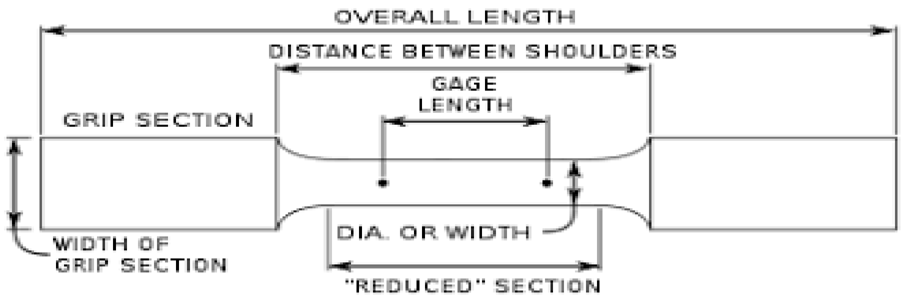


Fig 8: sample for tensile test [F8]

3.3.3 Wear Test

We considered “Pin on disc” tribometer for the study of wear behavior of a specimen. It has a stationary pin by an load in touch with a disc which is in rotation. Frictional coefficient measured by the ratio of the frictional force to the force loading on the pin. The pin on disc test was proved its ability in providing a simple wear and friction test.

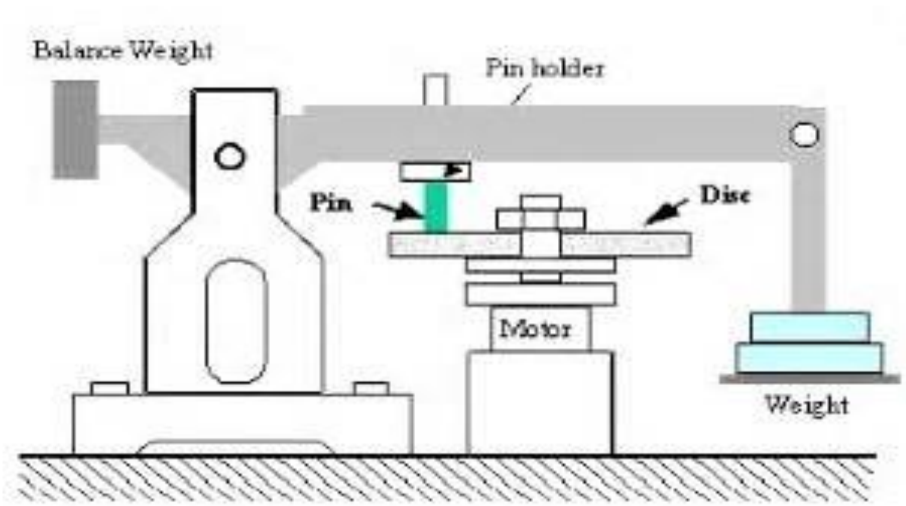


Fig 9: Schematic diagram of Pin on disc wear test setup [9]

3.4 Experimental Set up

We can use many machine for FSP process like CNC machine, Vertical milling machine. By considering availability and accuracy we are using TAL V – 350 vertical milling machine.

FSP tool is important and crucial element of the process. The tool assembly consists of a shoulder and concentric pin. We need to mount tool on Milling machine.

Fig 10 : TAL V – 350 vertical milling machine

3.4.1 Fixtures used

It is used to fix work specimen properly during process

Length –	40 cm
Breadth –	40 cm
Thickness –	3.8 cm
Material used	Cast Iron

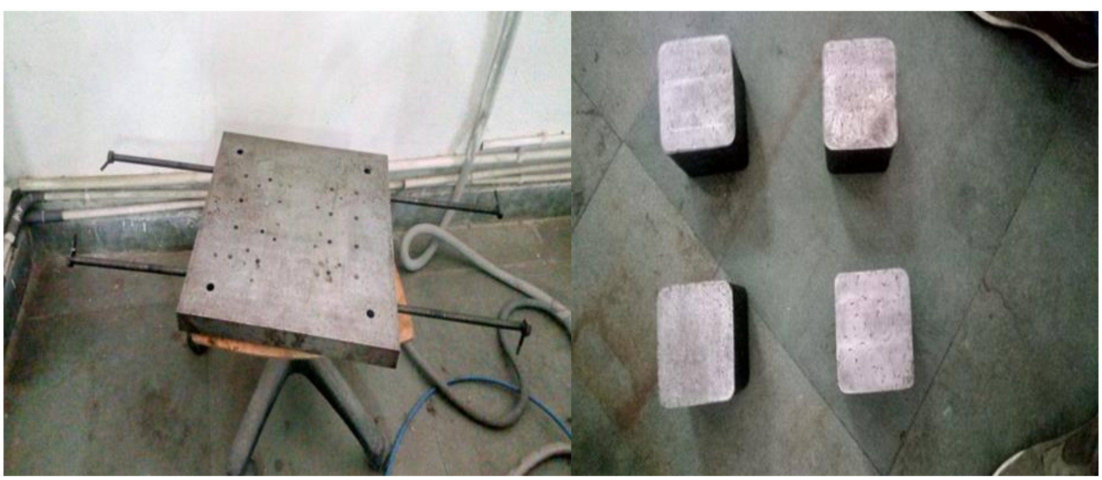


Fig11: Fixture desig

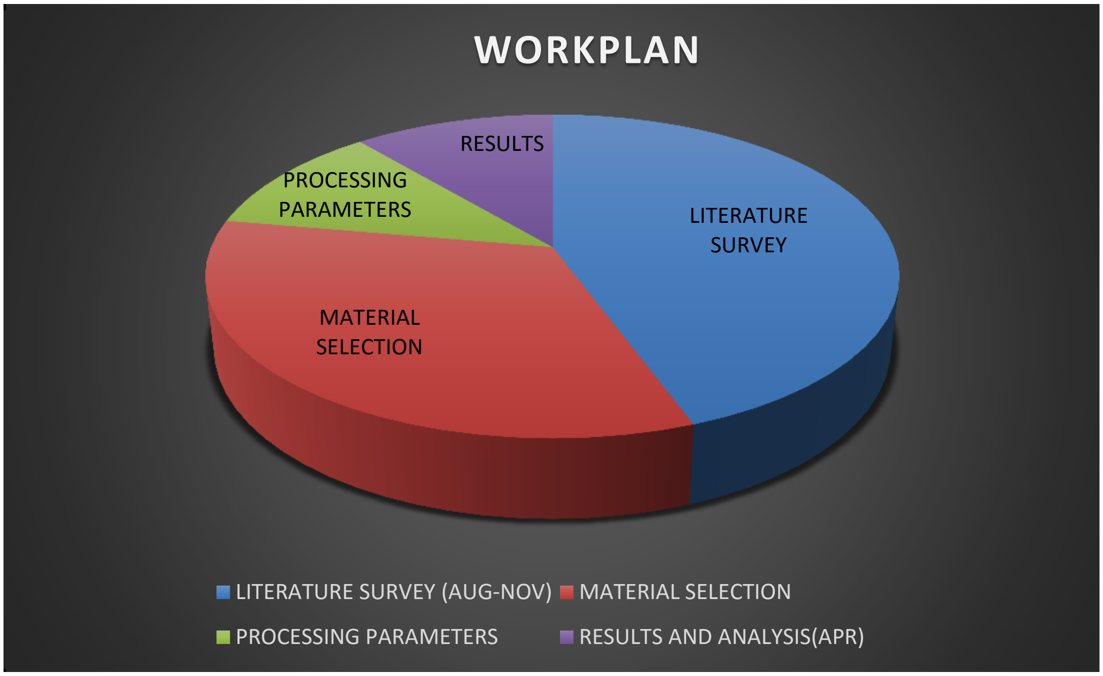
CHAPTER 4

4.1 Methodology

Investigation of mechanical and wear properties of a friction stir processed aluminum alloy reinforced composite in a corrosive environment will be accomplished with a several series of process. Aluminum 7075 with 5 mm thickness is going to be used as our plate and reinforcement of B4C powders will be carried by friction stir process. Distinctive type of processing will be held by certain proportion of B4C, tool pass and parameters. For dispersal of B4C we need to make a small groove on aluminum. Groove must closed aluminum tape. Further processing will be completed. Then evaluation of aluminum mechanical and wear properties of unprocessed aluminum, processed aluminum and reinforced aluminum will be measured. Test will be carried before corrosion and after corrosion. For revealing how corrosion varies mechanical and wear properties of friction stir processed aluminum alloy.

CHAPTER 5

WORK PLAN AND TIME LINE



Work Plan Pie-Chart

CHAPTER 6

6.1 Expected outcomes

Corrosion resistance if aluminum 7075 was not that good but we expected that there will be an betterment in corrosion resistance by dispersing B_4C reinforcement into the aluminum 7075 by using friction stir process.

By using appropriate parameters we hope friction stir process will bring about huge grain refinement of the microstructure compound and it can be controlled by tool parameter of FSP technique.

CHAPTER 7

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2) [F2] https://goo.gl/images/fspWV
3) [F3] https://goo.gl/images/LQrqWV
4) [F4] https://goo.gl/images/vpz2SE
5) [F5] https://goo.gl/images/82ayoX
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