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Influence of Mechanical Properties and Microstructure of the Aluminium5083 with Nano Silicon Carbide Particles(50-60nm) Casted by Stir casting 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 used in areas that require a combination of light weight and high wear resistant. But all these performances of these alloys depends on the grain refinement and particularly dendrite arm spacing of silicon particles. These applications demand the study of techniques to improve mechanical properties and grain structure by SEM analysis of these alloys. As a result, this review will provide the improvement in mechanical properties and grain structure alloy by applying mechanical mold vibrations during the casting process. After the casting process is done the alloy will be in molten state and then the alloy will be subjected to mechanical vibration during solidification. We will give different frequencies from 120-180 Hz for proper grain size, dendrite arm spacing also the inner defects will be reduced. Furthermore, test results indicates that mechanical and physical properties of aluminium alloys improves with the stir casting process.*

Aluminium 5083 is an aluminium-magnesium alloy with magnesium and traces of manganese and chromium. The chemical composition of 5083 aluminium alloy is as follows 1:Aluminium: balance Chromium: 0.05-0.25% max Copper: 0.1% max Iron: 0.4% max Magnesium: 4.0 to 4.9%Manganese: 0.4 to 1.0%Silicon: 0.4% max Titanium: 0.15% max Zinc: 0.25% max.

Keywords: Sem analysis, Mechanical properties

I. INTRODUCTION

In recent times, Aluminum Matrix Composites (AMCs) have become increasingly popular in various industries due to their strong mechanical properties. AMCs are made up of at least two parts: the pure aluminum alloy and another material for reinforcement. 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 melting, stirring, vibration is a cost-effective way to produce them. These composites have shown

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that they are better than regular materials for being strong and stiff in fields like mining, cars, and airplanes. This process can be improved by controlling the conditions and getting the particles to spread out evenly in the main material. People study how AMCs are made, their hardness, and how they resist wear compared to the basic material. The uniform dispersion of tiny particles contributes to enhanced material hardness and strength. This effect becomes even more pronounced with higher quantities of added material. AMCs find widespread application primarily due to their lightweight nature and exceptional strength properties. This makes them exceptionally valuable in fabricating components for aircraft, automobiles, and electronic devices. The process involves the heating of the matrix placed in the crucible by raisingits temperature till molten state. Preheating the mixture result in obtaining increased wet-ability and bonding between the matrix and reinforcements. An inert condition is maintained during mixing of materials with help of the stirring in order to minimize the chances of casting defects also applying the mechanical vibration to reduce the porosity, blowholes, etc. There are many different types of AMCs, each with its own unique properties. Some of the most common types of AMCs include these composites are reinforced with ceramic particles, such as silicon carbide (Sic) and boron carbide (B4C).The particles are typically added to the molten aluminum matrix during casting. Particulate-reinforced AMCs have good strength, stiffness, and wear resistance.Owing to the research and development in existing or new processing techniques, a consistent increase in demand for MMC or replacement of conventional alloys by MMC can be observed. The characteristic of composites such as distribution of secondary phase particles in the matrix phase, mechanical properties, morphological characteristics, tribological properties and many more depends upon the techniques implemented to manufacture the composites.

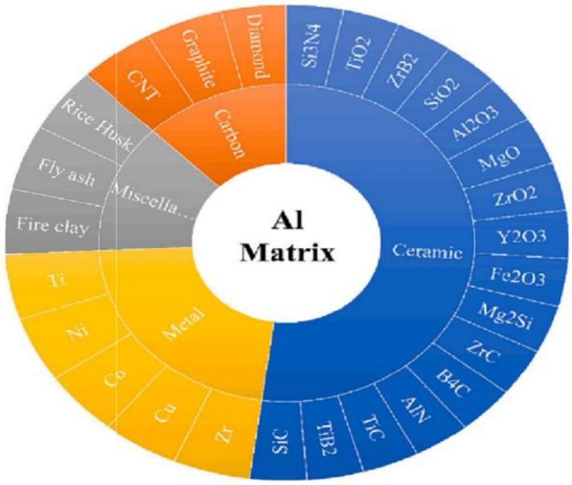

Fig 1. Sunburst diagram shows the commonly used reinforcement for Aluminum metal matrix composites.

1.1 Matrix and Reinforcement

Matrix: The matrix is the continuous phase of the composite material. It is typically a metal, such as aluminium, titanium, or magnesium. The matrix provides strength and stiffness to the composite material.

Reinforcement: The reinforcement is the dispersed phase of the composite material. It is typically a ceramic, such as aluminium oxide or silicon carbide. The reinforcement provides high strength, stiffness, and wear resistance to the composite material.

The reinforcement is typically coated with a thin layer of a material, such as Silicon carbide to prevent it from chemically reacting with the matrix. This coating also helps to improve the bonding between the reinforcement and the matrix. The matrix and reinforcement are mixed together in a molten state. The molten mixture is then cast into a mould, where it solidifies to form the composite material.

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

Table 1-Poperty,Matrix,reinforcement

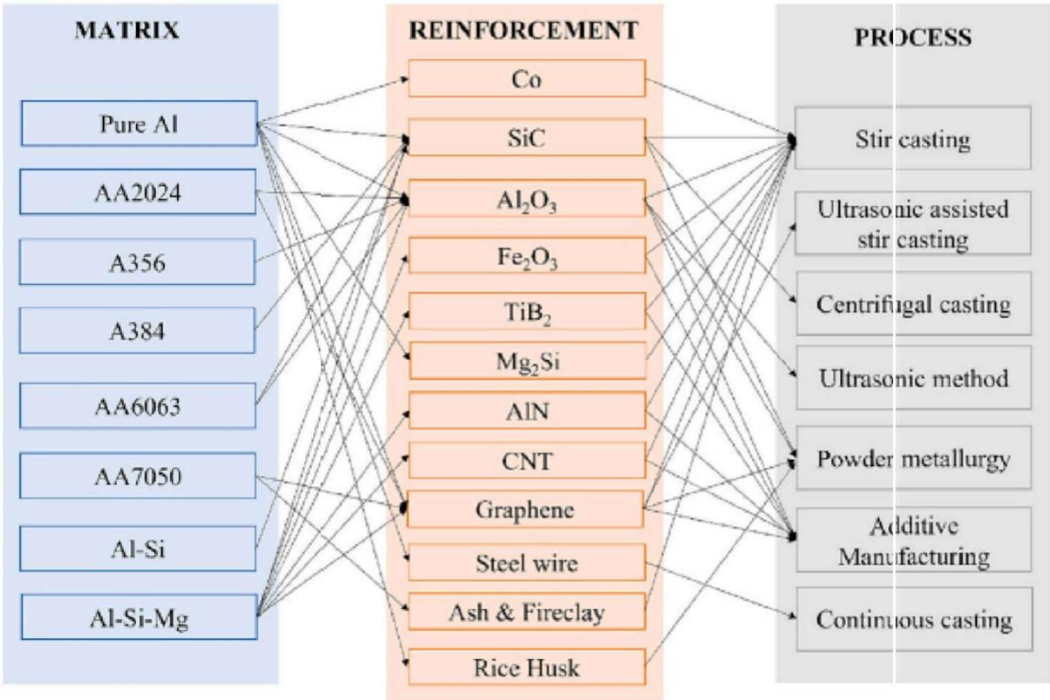

Fig. 2.Relationship chart shows the commonly used Aluminum matrix, reinforcement, and manufacturing processes.

II. METHODOLOGY

The process initiates with the melting of the matrix alloy within a crucible. The melting temperature requirement of the alloy is subject to variation based on the specific type of alloy being used. In parallel, the reinforcement particles undergo preheating, carefully regulated to maintain a temperature just below the melting point of the alloy. This strategic preheating serves the crucial purpose of preventing the undesirable agglomeration of the reinforcement particles

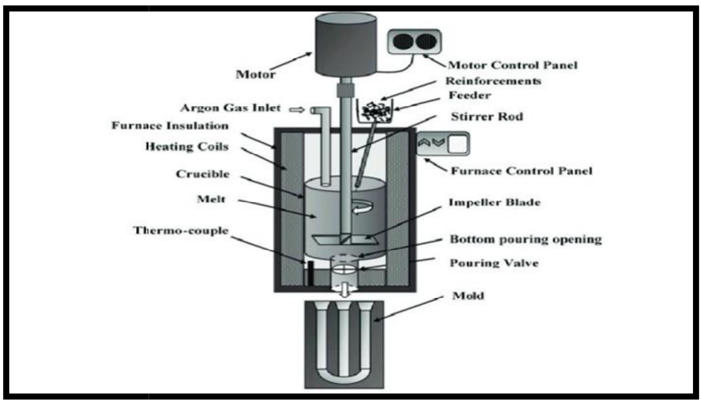

Fig. 3. Schematic view of gravity Stir casting

Once the reinforcement particles attain their preheated state, they are introduced into the molten alloy. This amalgamation of the molten alloy and preheated reinforcement particles is achieved through diligent stirring, carried out by a specialized stirrer. The parameters governing the stirring process, including the speed and duration, are adapted according to the unique characteristics of both the alloy and the reinforcement particles.

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**

Subsequently, the thoroughly mixed molten combination is poured into a designated mould. The mould, typically fashioned from either metal or sand, provides the requisite structure for the shaping of the final product. Within the mould, the once-fluid amalgam undergoes a transformative phase, solidifying and taking on the intended form of the Aluminium Matrix Composite (AMC). This solidification process marks the culmination of the intricate synthesis, resulting in the creation of the desired AMC with its enhanced properties and performance capabilities. In this melt stirring, parameters including melting of matrix alloy, feeding of reinforcement, impeller position and stirrer design, speed of rotation, stirring time and temperature, pouring of materials, solidification, and mould temperature and coatings can play an important role throughout the course of action for developing AMC specimens.

Stir casting process parameters:

The utilization of an aluminium-based monolithic matrix is commonplace, wherein ceramic-based reinforcements are intricately integrated within the matrix. This integration is achieved in a manner that ensures homogeneous dispersion throughout the matrix. Ceramics, such as those used in conjunction with aluminium, nickel, magnesium, cobalt, and titanium matrices, necessitate a refined affinity with the strengthening phase of reinforcement. The attributes that render aluminium appealing and suitable encompass its lightweight nature, robustness, resilience, malleability, corrosion resistance, and wear resistance. The synthesis of Aluminium Matrix Composites (AMCs) falls into three categories: liquid, solid, and vapor phases. Various materials, such as continuous carbon, Sic, and ceramic fibres or particulates, can be employed as reinforcement within a pure aluminium matrix. The incorporation of reinforcement into a pure aluminium matrix entails a diverse array of techniques aimed at augmenting the mechanical properties of the resulting composites. The selection of the embedding material plays a pivotal role in determining the final component's performance attributes, including load-bearing capacity, specific strength, resistance to impacts, and flexural rigidity. Particulates are commonly employed to enhance the specific strength and related properties of economical materials by introducing judiciously chosen substances. In the realm of composites, the reinforcement factor encompasses crucial dynamics such as the nature, shape, size, weight or volume fraction of the reinforcement, as well as the preheating regimen of the particulates; all of these considerations are of notable significance within this study.The manufacturing process of AMCs using the stir casting technique is contingent upon meticulous operational considerations. A judicious management of various processing parameters is pivotal, as their effective control can lead to enhanced performance characteristics within AMCs

Stirring- Impeller:

The way the impeller works manages how the different components mix together in the materials. the best height for the impeller is usually around 30% of the height of the open surface of the melted material in the crucible base. The stirrer can have two or more blades to properly shape the mixing of the components. Different types of impellers, like single, double, or multi-step ones

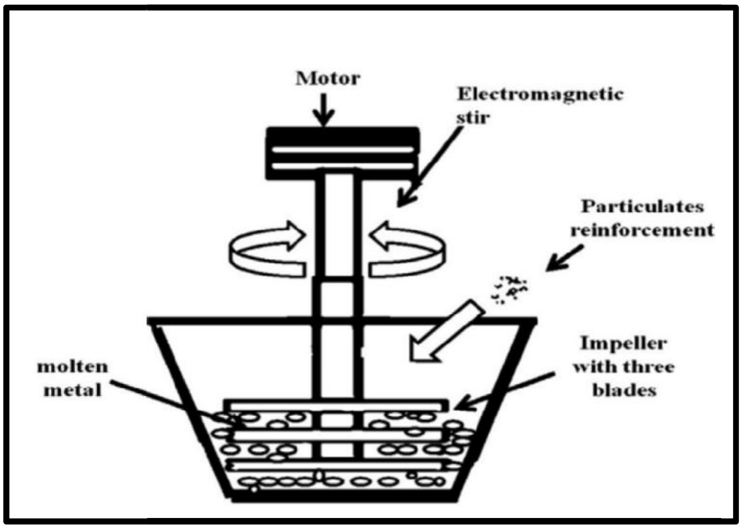

Fig. 4. Stir casting route incorporated electromagnetic rotation

can also be used to create a useful swirling motion and make stirring more efficient. Among these, single-stage impellers are more practical and suitable for making composites through melting and stirring. The swirling motion created by stirring helps move the reinforcing material around, and the shearing action breaks down the clustered reinforcing material, resulting in a consistent mixture. Researchers have found that the angle of the impeller blades, which can range from 15° to 90°, is important. In this study, the best results came from using a 30° angle, as it provides a very even distribution of particles. The design and placement of the impeller-stirrer setup, including the angle and pattern of the blades, have a big impact on how the mixture flows, and this is especially important for making sure the composite liquid melt is uniformly dispersed.

Stirring speed and time:

The control of the stirring speed is very important for the successful development of AMCs. The stirring speed also controls the formation of the microstructure. The general result of increasing the melt stirring is to refine the microstructure, while low speed results in instability of the liquid mixture. It is important to use a reasonable and consistent stirring speed that prevents tearing or destroying the composite. In a study by Prabu et al. (2006), they experimentally investigated the manufacturing of AMCs reinforced with Sic via stir casting processing. They controlled the stirring speed (500-700 rpm) and time (5-15 min) and found that the best properties were achieved with a mixing

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speed of 600 rpm and 10 min. The microhardness of the AMCs first increased with increasing stirring speed. However, further increasing the stirring speed (up to 1000 rpm) decreased the microhardness of the composites.Low stirring speed resulted in non-homogeneous dispersion of the reinforcement particles, which caused clustering in some localized areas in the matrix regions. Extremely high stirring speeds caused the reinforcement particles to flow near the surface of the AMCs, due to circumferential forces, which also increased clustering of particles near the surface. Therefore, nonuniform dispersion of reinforcement particles increases with increasing stirring speed beyond a certain speed. The maximum microhardness of the composites was achieved at 800 rpm.In another study by Raju et al. (2019), they found that the uniform distribution of aluminium oxide particles in the AA 5052 alloy was achieved by increasing the stirring speed and time (400 rpm and 10 min). The dispersion of the reinforcement was so uniform that it led to an increase in the ultimate tensile strength and microhardness of the developed AMCs.In this study, it was observed that stirring time promotes uniform dispersion of reinforcement particles. Stirring time is an important factor in melt stirring processing. Low stirring leads to non-homogeneous dispersion of particles, while over stirring can cause clustering. A stirring time of 10 min gave better results than 5 or 15 min.

Melt temperature: The preheat temperature of the ceramic reinforcement in the stir casting process of AMCs is not easy because of the poor wettability of the embedded particles. The reinforcement is heated (at 500°C for 40 min) to remove moisture and gases in the reinforcement. The reinforcement feed rate also affects the clustering of particles, which can lead to porosity. The best possible flow rate of reinforcement to melt stirring is estimated to be 0.5 g per second.In a study by Abdi Zadeh et al. (2008), they investigated the effect of melt stirring temperature on the viscosity of the liquid. They found that the viscosity of the liquid decreases by increasing the processing temperature and expanding holding time for stirring. This results in good wettability between the alloy matrix and particulates reinforcement.AA 356.1 was reinforced with $ZrSiO_4$ and TiB_2 particulates at three temperatures (750, 850, and 950°C). The microhardness of the specimens reinforced with $ZrSiO_4$ (at 850°C) and TiB_2 (at 950°C) based composites increased with an increase in the melt temperature. In another study by Samuel et al. (1995), they found that the melt temperature should be between 780 and 800°C. This is because the addition of reinforcement particles increases the viscosity, which can hinder the stirring speed. A melt temperature of 780-800°C is ideal for controlling the stirring speed and achieving a uniform distribution of the reinforcement particles. Lloyd (1989) also found that the most favourable temperature of aluminium alloy melts for distributing particulates is in the range of 740-800°C. Many researchers have varied the temperature of stirring from the range of 350-850°C during the addition of reinforcement, followed by melt stirring and holding at approximately the same temperature before pouring the material

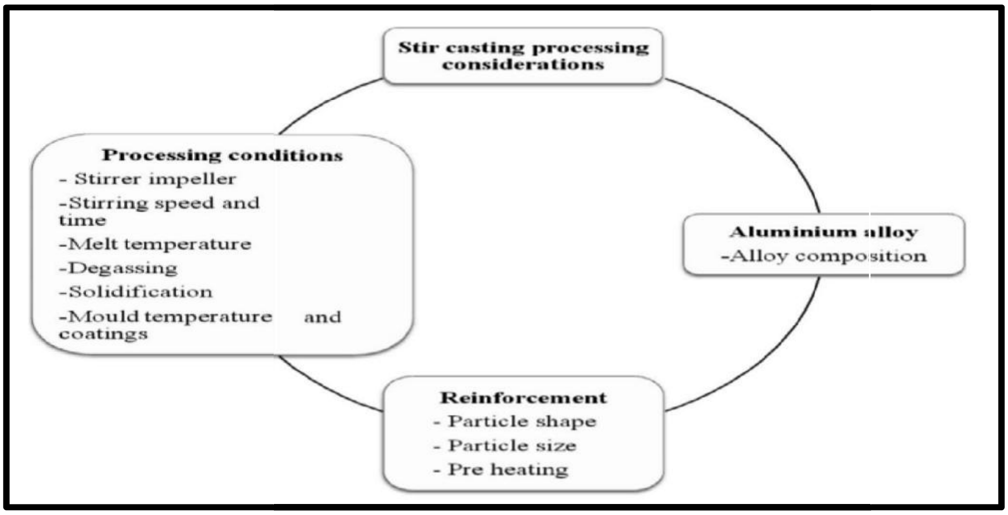

Fig. 5.Illustrates the stir casting processing consideration

Degassing:

Degassing or purging involves the introduction of nitrogen gas into the liquid mixture to remove bubbles and inclusions from the melt stirring. Chemical agents such as tetra-chloro-ethane, hexa-chloro-ethane, and sodium hexachloride aluminate can also be used as degassers. The forms of tablets can also be used to remove oxidation and to reduce the presence of CO2 and H2 gases from the molten metal.The amount of degassing required depends on the type of alloy and the reinforcement being used. The concentration of the particulate reinforcement typically ranges from 5 to 30% by weight or volume. The dimension, shape, and nature of the ceramic reinforcement also affect the amount of degassing required.

Solidification:

The mode of solidification (how the molten metal solidifies) has a big impact on the pouring temperature. The pouring temperature needs to be high enough to allow the molten metal to flow smoothly and prevent the formation of cold laps (defects in the casting), but not so high that it causes coarse structures.A higher pouring temperature will promote columnar growth, which is a type of grain structure that is not desirable in most AMCs. A lower pouring temperature will promote equiaxed grain refinement, which is a more desirable grain structure.There are two main methods for pouring AMCs: top pouring and bottom pouring. Top pouring is the most common method. The pouring arrangement should be relatively stable and open-shaped to minimize defects in the casting.Traditionally, a slow pouring rate is preferred. This allows for directional solidification and feeding, which helps to prevent tearing. However, if the pouring rate is too slow or the pouring temperature is too low, surface laps can form. Mould pre heating and coatings:

The preheating of the mould is important to prevent casting defects such as cold shuts. Cold shuts are defects that occur when the molten metal solidifies too quickly and does not have time to fill the mould completely. Preheating the mould helps to slow down the solidification process and prevent cold shuts. However, preheating the mould too much can also damage the mould. The ideal preheating temperature depends on the type of mould material and the size of the casting. A minimum thickness of 25 mm is recommended for the mould. The thickness of the mould should increase with the size of the casting. Various coatings can be applied to the mould to improve its properties. The coating helps to reduce the heat transfer from the molten metal to the mould, which can help to prevent cracking and shrinkage defects. The most common coating for AMCs is a mixture of graphite and silicate in water. This coating helps to achieve the desired mechanical properties of the AMC.

Vibrations:

The specific method and frequency of vibration used in casting can vary depending on the material being cast, the casting process, and the desired outcome. It's essential to carefully control and optimize the vibration parameters to achieve the desired results without introducing new defects. Vibration equipment, such as vibratory tables or ultrasonic vibration systems, may be used in the casting process to apply controlled mechanical vibrations.

Mechanical vibrations can be used during the casting process, particularly in die casting and other precision casting methods, to improve the quality of the cast parts and reduce defects. The application of mechanical vibrations in casting serves several purposes.

Air Bubble Removal: Vibrations can help dislodge and remove air bubbles or trapped gases from the molten metal as it is poured into the die cavity. This reduces the likelihood of porosity and internal defects in the finished casting. Enhanced Metal Flow: Vibration can improve the flow of molten metal into all areas of the mold cavity, ensuring that the entire part is properly filled. This is especially important for intricate or thin-walled parts.

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

Reduced Grain Size: Vibrations can refine the grain structure of the cast metal, resulting in a finer and more uniform microstructure, which can enhance the mechanical properties of the final part.

Minimized Hot Spots: Vibrations can help dissipate heat more evenly throughout the mould, reducing the risk of localized hot spots that can lead to defects like cold shuts or hot tears.

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Fig.6-Manufactured cast product

Fig.7- Preheated Silicon Carbide particles

III. RESULTS

Fig.8. Mechanical vibrator

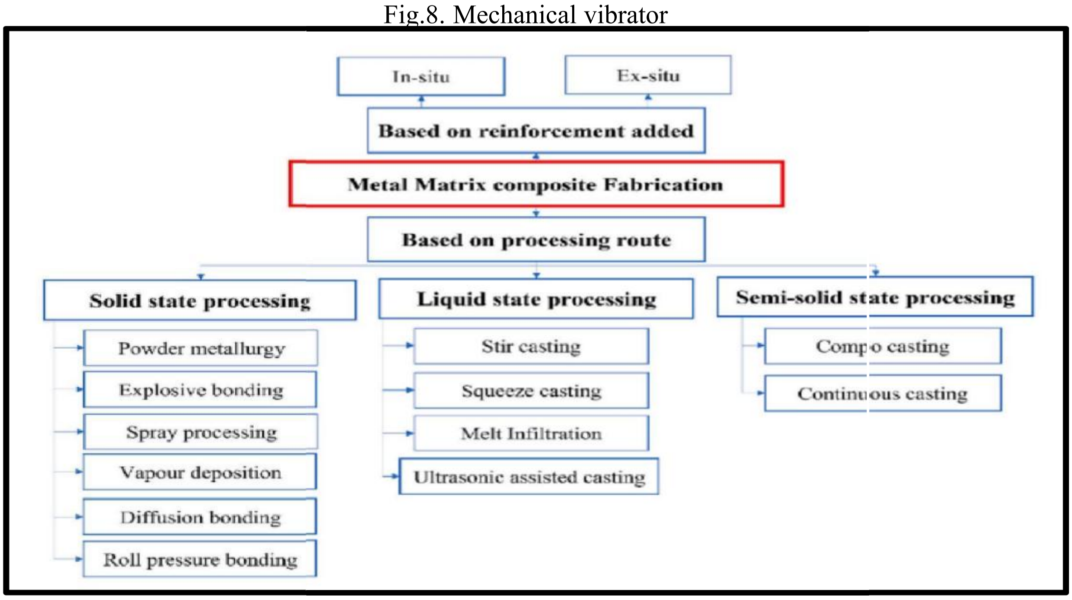


Fig. 9. Categorization of the processing route to fabricate metal matrix composite

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.(.ie 194.8Mpa & 234.5Mpa for with and without vibration specimens respectively)

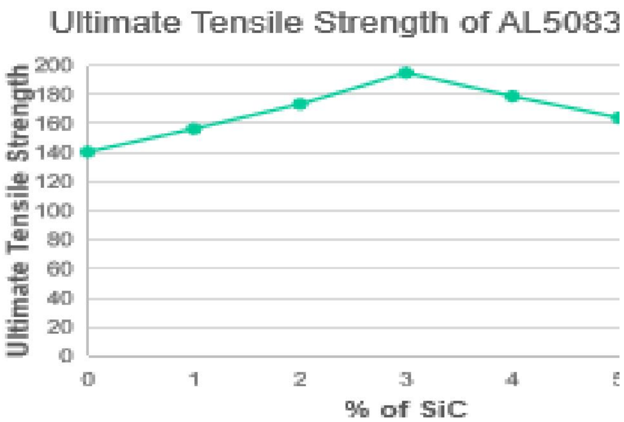
2. From the Fig-13& 14

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 & 67 respecitively.

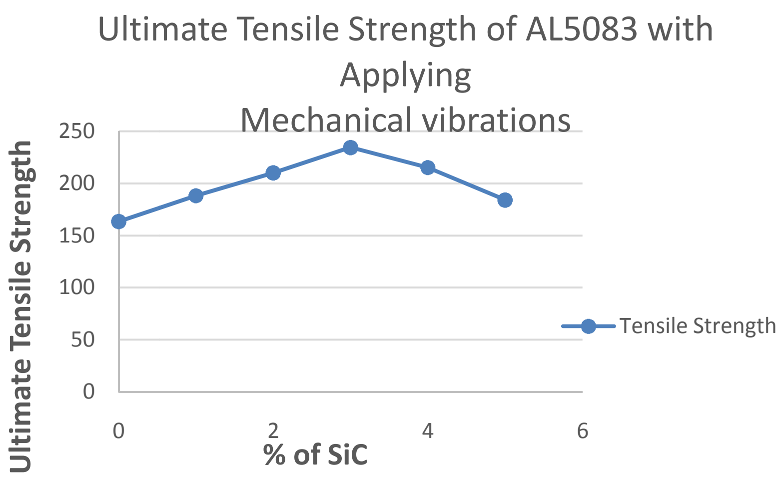
3. From the Fig-15

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



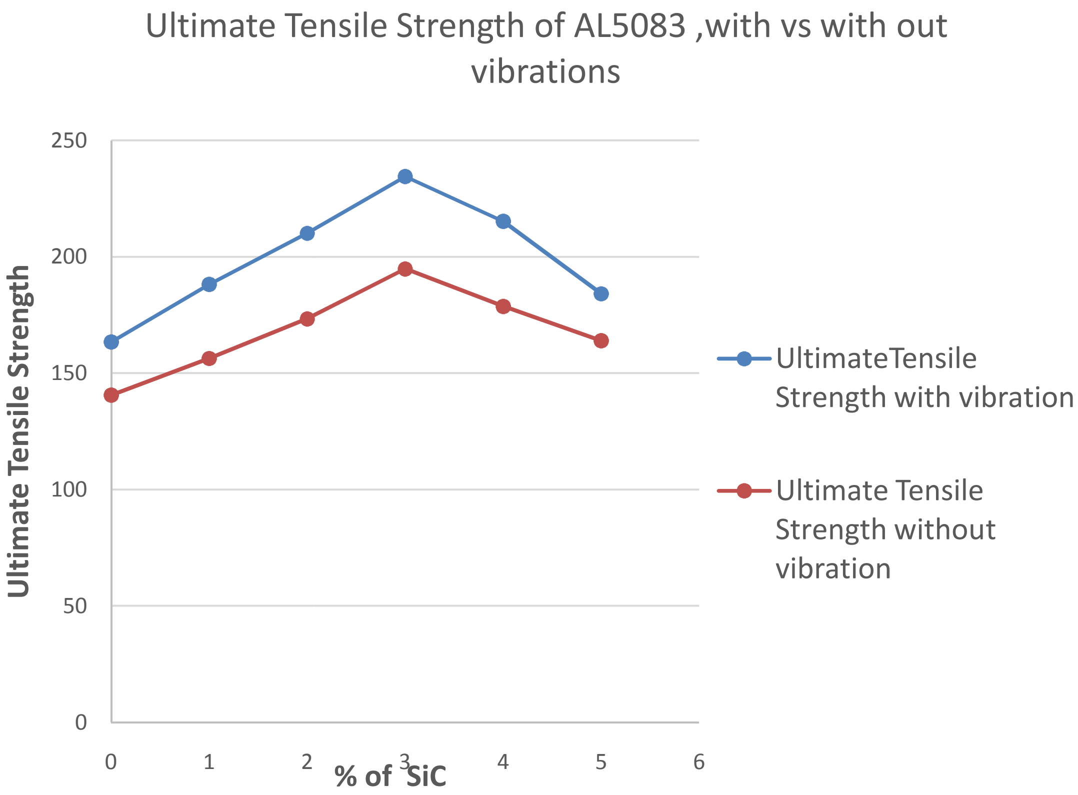
S.no	% SiC	Ultimate tensile strength (Mpa)
1	0	140 5
2	1	156.3
3	2	173.3
4	3	194.8
5	4	178.7
6	5	163.9

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



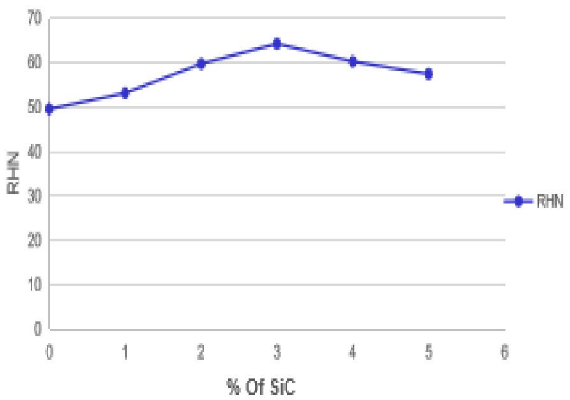
s.no	% of SiC	Ultimate Tensile Strength (Mpa)
1	0	163.4
2	1	188.2
3	2	210.1
4	3	234.5
5	4	215.2
6	5	184.1

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



S.No	% SiC	UltimateTensile Strength with vibration	Ultimate Tensile Strength without vibration (Mpa)
1	0	163.4	140.5
2	1	188.2	156.3
3	2	210.1	173.3
4	3	234.5	194.8
5	4	215.2	178.7
6	5	184.1	163.9

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



S. no	% of SIC	With Vibration (RHN)
1	0	49.5
2	1	53.1
3	2	59.7
4	3	64.2
5	4	60.2
6	5	57.4

Figure 13: Graph for Hardness of Al5083,With Vibrations

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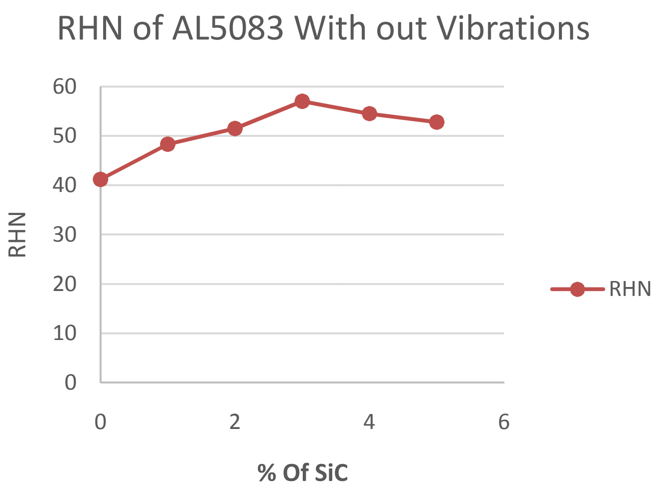
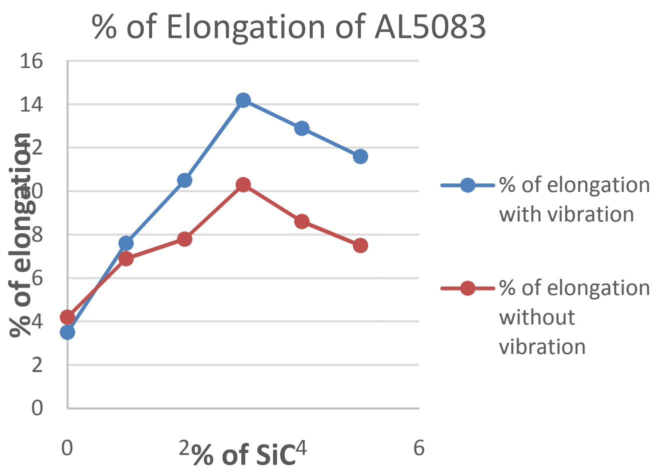


S.no	% of SiC	Without Vibration (RHN)
1	0	41.2
2	1	48.3
3	2	51.5
4	3	57
5	4	54.5
6	5	52.8

Fig 14.Graph for Hardness of Al 5083 Without Vibrations



S.No	% SiC	% of elongation with vibration	% of elongation without vibration
1	0	3.5	4.2
2	1	7.6	6.9
3	2	10.5	7.8
4	3	14.2	10.3
5	4	12.9	8.6
6	5	11.6	7.5

Fig 15 Graph for % Elongation of Al5083,With and Without Vibrations

IV. CONCLUSION

1. Effect on Ultimate Tensile Strength (UTS): The use of mechanical vibration during the casting process has a significant impact on the ultimate tensile strength of the composite material. At a 3% SiC particle content, it was observed that both with and without vibration specimens achieved similar UTS values, around 3% improvement. However, without vibration, the UTS was lower at 194.8 MPa, while with vibration, it increased to 234.5 MPa. This indicates that mechanical vibration enhances the UTS of the composite, potentially due to improved dispersion and distribution of SiC particles within the aluminum matrix.

2. Effect on Rockwell Hardness Number (RHN):The Rockwell Hardness Number is an important indicator of material hardness and strength. At a 3% SiC particle content, both with and without vibration specimens achieved maximum RHN values. However, it was observed that with vibration, the RHN was significantly higher (67) compared to without vibration (54.2). This suggests that mechanical vibration enhances the hardness and strength of the composite material, making it a promising technique for improving these properties.

3. Effect on Elongation: Elongation is an important mechanical property that indicates the material's ability to deform before failure. At a 3% SiC particle content, with vibration specimens showed a higher elongation of 14.2%, whereas without vibration, the elongation was lower at 10.3%. This indicates that mechanical vibration contributes to increased ductility and deformability of the composite material.

However, beyond 3% SiC content, elongation decreased, likely due to agglomeration of SiC particles causing the formation of blowholes and subsequent failure.

In summary, the incorporation of mechanical vibration in the casting process for aluminum alloy (5083) with SiC particles using stir casting has several positive effects on the material's mechanical properties. It enhances ultimate tensile strength, Rockwell Hardness Number, and elongation at lower SiC content (3%). However, it is essential to note that the benefits diminish at higher SiC content due to particle agglomeration. Overall, mechanical vibratory casting with optimized parameters appears to be a promising method for producing aluminum-SiC composite materials with improved mechanical properties. Further research and optimization may be necessary to explore its full potential and address challenges at higher particle concentrations.

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