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Characterization of Al6082 and Magnesium AZ3lB Composite Produced by The Friction Stir Additive Manufacturing

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Abstract

In this modern era, lighter and stronger materials are needed. This is especially true for materials needed in aerospace, robotics, light aircraft, defence, and transportation. When comparison to backbone products in order composite goods have a higher durability & stiffness-to-weight proportion. Most of the newer fabricating methods, called friction stir additive manufacturing (FSAM), uses solid-state drives friction stirring technology to produce bilayer structures by sequentially fusing discrete strata. In this study, researchers developed a composite material and found tensile strength up to 213.7 Mpa and the hardness of the composite up to 94.8 BHN. FESEM, EDX mapping has been done for examining the microstructure and found that better mixing of the reinforcement is done. After completion of the processes and study of the mechanical properties as well as the less porosity, and fine grain size. Many machines part required different materials and different strengths in the part, at this place Friction Stir Additive Manufacturing (FSAM) is the best way to develop the composite material. The selection of a process (FSAM) depends on behalf of the homogeneous distribution of the particles in the matrix alloy and the accuracy of the metal matrix composites.

Keywords: Friction Stir Additive Manufacturing, Composite Material, Matrix Material, Reinforcement, Grain Size, Hardness, Tensile Strength.

INTRODUCTION

Biochemical developments in the first decades of the twentieth century led to the discovery of polyethylene, polythene, phenolic, and vinyl chloride, and strengthening was required. Since it was the first synthetic plastic, bakelite was noteworthy. synthetic fibreglass was introduced by Owens Corning Limited in 1935, kicking off the fiber-reinforced polymer (FRP) market. Alternative higher-performance glue infrastructure, notably the substance, also became accessible by 1938. Unrefined polyesters were initial commercialised in 1936. During development to output, the fibre reinforced plastic (FRP) market acquired knowledge from the demands of Second World War that fibreglass composition is radioactively permeable. This is used for radar and other electronic equipment. A totally nanocomposite bodied car had been evaluated as a concept by 1947. The invention of the motor car caused the introduction of various novel modelling techniques, principally two techniques: bulk modelling composite (BMC) and sheeting mould compound (SMC). The initial form of synthetic fibre was developed in 1961, and after some time it became widely used in industry. The marine industry was the nation's largest consumer of composite substances in 1960. In 1970 -1980, the composite material market advance and advanced fiber were used in aerospace components, sporting equipment, medical device etc.

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By "The weld Institute" (TWI), FSP emerged in 1991 [1]. The desire for advanced designed materials with distinctive features increases regularly. Aluminium has shown it's a great alternative to composites, whose are getting more popular because to their relatively light weight, lower density, outstanding strength, and ability to withstand corrosion. Different substances, including Al, Mg, and Cu, can be used for FSP, but it aluminium was chosen for this research. It is widely employed in the construction of spaceships, autos, and other vehicles, as well as for structural support necessities. These types of firms are expanding daily due to to the exceptional strength-to-weight value of aluminium [2].]. Kumar et. al fabricated composite material with FSP. Microscopy proved that an alterations in the microstructure happens on the composite's surface. The presence of components with properties resembling the Al/SiC/RHP combination composition has been found by X-ray diffraction investigation. It has been showed that when compared to base aluminium material, UTS tearing strength and Brinell hardness increase by factors of 1.36 and 1.75, respective [3]. SEM photos of the blended material made by Singh et al. display the grain shape structure, while EDS data display the elements arrangement in the forged AZ31 alloy. The mineral magnesium is properly distributed along each grain according to the EDS visuals, however the aggregation of brass at the borders of the grain and the abundance of magnesium there further point to the creation of the Mg17Al12 secondary phase [4]. The financial status of a corporation is impacted by the expense of upkeep, equipment for and fitment owing to the wear and stress from interfacial issues [5]. The Tensile Test will demonstrate a range of outcomes due to the properties of the material, including shear the modulus of the yield and peak strength, fraction extension, as well as other dynamic ratios. Generalised Hook's law provides a broad answer for the material's elasticity. The predicted findings may be employed as well to determine the elastic constants and other mechanical properties, which can be helpful in predicting them before the real-life run [6]. Utilising a method called energy- (EDS), aspect the mapping and will and periodic profile pictures taken using field-emitting scanning electron microscopy (FESEM), the microstructural personality development was able to be determined. [7]. By transferring excellent electricity into solid-state drives form, friction-stirred being processed, a cutting-edge method built on the This friction Stir The process of welding (FSW) fundamental nature, nationally avoids flaws in castings and adjusts microstructures. This results in enhanced the physical characteristics, increased defence against oxidation and weakness, increased or accessibility, as well as other characteristics [8]. Aircraft industry organisations are currently calling for advancement of powerful and light-weight technologies. Composites made from aluminium alloys have good optical and chemical properties and a low thickness. Manganese alloy an AZ31B is utilised as a form of reinforcement in the present investigation. additionally, the usage of particles of graphene as fortification. When creating composite materials, the Stir casting method is employed.[9].

A basis in the concept of stirred friction welding because friction agitate additive assembly (FSAM) is a set of novel techniques for stripe-by-stripe material additive assembly. In light of the advantages of solid states welding, and the features intrinsic of this process (MAM), this technology is acknowledged as development in the context of iron additive manufacturing, or MAM for short. The study addresses the essential technology of friction stir additive manufacturing (FSAM), examines recent developments in this largely unstudied a subject, and emphasises the benefits of FSAM over fusion-based alternatives [10]. Friction mix preparation is an emerging technique for creating new composites of surfaces or altering various characteristics of an ingredient by strong, localised elastic deformation in its solid form. When a non-consumable rotating tool is inserted within the workpiece, a distortion is created that goes longitudinally via the workpiece, causing a variation in properties [11].

The component's a microhardness score and stiffness enhanced after frictional stirring treatments. As support was added, the compound's fluidity and yield strength decreased, while its microhardness of the and resistance to corrosion increased. The investigated tensile and wear parameters and tool rate of rotation exhibited a direct correlation. The main stress cause was adherent wear, whereas Fe deposit development was seen on the scarred come to rest, increasing resistance to wearing.[12] During microstructural investigations, FE-SEM using EDS tracing and fluorescent microscopy are both applied. The metal in the matrix strengthens SiC, Al2O3, overall B4C, increasing their strength against stress, yield strength, and durability but decreasing their ability to bend. Both liquid-phase and solid-phase method of manufacturing have been used to create the ideal nanocomposite.[13].

The outcomes indicate that the SiC or B4C granules are evenly dispersed throughout the Mg framework. There was no defects found. L9 orthogonal array was used to improve the process variables [14].

Friction-stir welding (FSW) was developed and put into use to provide a cutting-edge solid states technique for combining incompatible materials, among them metals as well as materials like polysaccharides. This kind of joint design is very interesting for structural applications, especially in the case of the automotive industry. In this regard, several combinations of materials in terms of metals (mainly focused on aluminium) and polymers (mostly thermoplastic compounds) were assessed in two joint designs but and lap in terms of processing parameters optimization, microstructural features, interfacial bonding, and mechanical behaviour [15].

Palanivel, et. al evaluated MELD® technology-assisted chemical frictional stirred coating of AZ31B mg alloy. A solid friction-driven stirring tool was used to stir AZ31B metal bar stock while moving within an uninterrupted 400 rpm and translate at a range of 4.2 to 6.3 mm/s. Typically operating step resulted in the deposition of an only wall made up of a total of five layers, typically having a measurement of 140 mm3 x 40 mm3 x 1.[16].

The latest approach for developing and making fragile assemblies is known as additive manufacturing (AM), which builds things step by flake in accordance with a digital model and is extensively employed in aerospace production [17]. An innovative technology for manufacturing known as additive manufacture, or AM, enables the creation of extremely complicated geometrically tailored 3D things that are impossible to produce using conventional fabrication methods. The procedure requires gradually construction of the component [18]. Regarding Mg-based composites, the substance SiC has proved a great support ingredient. SiC exhibits an exceptionally high elastic modulus, and it is robust, temperature shock-resistant, and heat-resistant [19]. The objective of this investigation is to understand the molecular interactions that mediate the adsorption and desorption of the pharmaceutical species methylprednisolone from the functionalized surfaces of mesoporous SBA-15 silicas to establish design criteria for controlled release applications [20]. To evaluate the two-dimensional The user interface scanning electron microscopy (SEM) was employed [21]. The handled zone undergoes high microstructural improvement consolidation, and homogeneous as the outcome due to the FSP's severe deformation caused by plasticity, material interaction, combined heated processing [22]. Technologies for solid-state drives additive design are still in their infancy. Among these, friction stir-based techniques demand significant materials deformation caused by shear during construction. In the present article, we concentrate on additional friction stir deposition (AFSD) and irritation stir additive manufacture (FSAM) (Figure1). These stirred welding-derived procedures can, in many situations, overcome the typical strength-ductility A trade-off paradigm and create tiny structures which exhibit superior mechanical properties compared to the initial alloys when are handled ordinarily [23]. Biomedical implants/scaffolds made from biodegradable materials and, once implanted, are to assist with tissue functions and healing while corroding gradually into the by-products that should be metabolized and not elicit harmful reactions [24].

An sophisticated manufacturing method known as AM (additive manufacturing) enables the development of exceptionally intricate geometrically tailored three dimensions things that are impossible to produce using traditional manufacturing methods. The procedure entails gradually construction of this component [25].

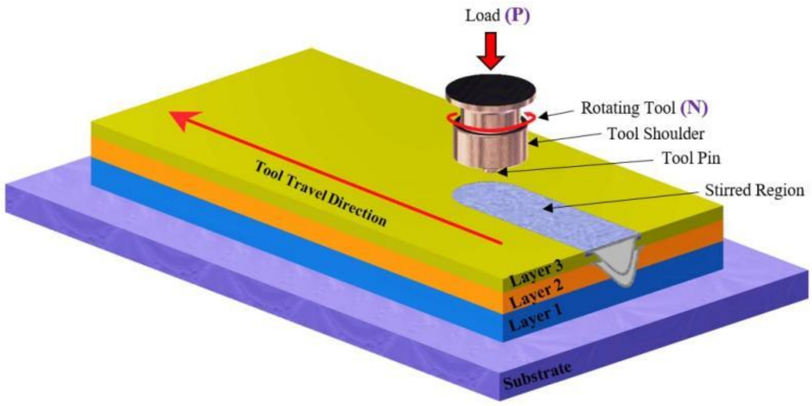


Figure 1. FSAM (friction stir additive manufacturing).

In order to link layers or plates, a non-consumable revolving tool featuring a specially made pin as socket is put into the sides and moved on the union line.

Collaborative production involves no cooling and occurs in a solid form. The depth of the panels or plates and the quantity of assembly layers determine the joint's final size. FSAM results in hammered structures as opposed to the cast method in fusion-based procedures..

MATERIAL AND METHODOLOGY

Composite Material

A composite material consisting primarily of reinforcements (fibres, particles, or fillers) contained within a matrix material (polymer, metal, or ceramicThe main purpose for building materials is to enhance the completed material's durability. The entire procedure of creating products and manufacturing them involves the essential step known as composite characterisation.. The properties of composite materials are mainly based on the properties of the components, their mixtures, and the cooperation between them. A property is a volume subset of a component. Alternatively, the components are related in a way that yields movement or better properties. The density of the matrix material and the orientation of the stiffeners also affect the properties [4].

Metal Matrix Composite

Composites made from metal matrix materials may give a variety of unique benefits.. Common combinations of these include adequate corrosion resistance, excellent stiffness, improved damping capacity, and strong wear resistance. MMCs are superior to base metal alloys because they consist of stiffeners integrated into a metal matrix. The requirement for products of greater quality is growing as a result of rapid technological advancements.

Selection of the Material

In this research, work material was selected based on a literature review. After developing the metal matrix composite find a better result.

1. Aluminium

Because of their excellent strength-to-weight relationship and softness, alloys made from aluminium are utilised for numerous vehicle parts, including brake shoes, tyres, and other elements.The initial study of 6082 alloys has been carried out in terms and large temperature effects etc.

Aluminium 6082

The main objective of this research has been an improvement of sheet metal forming processes. Aluminium alloys 6082 were recently the subject to evaluation under various heated procedures. The significant amounts of both magnesium and silicon in this combination are displayed in Table 1.

Table. 1. Aluminium 6082 chemical composition (wt%)

S. N	Si	Fe	Cu	Mn	Mg	Zn	Ti	Cr	Others
1	0.7-1.2	0.5	0.1	0.4-1	0.6-1.2	0.2	0.1	0.25	0.1

2. Magnesium

Magnesium alloys are constantly gaining importance as lightweight materials for automotive applications. Mg alloys are especially attractive due to their low density high specific stiffness and strength as well as recycling ability.

Magnesium AZ31B

A thin plate of 3 mm thickness AZ31B magnesium alloys was cut the small pieces as per requirement. After cutting the plate then cut the grove on the plate. Figure shows the magnesium without grove as well as with grove. And Table 2 shows the chemical composition of the AZ31B.

Table 2. Chemical compositions (wt. %) of AZ31B Magnesium Alloy.

S. N.	Al	Mn	Zn	Cu	Ni	Si	Fe	Mg
1	3	2	1	0.05	0.005	0.1	0.005	Balance

3. Reinforcement

It is mixing a little amount of some other material in the base metal. It is done to impart some specific properties in the base metal as per the requirement. Generally, strength-enhancing materials are incorporated into weaker metals to improve their strength. Examples of reinforcements (Figure 2) are Silicon Carbide, Carbon nanotubes, Titanium carbides etc.

(a) B_4C (b) SiC (c) Al_2O_3

Figure 2. Reinforcement.

SiC

Coal and silicon combine to form carbide made from silicon, usually referred to as carborundum. A fresh material for use in electronic gadgets is silicon carbide, which is a material used in semiconductors. A few of those most significant manufacturing ceramic substances is this one. serves a significant part in the rise of capitalism and is still widely employed as a structural material made of ceramics metals complementary and gritty.

B4C

The high melting point and thermal stability of boron carbide make it ideal for use in refractory materials. As a result of its extraordinary wear resistance, it is employed as an abrasive powder and coating It excels in the ballistics due to its low density and great toughness. regularly used in nuclear technologies.

Al2O3

It is offered for sale in the form of a white powder that is both hazardous and odourless. It is an outstanding heat reflector and quickly absorbs power. 2040 ° C is a melting temperature that defines it. 2977 ° C is the temperature that boils of it. Except in the setting of a strong base, aluminium oxide does not react with oxygen. for its great immunity to corrosion and damage at higher temperatures, it is employed as a material for ceramics. Particularly in electrolytic devices, it serves as a form of thermal insulation. It is utilised as an oxidising in chemistry processes that take place at high heats because of its excellent stability at high temperatures. It operates excellently due to it's low density and substantial toughness. stops the anodized and cathodic connections in a cell with electrolytes from oxidising. It works well as an insulation for electricity in gasoline-powered automobiles' ignition switches. It is utilised in manufacturing procedures to construct aircraft because of its thinness. It has been utilised to create kitchenware like saucepans for frying other refractory plates due of its high temperatures.

Tool Design

In this research work, three types of tool profiles are designed with the help of a CNC machine as well as a grinder machine. The high-Speed Steel material used for the tool material. Figure 3 shows the step of the tool design.

(a) HSS rod (b) CNC machine (c) Grinder machine.

Figure 3. Tool design steps.

(a) Triangular Shap (b) Octagon Shape (c) Circular Threaded

Figure 4. Tool.

Fixer Development

This inspection requires a special arrangement to properly hold the workpiece and perform the operation with high precision. So first take an MS plate 24x18cm and clean the surface from both sides.(figure 4). After cleaning the surface, use a drill to evenly space the holes. After this operation, place the fixer on the table vertical milling machine and hold the workpiece with clamping bars or bolts. The sole purpose of this fixer is to complete the process with high accuracy.

Figure 5. Development of the fixer.

EXPERIMENTAL PROCEDURES

Irritation stir additive manufacturing is a technique for creating materials from composites that builds bilayer items by gradually connecting solid states frictional stir processes.. In this research work firstly developed the fixer for holding the workpiece (fig 5 shows the fixer). After that cut the aluminium 6082 and magnesium AZ31B into equal sizes as well as cut the grove by the shaper machine on both aluminium and magnesium plates, after cleaning the surface with emery paper. Now fix the tool no in the collet of the vertical milling machine and fix both plates on the fixer and set the heteroses parameter.

After the course of experiment preparation, these criteria were complied with. On a horizontal milling machine (of the "Rainu machine tools" brand), the FSAM activity is carried via the aid of an exclusive device that holds the piece being worked on. Nine trials were completed, and nine FSAM specimens were created for the study's objectives in accordance with the procedure parameters listed in Table 3..

Table 3. Processes parameter during experimentation.

S. N.	Parameter	Values
1	Tool Rotational Speed (RPM)	1400, 1600
2	Tool Traverse Speed (mm/min)	5
3	Axial Force (N)	5
4	Tol Pin Profile	Cylindrical
5	Tool Shoulder Diameter (D)(mm)	16
6	Tool Pin Diameter (d) (mm)	5mm,6mm,7mm
8	The ratio of the Tool (D/d)	3.2mm,2.66mm,2.22mm
9	Tool Tilt Angle	0^0, 1^0
10	Welding Temperature	730 – 750 ^{0}C
11	Tool Material	High-Speed Steel (HSS)

After all, is set, the parameter firstly joins the two-layer, aluminium 6082 is the matrix material and fills the reinforcement in the grove and fixes another magnesium plate AZ31B on the top of the aluminium, and fixes the tightly on the fixer, tool insert in the plate slowly or stay the tool till generating the heat when heat is generated then the table is moved forward slowly or complete the processes similarly tow layer joining is complete after two layers joining the third plate which aluminium 6082 fix at the top of the two plates which already joined but at this time tool change because the thickness of all plate was 9 mm so tool nib is too large as compare to the first tool and fix all parameter for three-layer joining the processes is going on, when complete the three-layer joining the workpiece is move out the fixer and keep in side till colling, after colling the sample it’s ready for the preparing the specimens. Table 4 shows the composition of the developed Metal Matrix Composite.

Table 4. Composition of the Developed Metal Matrix Composite.

S.N.	Aluminium Plate (wt. gram)	Magnesium Plate (wt. gram)	Reinforcement (SiC)	Reinforcement (B4C)	Reinforcement (Al2O3)
1	111.5	38.6	2	2	2
2	112.2	39.3	2.5	2.5	2.5
3	113.4	39.2	3	3	3
4	112.3	40.3	3.6	3.6	3.6
5	111.9	38.9	4	4	4
6	112.8	39.4	4.5	4.5	4.5
7	113.1	40.7	5	5	5
8	113.6	41.9	5.7	5.7	5.7
9	114.2	41.6	6.2	6.2	6.2

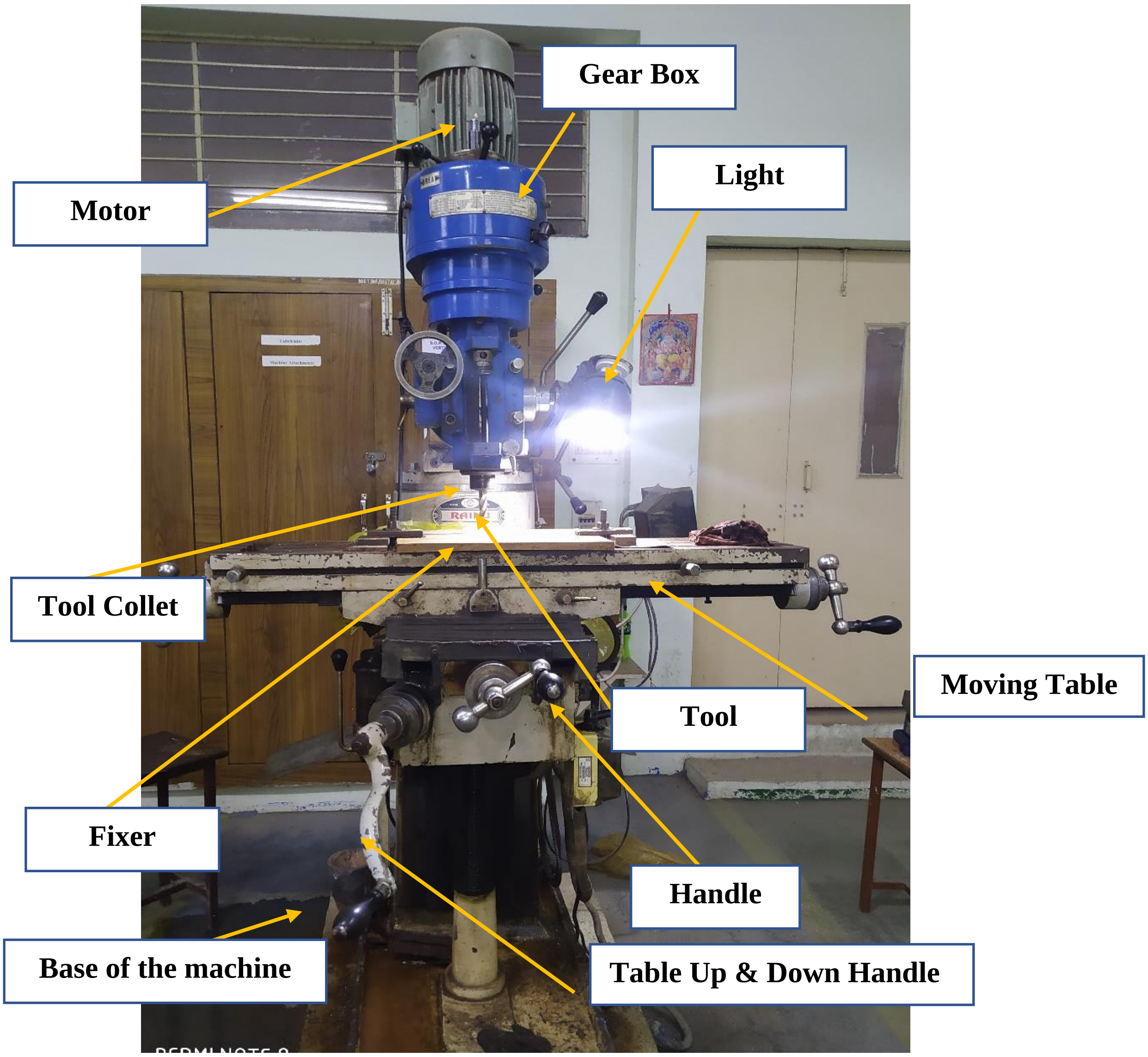
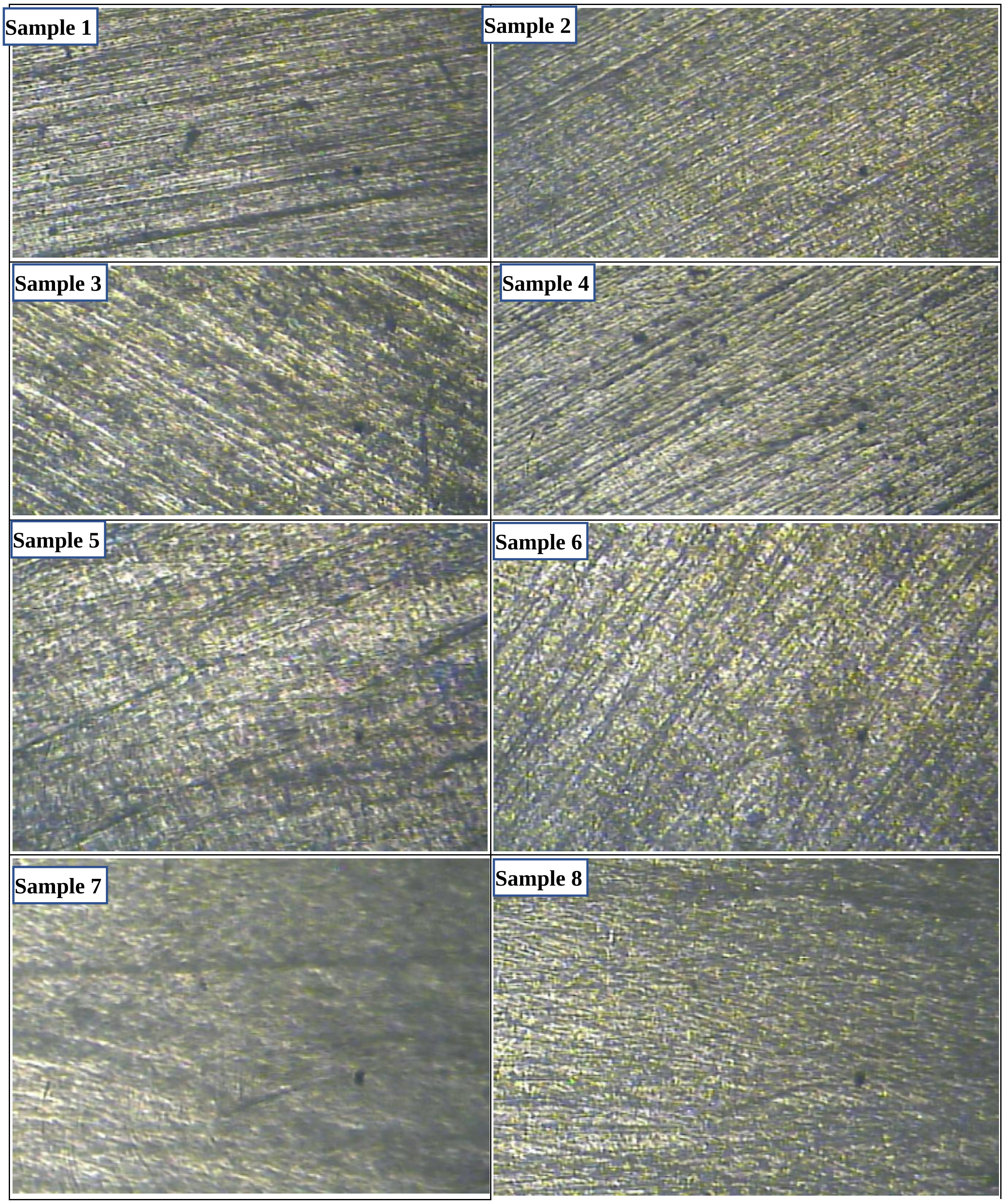


Figure 6. Vertical milling machine.

RESULT AND DISCUSSION

Microstructure Analysis

Microstructural characteristics including grain size, impurity incorporation, porosity, segregation, and surface effects are influenced by the incorporation of the material as well as any further processing or treatments. Materials' mechanical and physical properties are impacted by microstructure, which also accommodates a variety of flaws that may or may not be present. Optical microstructure saw that the microstructure of as-cast alloy consists of equiaxed grains without dendritic. The microstructure of magnesium alloys will generally be impacted by various extrusion circumstances, which will also impact their physical characteristics (Figure 7). the impact on the structural integrity of melting factors and thermal treatment techniques with the value melting speed, and pre-forging, heating duration, melting proportions, and speed of cooling. Figure 6 represents the Vertical Milling Machine.



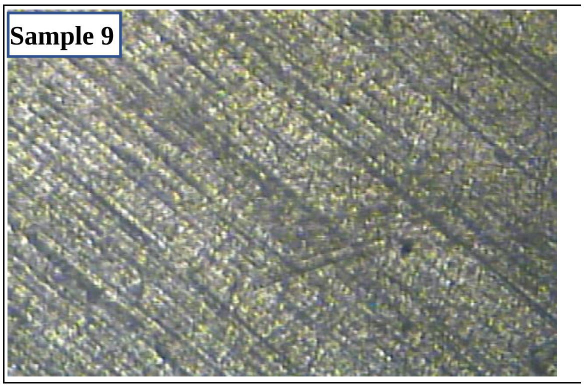


Figure 7. Optical Microstructure images of specimen.

FESEM

Utilising the use of FESEM pictures, an EDS analysis, and mechanical information including tensile toughness and hardness (BHN), each sample was examined for geometric categorization. For 2% SiC/2% of all kinds of encouragement the microstructural experiments were made (Figure 8).

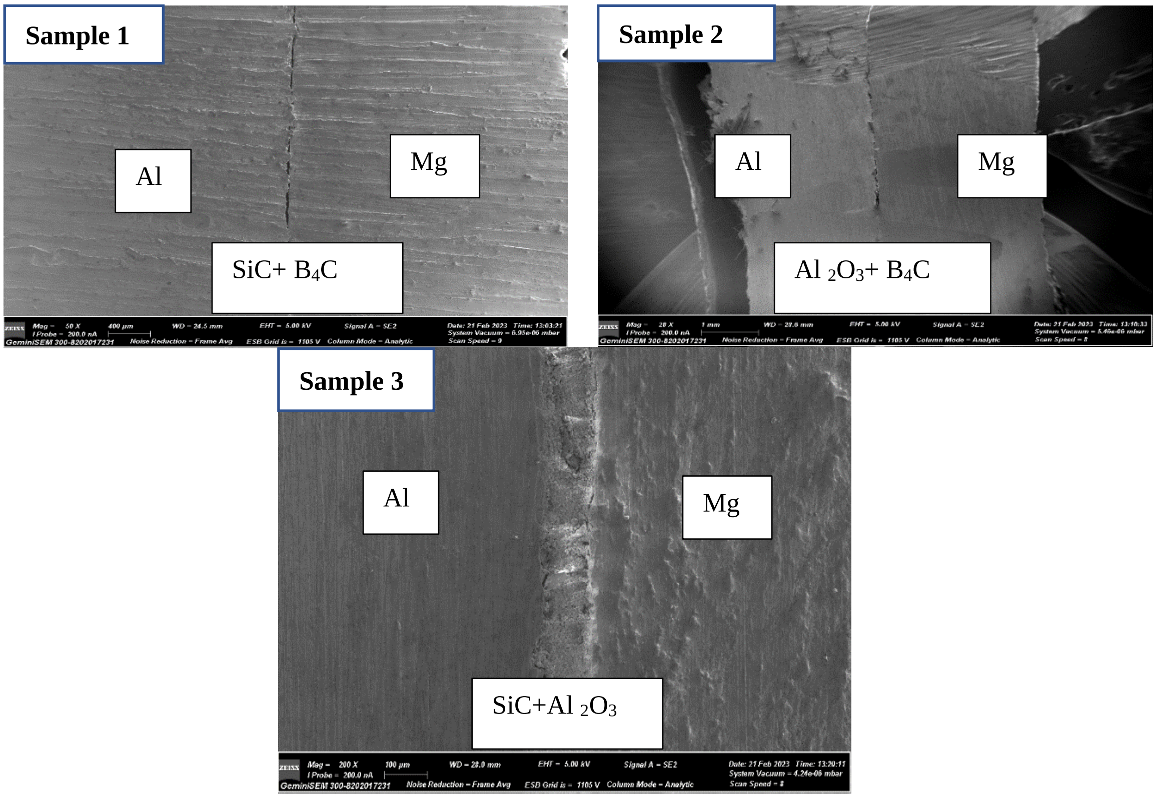


Figure 8. FESEM images of the specimens.

(Al 2O3,B4C). The model was first prepared according to ASTM E3 standard, then it was etched using Keller's reagent (15 mL HCL + 25 mL HNO3 + 10 mL HF + 50 mL H2O). Images of our field emission scanning electron microscope (FESEM) were captured by a Joel jsm-7800 Prime field emission scanning electron magnifying glass coupled with an EDS detector (LN2 Free SDD X-max 80 Energy dispersive detector) at a voltage for acceleration of 23 Kv and acquisition time using an LN2 Free SDD Xmax 80. Energy dispersive detector) at a 23 Kv acceleration voltage and a 60.8 second duration of acquisition Additional analysis of the spectrum of the EDS is done to establish whether there is of the elements and their percentages of the primary (SiC) and supplementary (Sic, B4C, and Al2O3) reinforcing types. As a result of the investigation, the strength of tensile is examined for each of the nine different sample to determine the ideal figure to use as the FSAM procedure settings. On an upright Tensometer built of KIPL, Model PC-2000, a tensile examination was performed. As per the specifications of the ASTM E8 accepted, sample for the purpose of compressive research were created.

Tensile Strength

Tensile tests are performed to assess the cohesion and safety of materials. This assures the manufacturer that the finished product is of the highest possible quality. A tensile test determines the maximum load a material can withstand. Generally, this test is used to assess the quality of similar batches of manufactured products. After doing the tensile test, find the maximum tensile strength of the sample number (Table 5).

In tensile specimen, Figure 9 describe to prove inhomogeneous micro structural properties in the transverse direction

Table 5. Tensile strength results.

Sample No.	Tool Pin Profile	Rotational Speed	Tilt Angle	Tensile Strength (Mpa)
Sample 1	Triangular	1000	0	140.45
Sample 2	Triangular	1200	1	159.32
Sample 3	Triangular	1600	2	163.76
Sample 4	Hexagonal	1000	1	173.59
Sample 5	Hexagonal	1200	2	185.66
Sample 6	Hexagonal	1600	0	197.25
Sample 7	Circular	1000	2	216.47
Sample 8	Circular	1200	1	203.36
Sample 9	Circular	1600	0	191.31

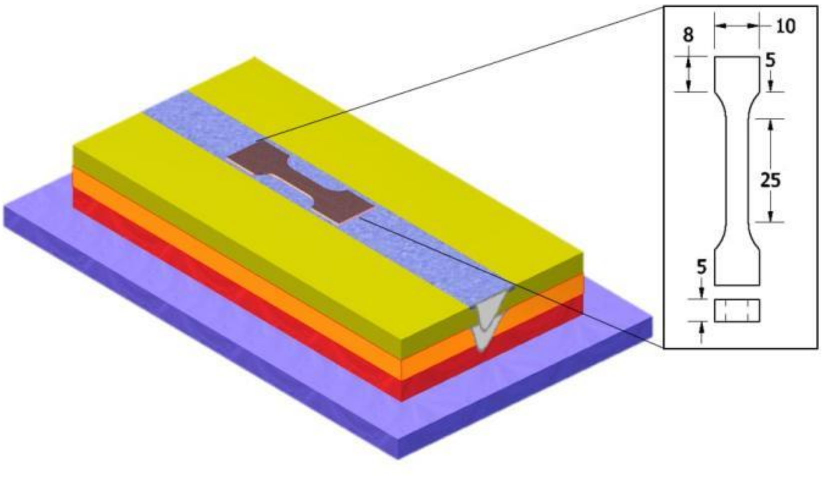


Figure 9. Tensile specimen.

Hardness

Brinell hardness was done, and some hardness parameters is used according to the composite material. Hardness parameters show in the Table 6. After completion of the test analysis the hardness result, sample no 1 is considered the reference sample, sample no 1 has the hardness 63.5 BHN similarly all sample has been done and find the best result sample no. 7 which is 99.3 BHN which is 56.37 % higher of the reference sample but sample no. 8,9 has recorded the 97.2 BHN and 93.2 which 53.07 % as well as 46.77 % higher of the sample no. 1. So, sample no. 8,9 shows the decreasing the as compared to sample no. 7. So, sample no. 7 records the best results of the hardness (Table 7). Table 6 show the all-hardness results of the specimen. Figure 10 shows the Hardness Result Observation Graph

Table 6. Hardness test parameter.

S. N.	Parameter	Values
1	Indenter Diameter	5 mm
2	Load Apply	250 kgf
3	Type of Indenter	Ball Indenter

Table 7. Hardness results (Brinell Hardness).

S. N.	Sample	Hardness (BHN)	% Changes
1	Sample 1	63.5	0 %
2	Sample 2	69.7	9.76 % Increase
3	Sample 3	76.1	19.84% Increase
4	Sample 4	88.6	39.52% Increase
5	Sample 5	94.8	49.29% Increase
6	Sample 6	96.9	46.29% Increase
7	Sample 7	99.3	56.37% Increase
8	Sample 8	97.2	53.07% Increase
9	Sample 9	93.2	46.77% Increase

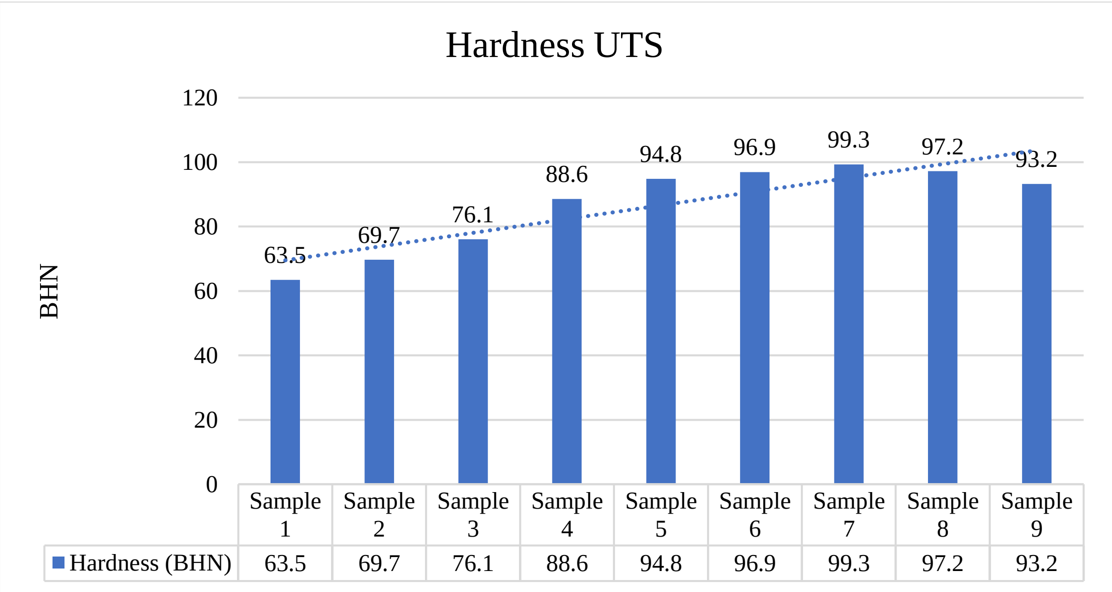


Figure10. Hardness result observation graph.

CONCLUSION

The physical properties of tensile durability and hardness are examined in the present project. Fabricated composite material, tensile strength is higher than the matrix material, as well as the hardness of the developed composite material.

- A total of nine specimens were developed through FSAM operation.
- To assess the impact of added secondary additions on tear strength, an additional trial is conducted with a second layer of 2% SiC (primary reinforcement) but any other reinforcement..
- The velocity of the traverse for FSAM action was set at 25 mm/min, and Taguchi's L9 matrix was used to determine the other procedure variables for nine specimen.
- Every single one of the biological objects appeared to be in good condition because they lacked any significant flaws like misrunning or sinking..
- On the upper portion of the FSAM locale, cutting plus tool traces may be seen. But before creating specimens for testing, possibly it disappeared by polishing it using grit newspaper..
- In this study examine the microstructure study clearly shows the reinforcement particle B_4C, SiC, and Al_2O_3. After microstructure analysis better mixing the reinforcement and less porosity and

refine grain size.
- Over mechanical analysis is better than the matrix material. In these processes (FSAM) fabrication of the composite material is easy and safe as well as better results.

Nomenclature
- FSP- Friction Stir Process
- FSAM- Friction Stir Additive Manufacturing
- MMC- Metal Matrix Composite
- CNC- Computer Numeric Control
- BHN- Brinell Hardness Number
- Mpa- Mega Pascal
- AL2O3- Aluminium Oxide
- SiC - Silicon Carbide
- B4C - Boron Barbie
- HSS - High-Speed Steel
- MS - Mild Steel
- BMC - Bulk Moulded Compound
- FRP – Fiber Reinforced

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