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# INFLUENCE OF MECHANICAL PROPERTIES AND MICROSTRUCTURE OF THE ALUMINIUM5083 WITH NANO SILICON CARBIDE PARTICLES(50-60nm) CASTED BY STIRCASTING USING WITH AND WITHOUT VIBRATIONS

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**Abstract:**

This study aims to investigate the influence of mechanical vibration of the mold on the mechanical properties of Al5083. Despite its importance, there is currently a lack of literature on this specific topic. To fill this gap, we will conduct a series of tests. Al-Si based alloys are the most important non-ferrous alloys. These alloys were enormously used in various sectors like marine, aerospace and automobile industries because of their excellent mechanical properties such as corrosion resistance, low density, low coefficient of thermal expansion, excellent wear and good strength.

These are employed in settings where a high level of wear resistance combined with light weight is necessary. However, the dendritic arm spacing of the silicon particles, in particular, and the degree of grain refinement, determine all of these alloys' performance. These applications necessitate researching methods to enhance these alloys' mechanical characteristics and grain structure through SEM analysis. Consequently, by applying mechanical mold vibrations during the casting process, this review will provide an improvement in the mechanical properties and grain structure of the alloy.

The alloy will be molten after the casting process is complete, and during the solidification process, it will be subjected to mechanical vibration. Different frequencies between 120 and 180 Hz will be applied to achieve the right dendritic arm spacing, grain size, and reduction of internal defects. Additionally, test results show that the stir casting process enhances the mechanical and physical properties of aluminum alloys. Aluminum 5083 is an alloy consisting of magnesium, aluminum, and trace amounts of chromium and manganese. The following is the 5083 aluminum alloy's chemical composition: Aluminum equilibrium Chromium: maximum 0.05–0.25% Copper: maximum 0.1% Iron: up to 0.4% Magnesium: 4.09–4.9 percent Manganese content: 0.4–1.0%Silicon: maximum 0.4% Titanium: 0.15% max Zinc: 0.25% max.

**Keywords:** Sem analysis, Mechanical properties

## I. INTRODUCTION

Because of their superior mechanical qualities, aluminum matrix composites, or AMCs, have grown in popularity recently across a wide range of industries. AMCs consist of a minimum of two components: an additional reinforcing material and the pure aluminum alloy. Aluminum matrix composites (AMCs) are a class of materials that have attracted increasing attention in recent years due to their superior mechanical properties, such as high strength, stiffness, and wear resistance. AMCs are made by combining a metal matrix, such as aluminum, with a reinforcing phase, such as ceramic particles or fibers. The reinforcing phase improves the mechanical properties of the matrix, while the matrix provides good formability and machinability. AMCs can be manufactured using a variety of methods, including powder metallurgy, stir casting, liquid metal infiltration and mechanical vibration. The choice of manufacturing method depends on the desired properties of the composite. Out of these methods, using melt stirring and mechanical vibration technique is a good way to create AMCs with desired properties. These composites are smart materials for industries because they can be used for many things. Mixing materials together is useful for making stronger composites. Making AMC materials by One economical way to make them is by melting, stirring, or vibrating them. These combinations have demonstrate that in industries like mining, automobiles, and aircraft, their strength and stiffness surpass those of conventional materials. By managing the environment and ensuring that the particles disperse uniformly throughout the primary material, this process can be enhanced. Researchers examine the composition, hardness, and wear resistance of AMCs in comparison to the base material. Improved material strength and hardness are partly attributed to the uniform dispersion of small particles. Higher addition amounts of material have an even more noticeable effect. AMCs are widely used because of their remarkable strength characteristics and lightweight design. This makes them extremely valuable in the fabrication of electronic, automotive Raising the temperature of the matrix inside the crucible until it melts is part of the process. Increased wet-ability and bonding between the matrix and reinforcements are the results of preheating the mixture. In order to reduce the likelihood of casting defects, an inert condition is maintained during the material mixing process with the assistance of stirring. Mechanical vibration is also applied to reduce porosity, blowholes, etc. AMCs come in a wide variety, each with special qualities of its own. The most popular kinds of AMCs are those that are reinforced with ceramic particles, like boron carbide (B4C) and silicon carbide (Sic).Usually, during casting, the particles are added to the molten aluminum matrix.

AMCs reinforced with particles exhibit good strength, stiffness, and resistance to wear. One can see a steady rise in the demand for MMC or the substitution of MMC for conventional alloys due to research and development in new or existing processing techniques. The processes used to manufacture the composites determine a variety of characteristics, including the distribution of secondary phase particles in the matrix phase, mechanical properties, morphological characteristics, tribological properties, and many more.

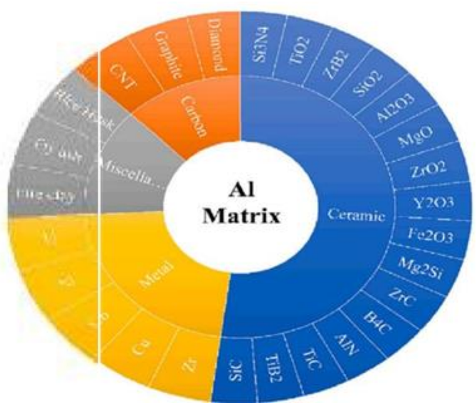


Fig 1. Sunburst diagram shows the commonly used reinforcement for Aluminum metal matrix composites.

**1.1 Matrix and Reinforcement**

Matrix: The composite material's continuous phase is called the matrix. Usually, it's a metal, like magnesium, titanium, or aluminum. The composite material's strength and stiffness are derived from the matrix. Reinforcement: The distributed portion of the composite material is the reinforcement. Usually, it is a ceramic, like silicon carbide or aluminum oxide. The composite material benefits from the reinforcement's high strength, stiffness, and resistance to wear.

To stop the reinforcement from reacting chemically with the matrix, it is usually covered in a thin layer of a substance, like silicon carbide. Additionally, the bond between the reinforcement and the matrix is strengthened by this coating. In a molten state, the reinforcement and matrix are combined. The composite material is created by solidifying the molten mixture after it is poured into a mold.

Table 1-Poperty,Matrix,reinforcement

| Property | Matrix | Reinforcement |
|---|---|---|
| Material | Metal | Ceramic |
| Strength | Low | High |
| Stiffness | Low | High |
| Wear resistance | Low | High |

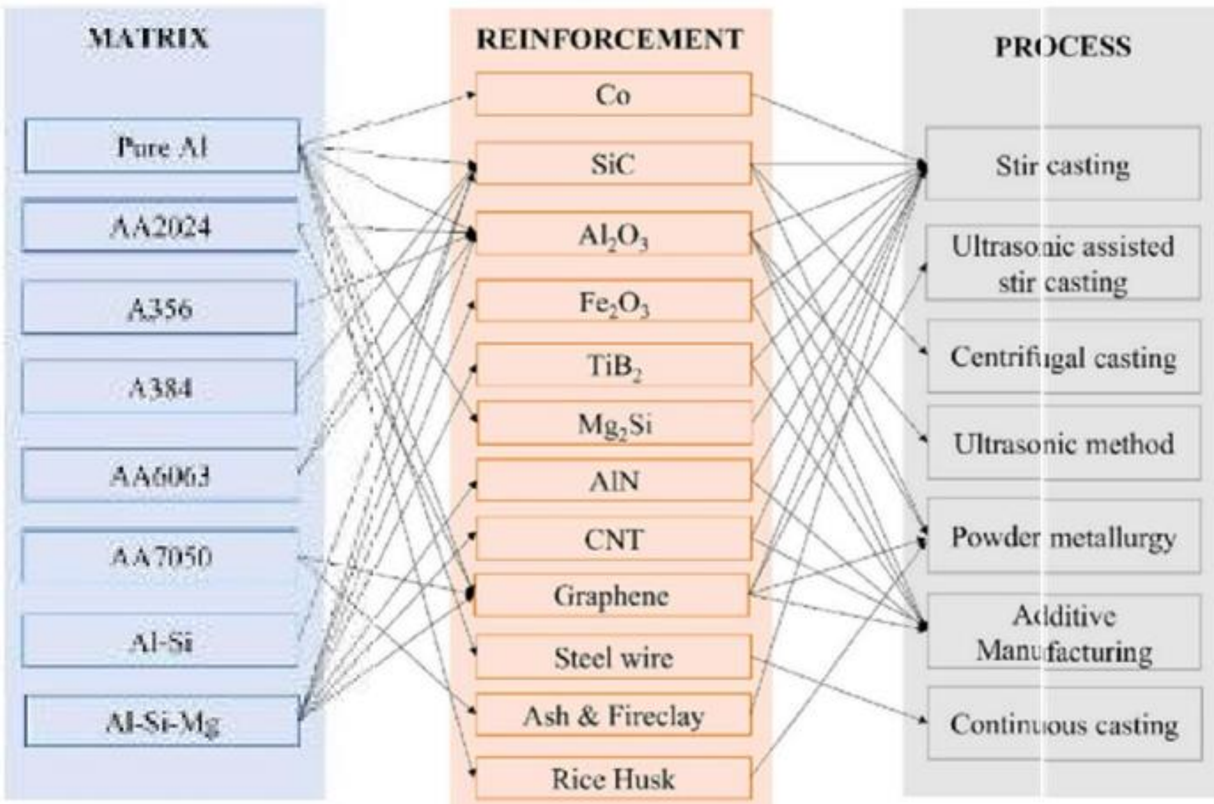


Fig. 2.Relationship chart shows the commonly used Aluminum matrix, reinforcement, and manufacturing processes.

## I. METHODOLOGY

The matrix alloy is melted in a crucible to start the process. Depending on the particular kind of alloy being used, the melting temperature requirement may change. Preheating is done in parallel to the reinforcement particles, with careful control to keep the temperature slightly below the alloy's melting point. The important goal of this deliberate preheating is to stop the reinforcement particles from clumping together.

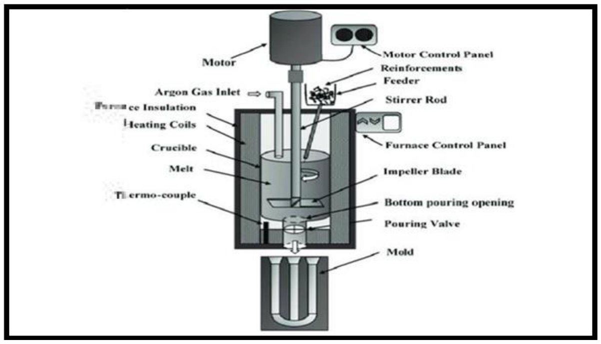


Fig. 3. Schematic view of gravity Stir casting

The reinforcement particles are added to the molten alloy once they have reached their preheated state. The careful stirring performed by a specialized stirrer allows the molten alloy and heated reinforcement particles to combine. The specific properties of the alloy and the reinforcement particles are taken into account when determining the parameters that control the stirring process, such as its speed and duration.

Table-2-Properties of Al 5083

| S.NO | PROPERTIES | VALUE |
|---|---|---|
| 1 | Melting Point | 660 degree Centigrade |
| 2 | Density | 2.66g/cc |
| 3 | Poissons Ratio | 0.33 |
| 4 | Tensile Strength | 317Mpa |
| 5 | Hardness(Rockwell) | 36.5 |
| 6 | Compression Modulus | 71.7Gpa |
| 7 | Elongation at break | 16% |

Table-3- Properties of Silicon carbide nano particles

| S.NO | PROPERTIES | VALUE |
|---|---|---|
| **1** | **Melting Point** | **2730 degree centigrade** |
| **2** | **Density** | **3.22g/cc** |
| **3** | **Ultimate Tensile Strength** | **210-370 Mpa** |
| **4** | **Poissons Ratio** | **0.15-0.21** |
| **5** | **Youngs modulus** | **370-490 Gpa** |
| **6** | **Molar Mass** | **40.11g/mol** |

Then the well-combined melted mixture is transferred into a prepared mold. The necessary structure for shaping the finished product is provided by the mould, which is usually made of sand or metal. The once-fluid amalgam goes through a transformational phase inside the mold, solidifying and assuming the desired shape of the Aluminum Matrix Composite (AMC). The complex synthesis culminates in this solidification process, which yields the desired AMC with improved properties and performance capabilities. The development of AMC specimens can be influenced by a number of parameters during the melt stirring process, such as the melting of the matrix alloy, feeding reinforcement, impeller position and stirrer design, speed rotation, stirring time and temperature, material pouring, solidification, mold temperature, and coatings.

**Parameters of the stir casting process:**

It is typical practice to employ an aluminum monolithic matrix with ceramic reinforcements that are finely woven into the matrix. This integration is accomplished in a way that guarantees uniform distribution across the matrix. Ceramics, like those combined with matrices of aluminum, nickel, magnesium, cobalt, and titanium, require a finely tuned affinity with the reinforcing phase. The qualities that make aluminum attractive and appropriate include its light weight, strength, durability, malleability, resistance to corrosion, and resistance to wear. Three phases are involved in the synthesis of aluminum matrix composites (AMCs): liquid, solid, and vapor. A variety of substances, including Sic, continuous carbon, and ceramic fibers or particles,

can be used as reinforcement in a matrix made entirely of aluminum. Reinforcement is added to a pure aluminum matrix using a variety of methods designed to improve the mechanical characteristics of the resulting composites. The ultimate component's performance qualities, such as its load-bearing capacity, specific strength, impact resistance, and flexural rigidity, are greatly influenced by the choice of embedding material. Particulates are frequently used to add carefully selected substances to inexpensive materials to improve their specific strength and associated properties. The reinforcement factor in the context of composites includes important dynamics like the kind, size, weight, or volume fraction of the reinforcement and the particulate preheating schedule; all of these factors are significant within Careful operational considerations are necessary during the stir casting method of manufacturing AMCs. Prudent control over a range of processing parameters is essential because it can result in improved AMC performance attributes.

**Stirring- Impeller:**

The impeller's mechanism controls the degree to which the various constituents in the materials combine. Usually, the impeller should be positioned at a height that is approximately 30% of the crucible base's open surface height when the material is melted. In order to properly shape the mixing of the components, the stirrer can have two or more blades. various impeller kinds, such as single, double, or multi-step

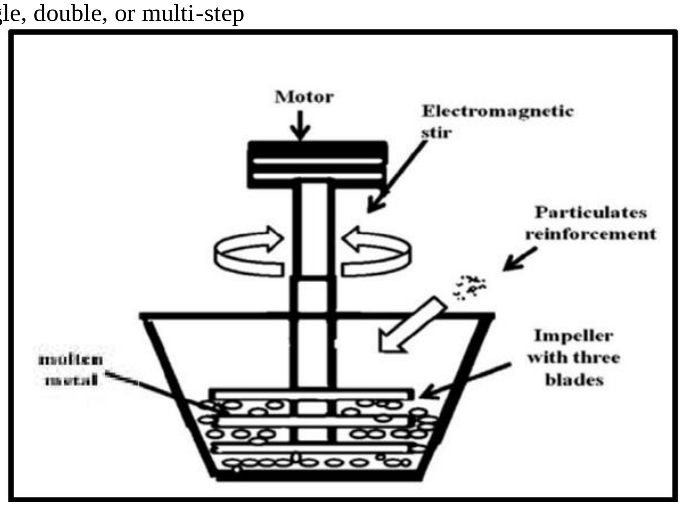


Fig. 4. Stir casting route incorporated electromagnetic rotation

can also be utilized to increase the efficiency of stirring and produce a beneficial swirling motion. Of these, single-stage impellers are more useful and appropriate for melting and stirring composite materials. The reinforcing material is moved around by the stirring motion, and the shearing action breaks down the reinforcing material that is clustered, producing a homogenous mixture. It has been discovered by researchers that the impeller blade angle—which varies from 15° to 90°—is significant. Using a 30° angle produced the best results in this study because it distributes the particles very evenly. The angle and arrangement of the blades in the impeller-stirrer setup, as well as its design, greatly influence the mixture's flow characteristics.

**Stirring speed and time:**

The development of AMCs requires careful control over the speed at which stirring occurs. The microstructure's formation is also governed by the speed at which it stirs. Increasing the melt stirring generally leads to microstructure refinement, whereas decreasing the speed causes the liquid mixture to become unstable. In order to avoid tearing or ruining the composite, it is crucial to stir at a steady and sensible speed. Prabu et al. (2006) conducted an experimental investigation into the production of AMCs reinforced with Sic using stir casting processing. After varying the stirring time (5–15 minutes) and speed (500–700 rpm), they discovered that a mixing method produced the best results. 600 rpm and 10 minutes at a speed. As the speed of stirring increased, the AMCs' microhardness first rose. Nevertheless, the microhardness of the composites was reduced when the stirring speed was increased further, up to 1000 rpm.In certain localized areas of the matrix regions, there was clustering due to the non-homogeneous dispersion of the reinforcement particles caused by low stirring speed. Circumferential forces generated by extremely high stirring speeds drove the reinforcement particles to flow close to the AMCs' surface, increasing particle clustering there as well.

As a result, after a certain speed, the nonuniform dispersion of reinforcement particles increases with increasing stirring speed. The composites reached their maximum microhardness at 800 rpm.In a different study, Raju et al. (2019) discovered that increasing the stirring speed and duration (400 rpm and 10 min) allowed for the uniform distribution of aluminum oxide particles in the AA 5052 alloy. The ultimate tensile strength and microhardness of the created AMCs increased as a result of the reinforcement's extremely uniform dispersion.This study found that the uniform dispersion of reinforcement particles is facilitated by stirring time.

When it comes to melt stirring processing, stirring time is crucial. Particles disperse non-homogeneously when stirring at low speeds, and clustering can result from excessive stirring. Melt temperature: Due to the poorly wettable embedded particles, it is difficult to preheat the ceramic reinforcement in the stir casting process of AMCs. To eliminate moisture and gases, the reinforcement is heated for 40 minutes at 500°C. Particle clustering is influenced by the reinforcement feed rate and can result in porosity. It is estimated that 0.5 g of reinforcement per second is the optimal flow rate for melting stirring.Abdi Zadeh et al. (2008) looked into how the liquid's viscosity was affected by the temperature at which melt stirring occurs. They discovered that raising the processing temperature and lengthening the stirring time reduces the liquid's viscosity. Good wettability is the result of this.

This is due to the fact that adding reinforcement particles makes mixtures more viscous, which can slow down stirring. It is best to control the stirring speed and achieve a uniform distribution of the reinforcement particles at a melt temperature between 780 and 800°C. Lloyd (1989) also discovered that the temperature range of 740–800°C is the most favorable for dispersing particulates in melts of aluminum alloys. When adding reinforcement, many researchers have stirred at temperatures between 350 and 850 degrees Celsius. Melt stirring is then performed, and the material is poured at a temperature that is roughly the same.

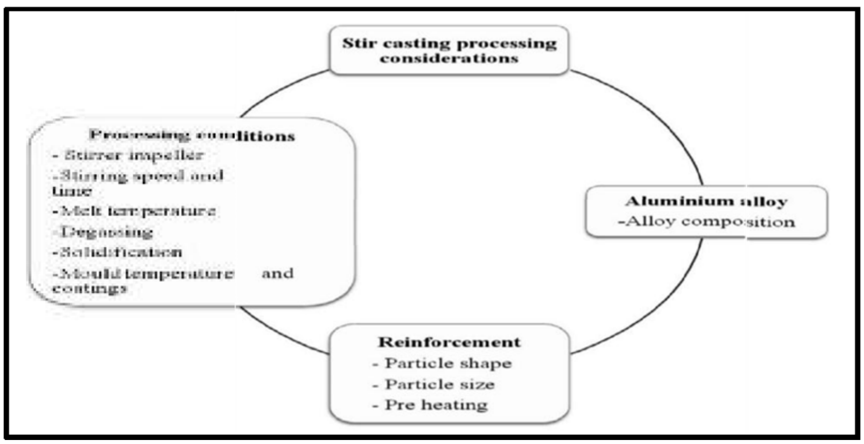


Fig. 5.Illustrates the stir casting processing consideration

**Degassing:**

Nitrogen gas is introduced into the liquid mixture during the degassing or purging process in order to eliminate inclusions and bubbles from the melt stirring. Chemicals like sodium hexachloride, hexa-chloro-ethane, and tetra-chloro-ethane Another use for aluminate is as a degasser. The tablet forms can also be utilized to eliminate oxidation and lessen the amount of $CO_2$ and $H_2$ gases that are present in the molten metal.The kind of alloy and the reinforcement being used determine how much degassing is necessary. Particulate reinforcement usually has a concentration of 5–30% by weight or volume. The amount of degassing needed also depends on the size, shape, and type of ceramic reinforcement.

**Solidification:**

The pouring temperature is greatly affected by the mode of solidification, or the process by which the molten metal solidifies. The pouring temperature must be high enough to avoid forming cold laps (casting defects) and facilitate the smooth flow of molten metal, but not so high as to result in coarse structures.One type of grain structure that is not ideal in most AMCs is columnar growth, which will be encouraged by a higher pouring temperature. Equiaxed grain refinement, a more desired grain structure, will be encouraged by a lower pouring temperature.AMCs can be poured using one of two primary techniques: top pouring or bottom pouring. Using a top pour is the most popular technique.

To reduce casting defects, the pouring arrangement should be open-shaped and relatively stable.Preferring a slow pouring rate is tradition. This facilitates feeding and solidification in a directed manner, reducing the risk of tearing. Surface laps, however, may develop if the pouring temperature is too low or the pouring rate is too slow. Coatings and preheating the

**Mold:**

It's crucial to heat up the mold beforehand to avoid casting flaws like cold shuts. Defects known as "cold shuts" happen when the molten metal solidifies too quickly and is unable to fully fill the mold.

One way to slow down the solidification process and avoid cold shuts is to pre-heat the mold. On the other hand, overheating the mold can also harm it. The size of the casting and the type of mold material determine the optimal preheating temperature. For the mold, a minimum thickness of 25 mm is advised. The size of the casting should correspond with an increase in the thickness of the mold. The mold can be coated with different materials to enhance its characteristics. By lessening the heat transfer from the molten metal to the mold, the coating may be able to stop shrinkage and cracking defects. AMCs are typically coated with a solution of graphite and silicate in water. This coating aids in obtaining the intended mechanical

**Vibrations:**

The material being cast, the casting procedure, and the intended result can all affect the precise technique and vibration frequency used in the casting process. To get the intended outcomes without creating new flaws, the vibration parameters must be properly adjusted and optimized. During the casting process, controlled mechanical vibrations can be applied using vibration equipment such as vibratory tables or ultrasonic vibration systems. During the casting process, mechanical vibrations can be used to reduce defects and improve part quality, especially in die casting and other precision casting methods. There are various reasons why mechanical vibrations are applied in casting.

**Air Bubble Removal:**

Vibrations can help release trapped gases or air bubbles when the molten metal is poured into the die cavity. This reduces the likelihood of internal defects and porosity in the finished casting. Better Metal Flow: Vibration can facilitate the more effortless flow of molten metal into the mold cavity, resulting in a fully and effectively filled part. This is especially important for components with intricate designs or thin walls.

**Decreased Shrinkage Porosity:** Mechanical vibrations can reduce the formation of shrinkage porosity in the casting and promote uniform solidification. This could lead to improved mechanical properties and dimensional accuracy.

**Reduced Grain Size:** The cast metal's grain structure can be smoothed out by vibrations, resulting in a finer, more uniform microstructure that can enhance

Fig.6-Manufactured cast product Fig.7- Preheated Silicon Carbide particles

## II. RESULTS

Fig.8. Mechanical vibrator

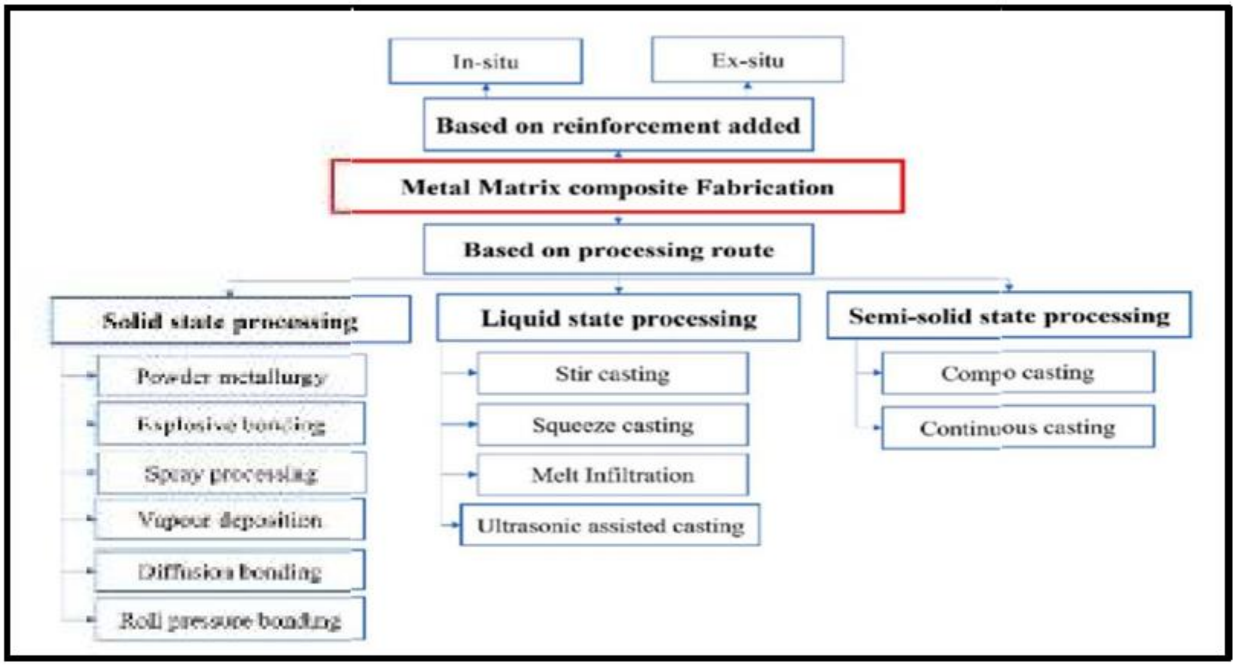


Fig. 9. Categoristal of the processing route to fabricate metal matrix composite

1. From the Fig-10 & 11

At 3% maximum ultimate tensile strength is obtained for both with and without vibration specimens. Observed an increase in utlimate tensile strength for with vibration specimen compared to without vibration.(.ie194.8Mpa & 234.5Mpa for with and without vibration specimens respectively)

2. From the Fig-13& 14

At 3% sic its is observed that maximum value of RHN is observed for both with and without vibrations specimens Observed an increase in RHN for with vibration specimen compared to without vibration (54.2& 53.2 respectively.

From the Fig-14

At 3% sic it is observed that maximum elogation of 14.2% for with vibration specimen and 10.3% for without vibration specimen.

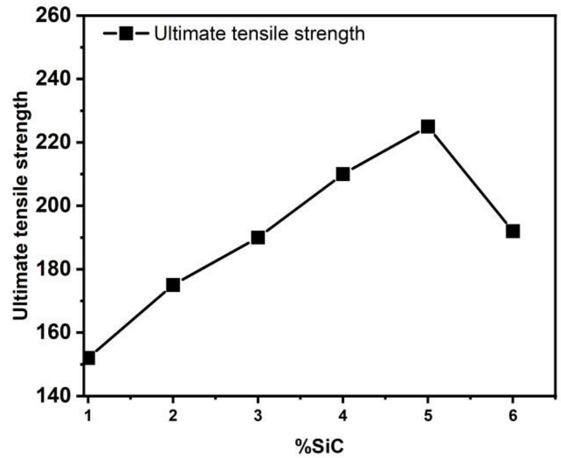


**Fig 10. Graph for Ultimate Tensile Strength of AL5083 Without Vibration**

**Ultimate Tensile Strength of AL5083 withApplying Mechanical vibrations**

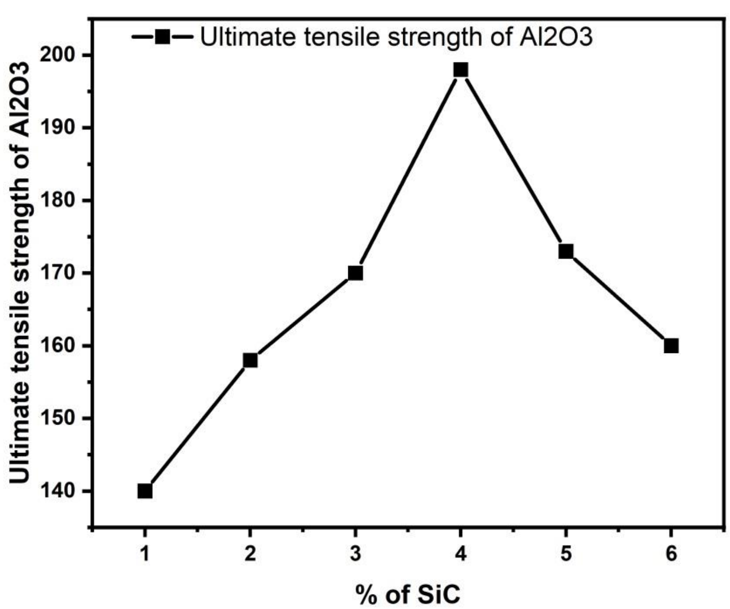


**Fig11.Graph for Ultimate Tensile Strength of AL5083 with Applying Mechanical vibrations**

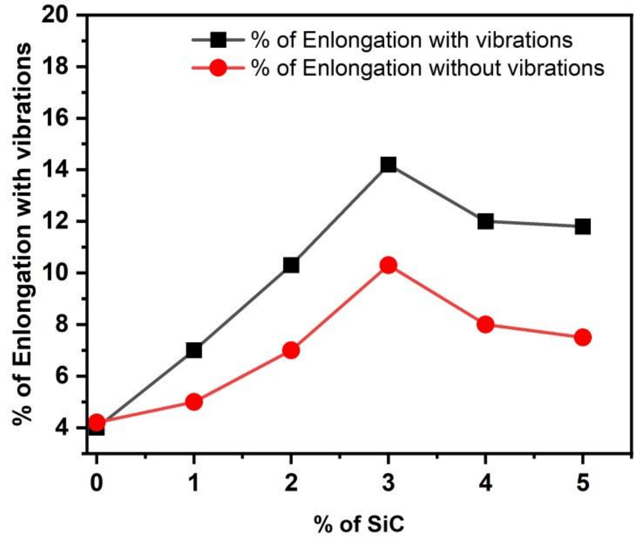


**Figure 12.Graph for Ultimate tensile strength of Al5083 ,With vs Without Vibrations**

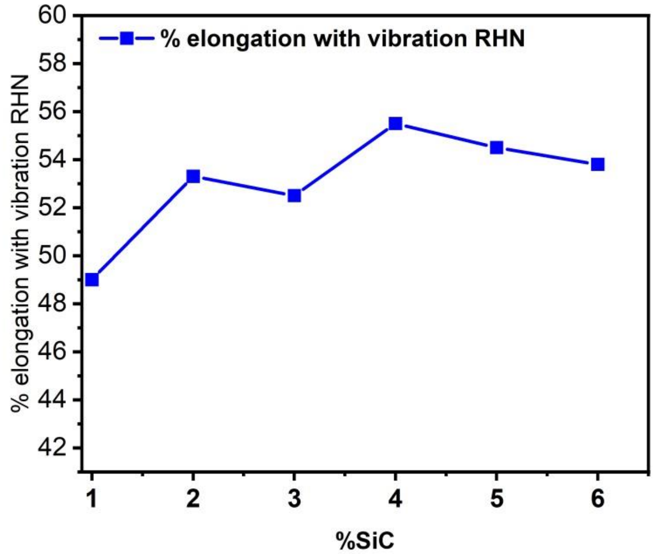


**Fig 13.Graph for Hardness of Al 5083 Without Vibrations**

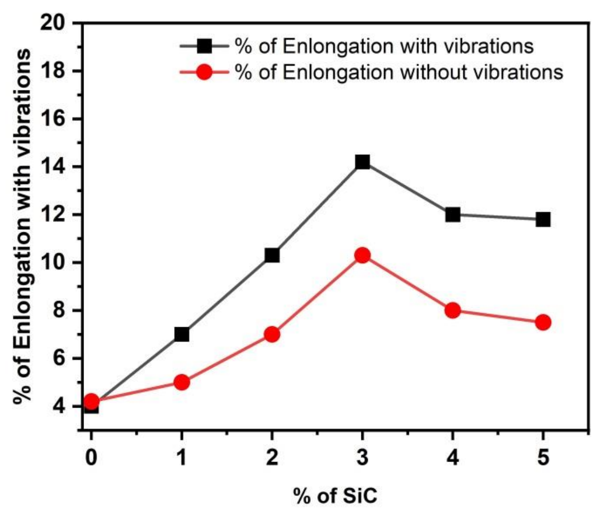


**Fig 14 Graph for % Elongation of Al5083,With and Without Vibrations**

**CONCLUSION**

**1.Impact on Ultimate Tensile Strength (UTS):** Using mechanical vibration during the casting process has a big effect on the composite material's max tensile strength. Similar UTS values, or about 3% improvement, were observed for specimens with and without vibration at a 3% SiC particle content. On the other hand, the UTS rose to 234.5 MPa with vibration and was lower at 194.8 MPa without it. This suggests that the UTS of the composite is improved by mechanical vibration, possibly as a result of better SiC particle dispersion and distribution within the aluminum matrix.

**2.Impact on Rockwell Hardness Number (RHN):** One crucial measure of a material's strength and hardness is its Rockwell Hardness Number. Specimens with and without vibration reached maximum RHN values at 3% SiC particle content. Nonetheless, it was noted that the RHN was considerably higher (67) when there was vibration as opposed to 54.2 when there was none. This indicates that mechanical vibration is a promising technique for improving the properties of hardness and strength of the composite material.

**3.Impact on Elongation:** Elongation is a crucial mechanical characteristic that shows how much a material can flex before failing. Specimens with vibration displayed a higher elongation of 14.2% at a 3% SiC particle content, while specimens without vibration showed a lower elongation of 10.3%. This suggests that the composite material's enhanced ductility and deformability are influenced by mechanical vibration.
owever, elongation decreased beyond 3% SiC content, most likely as a result of SiC particles clumping together and creating blowholes, which led to failure. In conclusion, the mechanical properties of aluminum alloy (5083) containing SiC particles are improved in a number of ways by the addition of mechanical vibration during the casting process. This is achieved through the use of stir casting. It improves elongation, Rockwell Hardness Number, and ultimate tensile strength at a lower SiC content of 3%. It is important to remember, though, that because of particle agglomeration, the benefits decrease with increasing SiC content. All things considered, mechanical vibratory casting under optimized conditions seems to be a viable technique for creating aluminum-SiC composite materials with enhanced mechanical qualities. In order to fully realize its potential and tackle obstacles at higher particle sizes, more investigation and optimization might be required.

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