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A Review On Fabrication And Mechanical Characterization Of Particulate Reinforced Al-7075 Metal Matrix Composites/ Hybrid Composites

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Abstract:
Requisites of design engineers are altering consistently and continuously, advancement of material science stretching its wings to meet these requirements. Composites are the new cohort materials whose properties can be ameliorated and tailored to meet this demand. Composite is an homogenous mixture of matrix and reinforcement constituents. Here, reinforcement is a critical component that can refine the metallurgical structure and mechanical properties to meet these requirements. The concentration and dispersion of reinforcement and production process of composites play a pivotal role to attain the desired properties. Every day, engineers and industries are looking for combinations of mechanical properties that combine high strength-to-weight ratios, high flexibility, and toughness to meet a variety of needs. One can obtain these weird properties by altering the type and concentration of reinforcement in a base metal of metal matrix composite. Aluminium matrix composites are the unique materials in the family of metal matrix composites which possess exceptional mechanical properties. However, recent research on MMCs has been overcome the set of technical challenges like processing technologies, design and development methods and control over characterization so on. Recent past is the evident for the usage of Aluminium based metal matrix composites (Al-MMC) instead of conventional hard materials like ferrous alloys by their lower overall weight without compromising on mechanical and other relevant properties. Al-MMC made a significant contribution to automobile and aerospace applications. Certain metrics those under scored in the maturity of MMCs are discussed. A way forward to next generation is presented on MMCs.

Keywords: Al-MMC; stir casting; casting parameters; reinforcement.

1
. Introduction

Metal matrix composite technology is a distinct and emerged technology in the era of engender of new materials. A paradigm of commercialization in engineering applications has been continuously improving to these new materials. MMCs are the unique and distinct grade of evolving material. Basically, it consists of two individual constituents: matrix- base material, and reinforcement – miscible materials. The study of MMCs is initiated at the late 1950s and the research on MMCs is reinvigorated from 1980s [1]. Nevertheless, past few decades are the evident for consistent growth rate in composite research.

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Adding different reinforcements can modify the properties of composite, for instance, adding chromium can ameliorates the corrosive nature while chromium along with magnesium affects the melting point and machinability. Copper can raise the hardness whereas silicon can enhance the strength and toughness and also can control the melting temperature of composite. Nickel improves the thermal stability of composite, mixture of boron and titanium can refine the grain size. Adding ferrous can improve strength and control the toughness[2].

The needs of design people and industries are increasing exceptionally and exponentially. Few engineering applications like marine, defence and aeronautics demanding versatile combinational properties like higher ductile, tough natures and corrosive resistance, which can be obtained by relatively soft materials [3]. The scanning electron microscopic convictions of various reinforcements viz. fibre, whisker and particulates embedded in composite are showed in Fig. 1

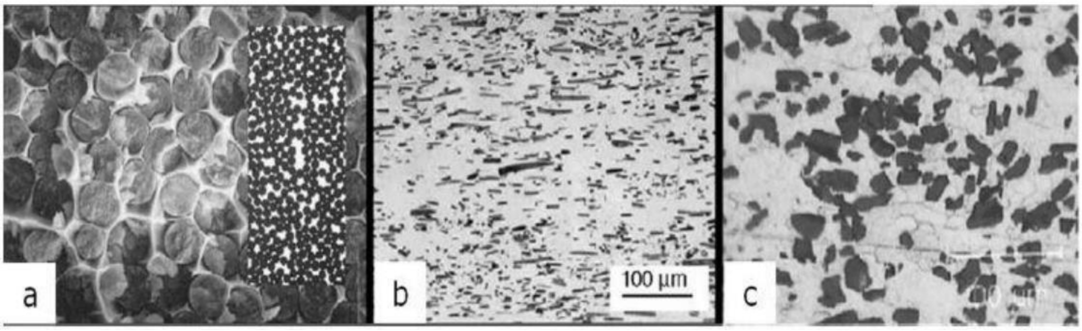

Fig.1: Microscopic views of (a) fibre (b) whisker and (c) particulate reinforcements [4]

The market Sensex ameliorates the demand of advanced composites in global market, it was observed to be 38.4 billion USD in 2021 is forecasted to a surpass of 109.8 billion USD in 2030, the growth rate in CAGR is about 12.38 % over a decade of 2020 to 2030 as depicted in Fig. 2 and 3. The rise of various base materials usage in global market is depicted in Fig. 2 while the growth in usage of Al based MMCs are exemplifies in Fig.3. The market demand for defence, aerospace and sporting goods may magnifies in the next decade. The tailored mechanical and electrical properties of advanced material open a new venture in global market.

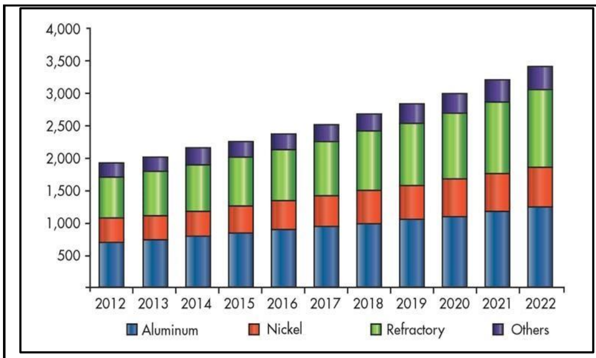

Fig. 2 Utilization rate of various base materials of MMCs in global market

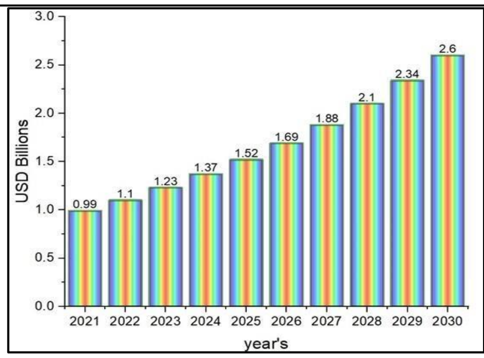

Fig. 3 Utilization rate of MMCs in global market

Growth rate of composites usage and their penetration in global market is represented in Fig. 4.

The enhanced utility rate and market contribution in various engineering applications is exemplified in Fig.4.

One can notice from the fig. 4 that, the usage of MMCs is progressing in various marine and aeronautical applications. However, structural and design attributes are exhibiting consistent growth, while transportation and infrastructure contributing marginal market share [5].

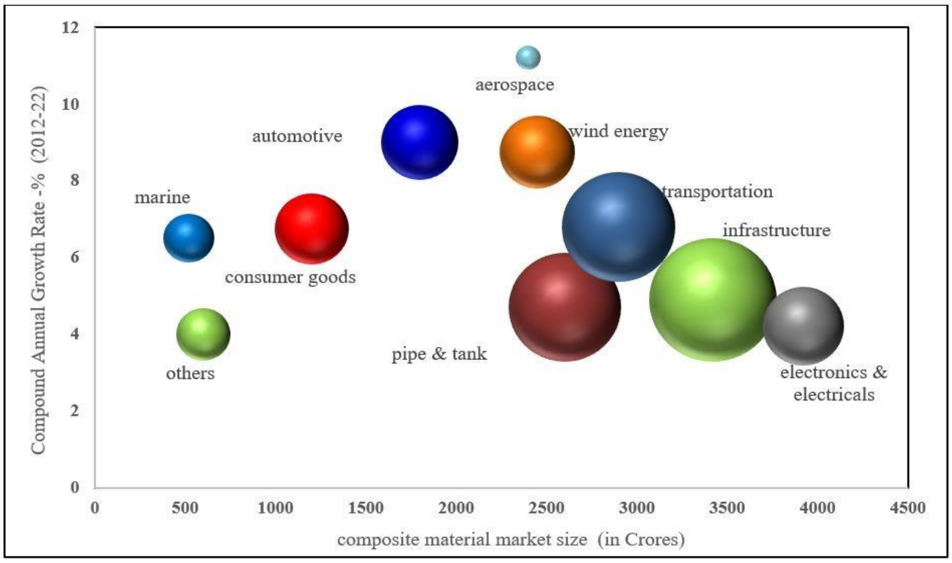

Fig. 4 composites contribution in open global market [6]

The ameliorated metrological and mechanical properties creates a marginal paradise shift in material usage from the traditional pure metals to composites due to their enhanced mechanical properties, low weight to cost ratio, eco-friendly [7]. Amid all MMC, Al based MMCs are unique and trending materials by their versatile nature and flexibility. Unlike other MMCs, one can alter the properties of Al-MMCs and can be tailored the mechanical, thermal and electrical properties by varying the composition of base and reinforcement materials. Al-MMCs are custom-made for various engineering applications and they offers higher flexural strength and stiffness than the conventional base materials [8], [9]. Various engineering, transportation and recreation applications of Al-MMCs are presented in Fig 5. Afresh research is the evident for the potential use of Al-MMCs in many engineering applications viz. components of automobiles, space vehicles, bicycles, marine and electrical fittings, electronic substrates and other engineering allied areas are turned to Al-7075 metal matrix hybrid composites by their high strength to weight ratio HSWR, high wear/ corrosion resistance, improved electrical performance, stiffness and reduced density [10]–[13].

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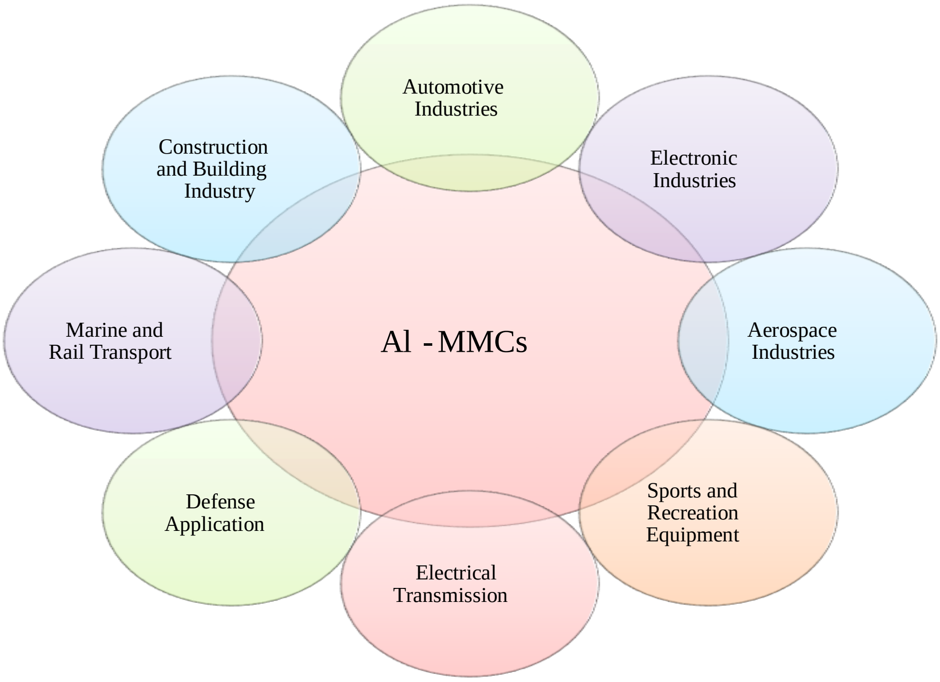

Fig.5. Applications of Al-MMCs

2. Constituents of Al-MMC: The major constituents of Al-MMC are Al of any series from 1xxx to 7xxx as a base metal and various reinforcements as a bonding/strengthening agent ranging from agricultural, ceramic, aquatic and any industrial and processing waste at different concentrations and particle sizes are considered in this review.

2.1Base Material: Base material is a monolithic substance, whose properties have to ameliorate to fit for a particular application. It is the major constituent of MMCs and it is also named as matrix material. Most common base metals are aluminum, titanium, nickel, magnesium, cobalt so on. Amid all aluminium is the most commonly used matrix material.

It acts as a bonding agent among reinforcement particles/fibers. It gave final shape of the product and surface quality of the product.

The composition of various metal constituents generally presented in aluminum-based composites are elucidated in Fig. 6. Various aluminium series and the major constituents are presented in table 1.

Table. 1 Guidelines for aluminium series materials for MMCs [14].

S. No	Designation	Alloying element	Composition	Yield strength	Tensile strength
1	1 XXX	Pure Aluminium	99% to 99.99%	28-152	80-160
2	2 XXX	Copper	202% to 6.8 %	75-345	186-461
3	3 XXX	Manganese	0.3 % to 1.5 %	40-250	110-282
4	4 XXX	Silicon	3.6 % to 13.5 % Si 0.1 % to 4.7% of Cu 0.05% to 5.5% Mg	45-180	172-414
5	5 XXX	Magnesium	0.5% to 5.5% Mg	40-345	123-351
6	6 XXX	Magnesium and Silicon	0.2 % to 1.8% Si 0.35 % to 1.5% Mg	55-275	124-310
7	7 XXX	Zinc	0.8 % to 8.2 % Zn 0.1 % to 3.4 % Mg 0.05 % to 2.6 % Cu	100-500	228-572
8	8 XXX	Other elements	Cast aluminium	There are 1xx.x to 8xx.x are the cast aluminium series.	
9	9 XXX	Unused series	All others aluminium bases alloys		

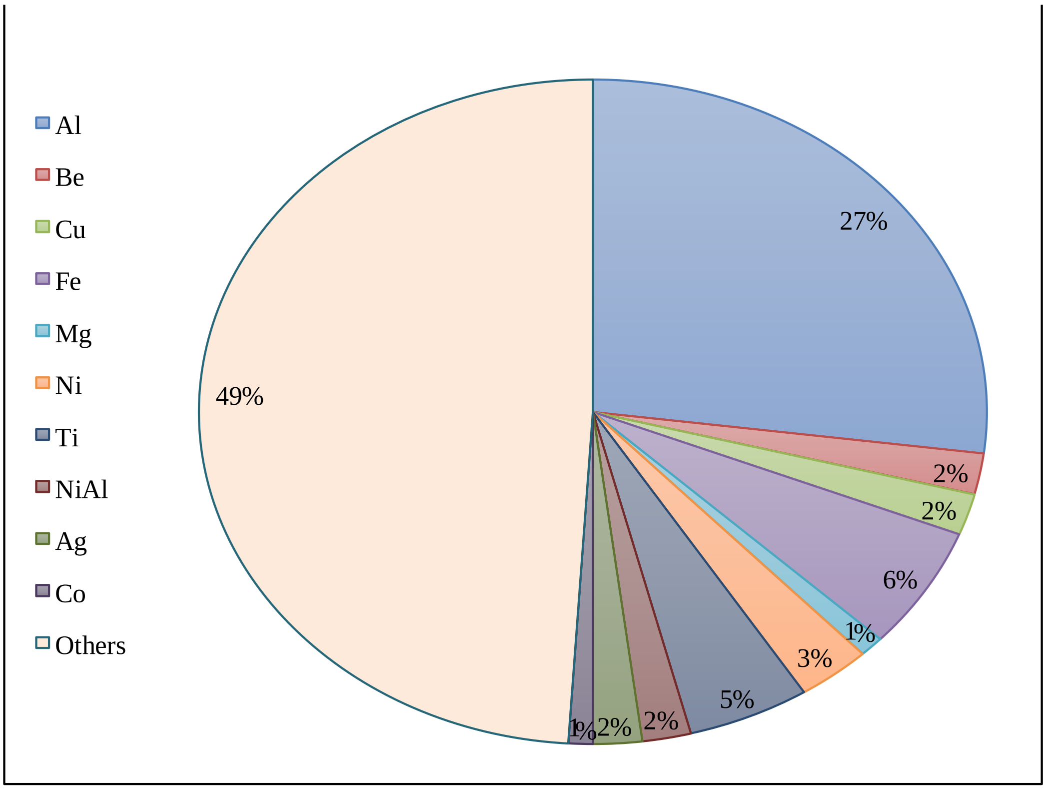

Fig. 6 percentage of composition of base material composition by volume

2.2Reinforcements: The altered and magnified metallurgical and mechanical properties can be attained by altering the amalgams of constituent compositions. The features of the materials can be improved by overcome the constraints of conservative materials.

The properties of composite can be personalized and can be contingent on shape, size, concentration, orientation, dispersion and location of reinforcement and method of fabrication. Al-MMCs can offer exceptional thermal properties, enhanced abrasion resistance, shear strength, high thermal and chemical stabilities. The Al-MMCs possess a flexibility to One can attain the desired properties by altering different reinforcements at different proportions.
However, type of reinforcement and its dispersion rate and concentration would refine the base material properties. The reinforcements may be either particulate, fibre or structural as described in Fig.7.

They may be orderly dispersed or randomly dispersed. Few of commonly used reinforcements are carbides, oxides and silicates of various ceramic materials such as TiC, SiC, WC, B_4C, Al_2O_3, and other conventional, industrial, agricultural and aqua waste viz. fly-ash, red mud, graphite, coco nut shell ash, rice husk ash, palm kenel shell ash, bagasse ash, been shell ash, bamboo leaf ash, aloe vera powder, egg shell, oyster shell, snail shell ash can be added to Al-MMCs. Availability, miscibility, feasibility defines and decides the reinforcement. Different types of reinforcements those can be accommodate in aluminum base material are illustrated in table 2 [15].

Table 2. Various kinds of reinforcement materials used in Al-MMCs

Type of reinforcement	Examples	Aspect ratio	Dimensions
Particulate	SiC, Al_2O_3, WC, TiC, B_4C, BN.	1-4	1-25 mm
Short fiber (whisker)	B, C, SiC, Al_2O_3, SiO_2, TiB_2.	10-10-4	1-5 mm
Continuous fiber	SiC, Al_2O_3, B, C, W, Nb+Ti, Nb_3Sn, Si_2N_4.	> 1000	3-150 mm
Nanoparticle	SiC, Al_2O_3, C.	1-4	<100nm
Nanotubes	C	> 1000	< 100nm

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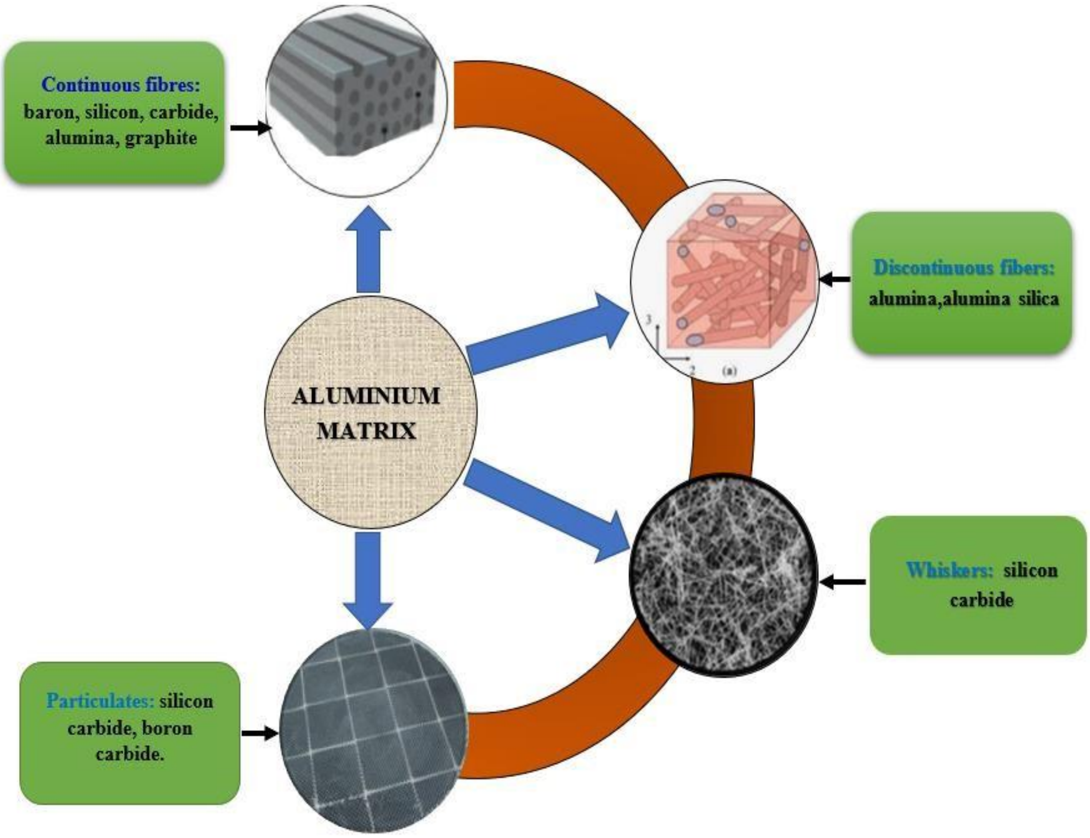

Fig. 7 Types of reinforcements

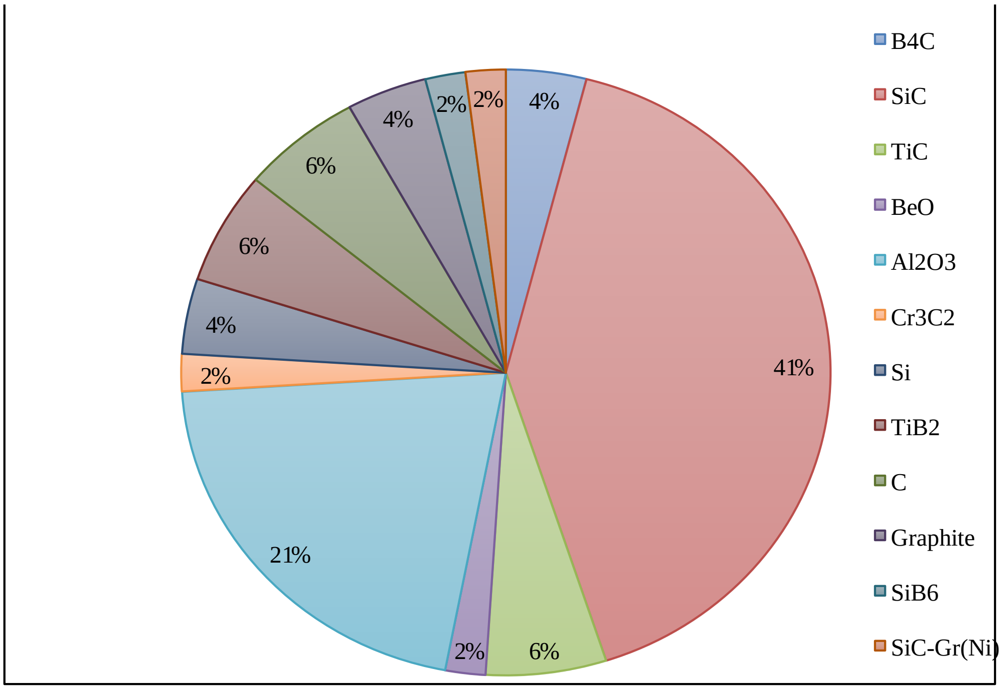

Fig.8 percentage of usage of reinforcement materials in research

The enhancement of Al-MMCs properties is due to the presence of reinforcement of particulates as well as presence of zinc up to 6.1% in Al-7075 alloy. The most commonly used concentration of particulate reinforcement materials is illustrated in Fig. 8. Al based hybrid metal matrix composites (AHMMC) are present generation composites reinforce with two or more particulate reinforcements known as Hybridization for further enhancement of properties compared to

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conventional metal matrix composites. It also lowers the manufacturing cost of composites.

Many researchers have studied the effect of hybrid reinforcement in Al-MMCs to enrich the metallurgical and mechanical characteristics with the modification in texture and surface of the composite. The present review article aims to study the technique of stir casting to fabricate Al-7075 based metal matrix and hybrid composites and how they influence in enhancing the various mechanical properties like compressive strength, impact strength, hardness, fracture toughness, wear resistance and corrosion resistance with the reduction in density of composite. The influence of type, size and shape of the reinforcing materials on characteristics of Al-7075 metal matrix composites and the possible reasons of increase/decrease in physical/ mechanical characteristics are studied.

The enhancement of mechanical properties of Al-MMCs with different reinforcements are discussed in table. 3

Table 3: Ameliorations of various mechanical properties of aluminium based MMCs by the addition of various reinforcements

S.No	Investigator	Base and Reinforcement material	Reinforcement %	Manufacturing Method	Tests conducted	Remarks
1	N.E. Udoye et al. [16]	Al-6061/ Snail shells	5%, 10%, 15%, 20%	Stir Casting	• Tensile strength • Rockwell's Hardness • Electrical Conductivity	Tensile strength was enhanced by 16.49% with the addition of 15 wt% Snail Shell particles RHN is gradually increasing with the mass fraction of reinforcement and it is higher at 20 wt%. However, the electrical conductivity follows the reverse trend. Highest conductivity is noticed at 5 wt% of Snail Shell and it is detreating with the particle concentration.
2	Harinath Gowda et al. [17]	A 7075/SiC	3%, 6%, and 9%	Stir Casting	• Tensile strength • Hardness	AA-7075 reinforced with MoS_2 and SiC and they noticed highest UTS and microhardness is gradually improving with 1 wt % and 9 wt% concentrations respectively.
3	V R. Rao et al. [18]	AA 7075/TiC	1%, 2%, and 3 wt%	Stir Casting	• Tensile strength • Hardness • Wear	They observed that heat treated castings gave better UTS and microhardness at 2 to 10 wt%.
4	Chinmayee Kar et al [19]	Al7075/TIC/red mud	3%, 6%, 9% and 12 %	Stir Casting	Yield strength Tensile Strength Microhardness % of Elongation	The UTS of Al/TiC is increased by 48%, whereas a 71% decrement was observed with red mud. Hardness is increased by 6%, and 62% with TiC and Red mud respectively.
5	R. Keshava murthy et. al [20]	Al7075/TiB2		Stir Casting	UTS Hardness	UTS and hardness of the composite is significantly improved due to excellent interfacial bond between matrix and reinforcement phases. The size and shape of the particulate would responsible to the enhanced tensile properties. By nature TiB_2 is a hard reinforcement, it renders the increase the hardness of base material inherently, thereby it improves the resistance to deformation.
6	Mir Irfan Ul Haq et. al [21]	Al7075/Si_3N_4	0 to 8 wt%.	Stir Casting	Compression strength Hardness	They noticed an increment of 20% hardness and 50 % compression strength at 8 wt% Si_3N_4 addition
7	R. Manikandan et.al [22]	Al 7075/B_4C/ cow dung ash		Stir Casting	Wear	Wear rate of composite was gradually decreased and maximum of 59.58%.
8	R. Manikandan et. al [15]	Al 7075/B_4C/ cow dung ash	0 to 10 wt%	Two Stage Stir Casting	SEM With EDX and XRD Tensile Impact Wear Hardness	They noticed enhanced tribological and mechanical properties, further impact strength has slightly reduced. The hardness was increased for all the samples due to the presence of B_4C in base metal. Hardness of the composite was enhanced by 38% uniform distribution of reinforcements, rate of solidification and it is decreased at 10% cow dung ash. Addition of 10% B_4C particles increased by 32 % of tensile strength.

9	K.R. Ramkumar et. al [23]	AA 7075/TiC	0, 2.5, 5 and 7.5 wt.%	Stir Casting	XRD Hardness	In XRD, it observed that the intensity of peak corresponding to TiC phase, it increasing with the increase of particle percentage. They observed that hardness was improved by 2 to 3 times, this may be due to
						refinement in grains, effective bonding between matrix and reinforcement phases.
9.	V.S. Aigbodion et. al [24]	Al 7075/ bagasse ash	2–10 wt%	double stircasting method	Hardness Microstructure Density UTS Hardness Impact strength	By adding bagasse ash to base Al-MMC hardness and compression strength were improved by 43.3% and 57.7% respectively While density and impact strengths are improved by 10.27% and 45% respectively yield strength and ultimate tensile strength increased by 49.76% and 34.25% at maximum of 8 wt.% bagasse ash The density of composite was decreased with increasing bagasse ash particles. They tested density of bagasse ash was 1.95 g/cm^3 and the overall density of bagasse ash composites was decreased by 29% with 8 wt.% additions of bagasse ash. It can observe that weight of the composite can be marginally controlled. Impact energy of test samples was decreased with the percent of bagasse particles addition increases in the alloy. They noticed 2 wt%
						bagasse ash particles have the highest impact energy
10	Yashpal a. et. al [25]	Al-6061/ Al_2O_3/bagasse ash	0, 2.5, 5 and 7.5 wt.%	Stir Casting	• UTS • Microhardness • Impact strength	• Tensile strength of composite proportionally decreased with the increase in particle size of bagasse ash. Al-6061with alumina 5% composite exhibits the higher tensile strength than all other combinations. • Similar trend like UTS is exhibited even for impact energy as well. • Similar to other studies, smaller particle sized samples exhibit surpassed hardness due to superior bonding between matrix and reinforcement materials, wettability may also be responsible for higher hardness than base alloy and further augmented with adding of bagasse ash.
11	S. Suresh [17]	Al-7075/Al_2O_3 /SiC	1.0, 2.0, 3.0 and 4.0 wt. %	Stir Casting	• Density • Microhardness • Wear	• Hybrid nano composite fabricated with two ceramic reinforcements with Mg as a binder. • Density of the composite decreases by adding wt. percentage of nano-reinforcement • Microhardness of the composite increase with wt.% of the reinforcement
						• increasing the weight percentages of hybrid reinforcement wear loss of the composite decreases. • Hybrid composites exhibits significant increase in coefficient of friction and wear resistance with loads. Optimal friction coefficient and wear resistance is at 4 wt.% of hybrid reinforcement compared to base material.
12	K. Ravi Kumar et. al [26]	Al6082/ZrO_2/ coconut shell ash (CSA)	0 to10%	Stir Casting	• Hardness • Density • impact strength • tensile strength • ductility and • flexural strength	• Density of composite initially diminished and then augmented and it is as higher as 11.1% compared to the base metal. • Hardness of the composite decreased by while adding coconut shell ash due to the lubrication effect. Further addition of ZrO_2 increased the hardness of composites by 31.5% compared to base metal. • Flexural strength of the hybrid composite is increased by 9.52 % compared to the base aluminium alloy.

						• Addition of hybrid particles leads to diminish the impact strength of the composite.
13	B. Praveen Kumar et.al [27]	Al-Cu	2%, 4% and 6% bamboo leaf ash (BLA)	Stir Casting	• density • porosity • hardness and • tensile strength	• Density of composite is gradually diminished by the addition of BLA particles • Porosity would increase with mass fraction of BLA particles. • Hardness and tensile strength were increased up to 4% of BLA in the composite, while it reversed with a further rise in BLA particle concentration.

3 Selection of Al-7075:

Al-7075 is a unique aluminium series alloy with zinc as a second major constituent. The presence of zinc leads to offer exceptional mechanical properties such as high tensile and flexural strengths, virtuous ductility, fatigue resistance and toughness.

It offers more susceptibility to embrittlement compared to other aluminium series alloys due to micro segregation of constituents and possess significant resistance to corrosion. This exceptional mechanical behavior promotes to use this alloy for aerospace applications where the material subjected to high structural stresses.

3.1 Processing of Al-7075 Matrix Composites:

The advancement in material technology stretches its hands to initiate various manufacturing methods to produce Al-MMCs. Major approaches are discussed in this article: Solid state, liquid state and twophase processing methods as presented in Fig.9. yet, sub approaches used to fabricate to produce MMCs are also illustrated hereunder in Fig 9(a) and 9(b).

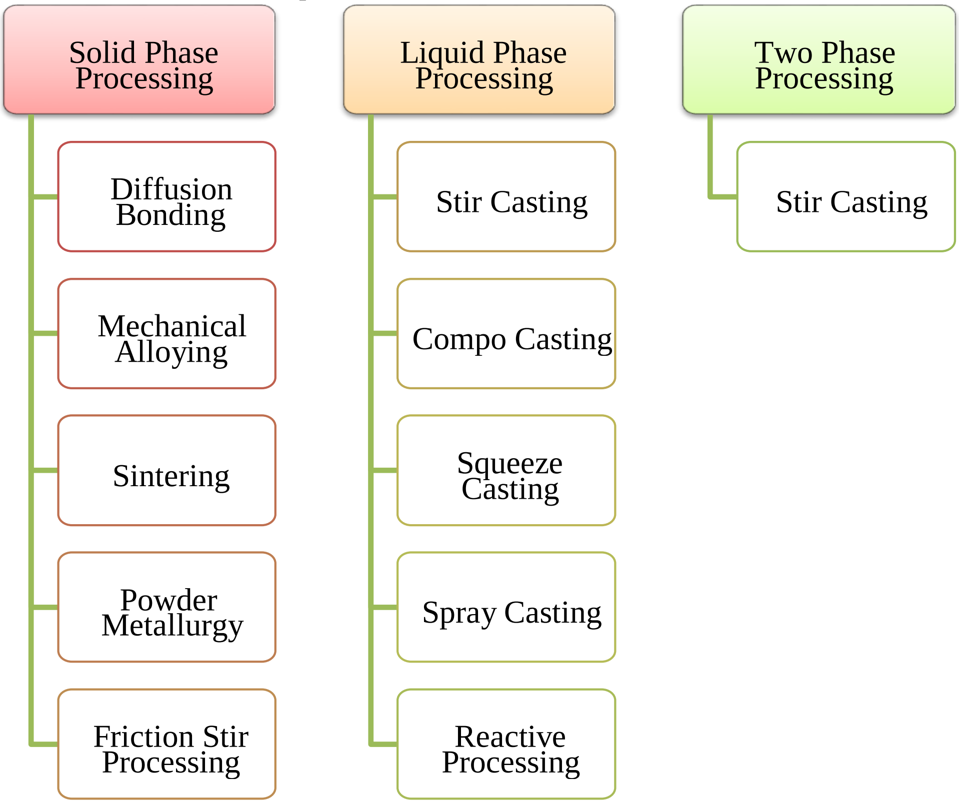

Fig. 9 (a) Methods of fabricating MMCs

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however other fabricating approaches are also discussed hereunder. However, casting is the most feasible technique to produce job ordered and mass production as well.

Powder Metallurgy	Melting and solidification	Thermal Spray	Electrochemical Deposition	Other Novel Techniques
• Mechanical Alloying and Sintering • Mechanical Alloying and pressing • Spark Plasma Sharing • Deformation processing of the powder composite	• Casting • Metal infiltration • Metal Spinning • Laser Deposition	• Plasma Spraying • Cold Spraying	• Electrodeposition • Electroless deposition	• Molecular level Mixing • Sandwich processing • Torsion/friction welding • Vapout deposition • Mixing as pastes • Nanoscale dispersion

Fig. 9 (b) Techniques to fabricate Al-MMCs

Amid all fabrication techniques, stir casting is the mostly used popular and unique technique to fabricate the MMCs, particularly Al-MMCs. Flexibility in adding mono and hybrid constituents made it exceptional to fabricate MMCs. The Al-7075 based composites with reinforcement are prepared by stir casting method as shown in Fig.8, which is one of the most economical and advanced method of fabrication.

The systematic procedure of stir casting is as follows [14]:

1. Al-7075 alloy is melted above its melting temperature in a graphite crucible.
2. Pre heated Reinforcing material is added/ mixed to Al-7075 alloy when its temperature reduces to semi solid temperature.
3. Reheating the mixture with continuous stirring to attain the refined microstructure as well as uniform distribution of reinforcement particulates throughout the matrix material. The parameters to be considered for mixing the matrix and reinforcement to refine the microstructure are relative density of materials, geometry of the stirrer, Temperature of melting and rate of solidification.
4. Molten metal is poured in to die to prepare the specimens as per ASTM Standards.
5. Testing of samples under experimental setups for characterization and micro structures.

4 Properties of Al-7075 metal matrix composites

The properties of Al-7075 metal matrix composites to be studied are (a) Physical Properties like density, temperature distribution, Thermal properties and electrical conductivity, (b) Mechanical Properties like Tensile Strength, Compressive Strength, Hardness, Impact Strength and fatigue strength, (c) Tribological Properties like wear. From the past investigations of researchers, it is observed that the mechanical properties of Al-7075 composites were enhanced with the reduction in weight, wear and corrosion compared to Al-7075 alloy. Further enhancement in properties has been noticed with the addition of two or more filler particulates as reinforcement [28]–[30].

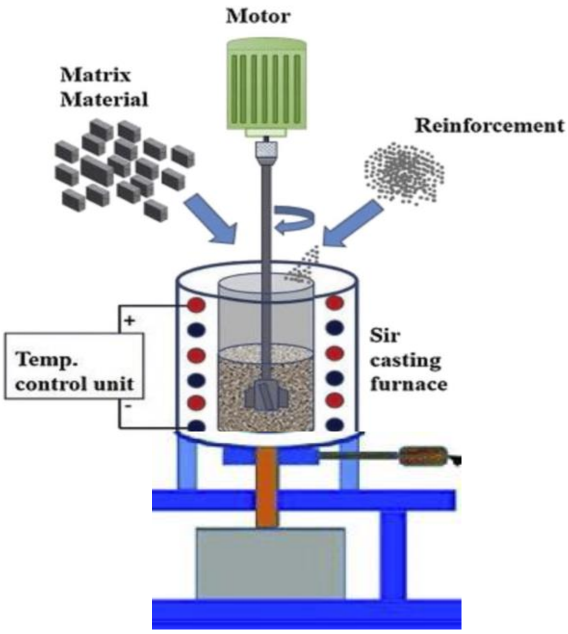

Fig. 10 Stir Casting Setup with bottom pouring attachment

Stir casting is a popular and versatile MMC fabricating technique and is as exemplified in Fig.10. In this technique, matrix material is initially preheated in a separate furnace and then melted in this stir casting unit. Reinforcement particulates are slowly added to the molten phase matrix material with the support of mechanical stirrer. As the reinforcement agent is separately adding to the matrix metal in a controlled environment leads to have control over the process parameters as well as final mechanical behavior of the casting as well [31].

Figure 11 illustrates the schematic arrangement of stir casting. The structure consists of electric furnace with mechanical stirrer and reinforcement particulate dispenser. Initially pre heat the matrix metal in a separate tubular like furnace up to recrystallization temperature, then loaded in a stir casting furnace which is bottom poring type machine. The preheated metal subjected to electric resistance arc so as to reach molten state. The reinforcement particulates are uniformly added to the base metal by rotating the stirrer at a predefined rated speed depending up on the quantity and type of compositions. Time of dispense, time of stirring and stirring speed play vital role for homogeneity of the composite. Bottom pouring privileges the avoiding of particulate sedimentation at the bottom of crucible also it does not give enough time to initiate the crystallization of composite. The homogeneous mixture of composite would provide better and isotropic mechanical behavior.

The profile of the impeller plays a key role on preparation of homogeneous matrix reinforcement mixture. There are several types of mechanical stirrers are used by the various researchers. From the open literature, on the basis of impeller blade profile and geometry of the blade, flat type three blades impeller gave better mixing of the composite and also reduces the power consumption as it develops axial flow to the fluid [32].

The rotary motion to the stirrer is imparted by the electric motor connected to it. A separate reinforcement feeder is provided above the stirrer at suitable location so as to feed the reinforcement with minimum work input or no separate work input, nut just by gravity. After through mixing of the matrix-reinforcement mixture, the liquidous composite fed into the mould. The mould may be either sand or investment type or permanent mould.

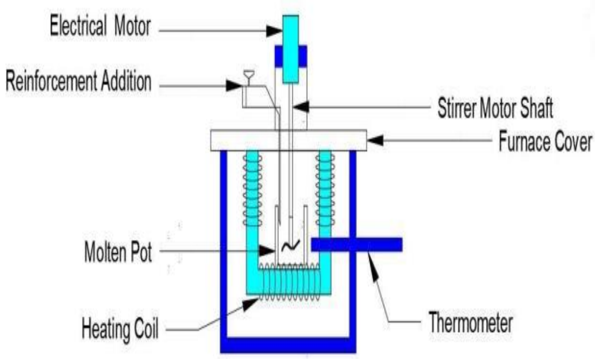

Fig. 11 Schematic view of stir casting process

The process of stir casting is depicted in the process flow diagram in Fig. 12. The process of stir casting is initiated by placing the matrix material in the furnace. Most of the stir casting test rigs have bottom poured attachments with lower feeding mechanism. Before feeding the constituents, both matrix and reinforcements are preheated. The matrix phase material to preheated to make it ready for melting while the reinforcement is preheated to remove moisture and contaminants. Separate preheating furnaces are required for both the constituents [33]. After melting the matrix phase material, a mechanical operated stirrer is switched on to create swirling action to the matrix liquid. While the matrix metal swirling reinforcement is fed to base material at a constant rate through the feeder. Feeder would allow to pour the reinforcement agent still the predetermined amount of reinforcement is fed and it is thoroughly mixed with the base phase material.

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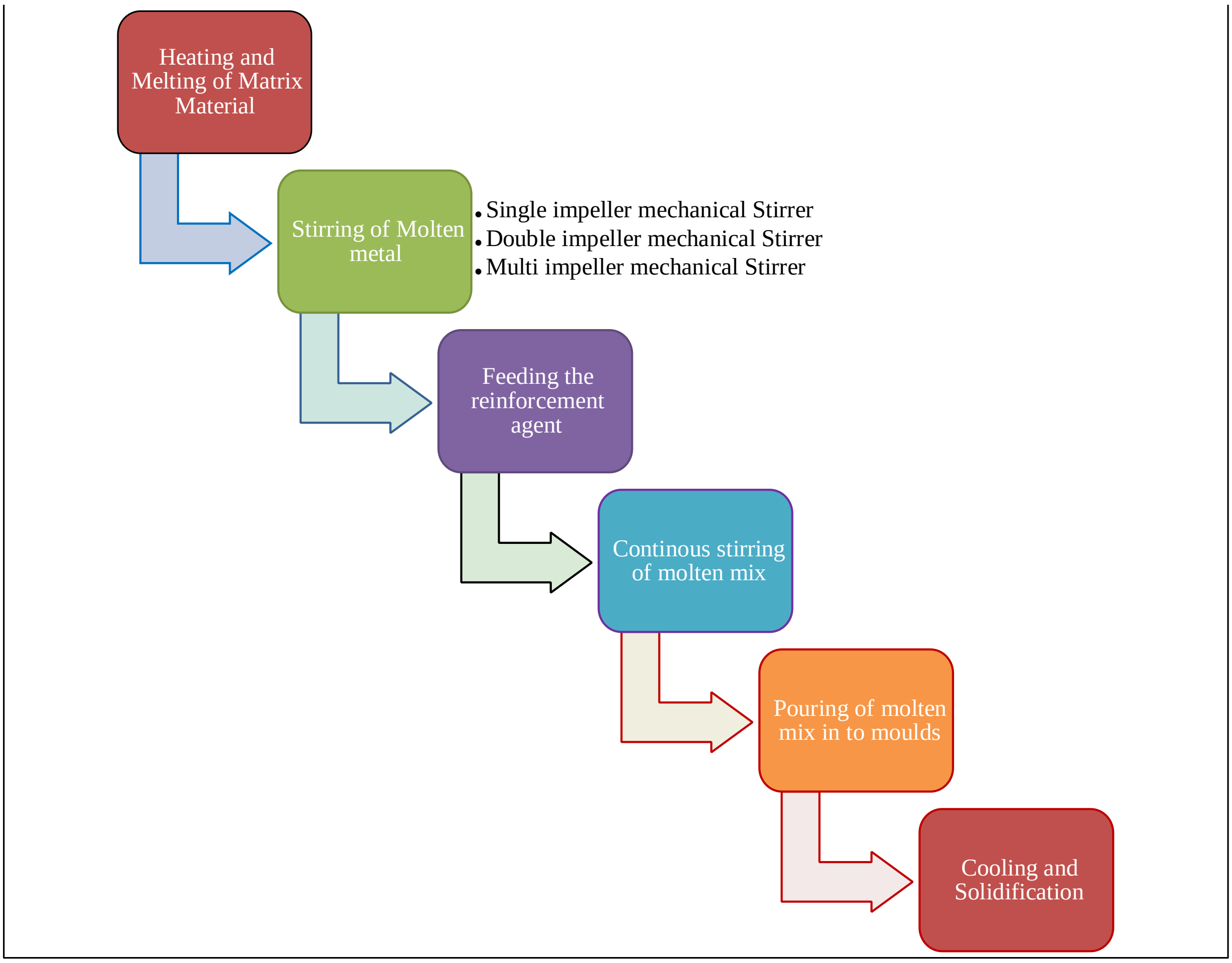

Fig. 12. Flow diagram showing the procedure of stir casting technique

Homogeneous mixture is prepared by adding the predetermined quantity of reinforcement agent and stirred it for desired duration, after preparation of homogeneous mixture, the red hot molten composite is allowed to preheated mould through bottom pour attachment and remains it in open atmosphere for solidification/cooling. The obtained new composite casting has to do metallurgical characterization and mechanical behaviour. However, the attained mechanical properties can be altered to some extent by heat treatment, extrusion, forging, rolling so on. Few several techniques are adopted by the researchers are squeeze casting type, rotary centrifugal casting type, vacuum die casting type and extrusion type castings so on [33]. The type of approach used for fabricating the casting depends up on the end application and profile of the object as well. Appropriate cast profile can be obtained feeding the molten metal with minimum time lag. Bottom feed mould is the best suitable method to feed the molten metal into mould cavity. Nevertheless, investment castings and low wax castings are best suited for bottom feed mechanism. In this type moulds, a pin hole like passage is created at the bottom of the crucible to allow the molten slurry into mould [14]. From the open literature, the feasible stirring time for the formation of homogeneous mixture of matrix-reinforcement is about 2 to 3 hrs. reinforcement particles are added to the molten matrix phase at predefined concentration. Thoroughly mixed composite is allowed to pour in mould cavities as per the requirement [34]. When the matrix phase material completely melts, then the process of stirring is initiated, profile and speed of the impeller plays a pivotal role in proper mixing of composite. impeller of stirrer is started to develop swirl in mix. For the homogeneous composite formation, stirring speed, stirrer angle, number of blades are highly influential parameters.

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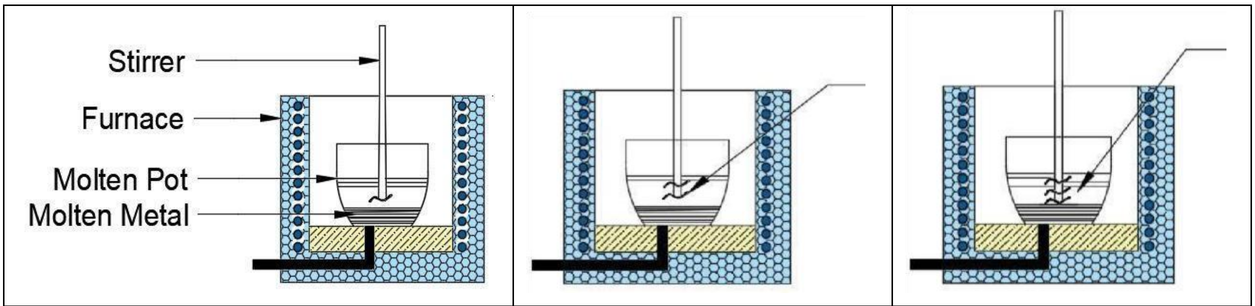
5 Parameters influencing the stir casting:

5.1 *Mechanical stirring:*

Stirring is a key parameter that influences the homogeneous mixing of reinforcement in matrix phase. Mechanical stirrers are the most common type in recent research. A servo-controlled motors are used to impart rotary motion to the stirrer and motor speed can altered by a regulator. The impeller may equipped with either one blade or two blades or multiple blades depending on the quantity of composite and quality of stirring required [35]. However, single blade mechanical stirrer is both technically effective and cost effective as well. Somehow, multi bladed impellers can be adopted in chemical and industrial processing units [32], [36]. Impeller blades plays a pivotal role in imparting centrifugal action, acceleration and mechanical energy to the molten metal. Single blade system may not able to create the enough centrifugal action, that leads to increase the deformation rate and lower the efficiency. However, multiple blade system can compensate the diffuser losses and leads to optimize the efficiency. The number of blades (single or multiple) attached to the impeller can be illustrated from Fig.13. however, the dispersion of reinforced particles with different number of blades at various stirring parameters can be visualised from the Fig. 14. The reinforcement distribution in the composite material highly influenced by process of stirring. The homogeneous distribution of reinforced particles will define the metallurgical structure of the composite and mechanical behaviour of the resultant of Aluminium based composite material in stir casting [33], [37]. This homogeneity can be attained by resolving the exertions associated with the stirring by controlling the stirring variables. The quality of the new developed composite would influence by various stirring parameters such as base and reinforcement materials, reinforcement concentration and its feed rate, time of stir, speed of stir so on.



(a) Single blade stirring	(b) Double blade stirring	(c) Multiple blade stirring

Fig. 13. Diagrammatic representation of various stirrer blade count

The augmented stirring parameters from the recent research on Al-MMC are abridged in table 4. Researchers chose different variables to develop the Al-MMC and it can be observe from the table 4 that the range of possible parameters are presented. The range of parameters considered by various researchers are, stirring speed 200 rpm to 700 rpm, feed 0.9 to 1.5 g/s and stirring duration is 5 to 15 min. Hence, it is better to adopt these range of stir parameters to generate properly distributed composite. Improper selection of process parameters may cause for generation of poor quality composite.

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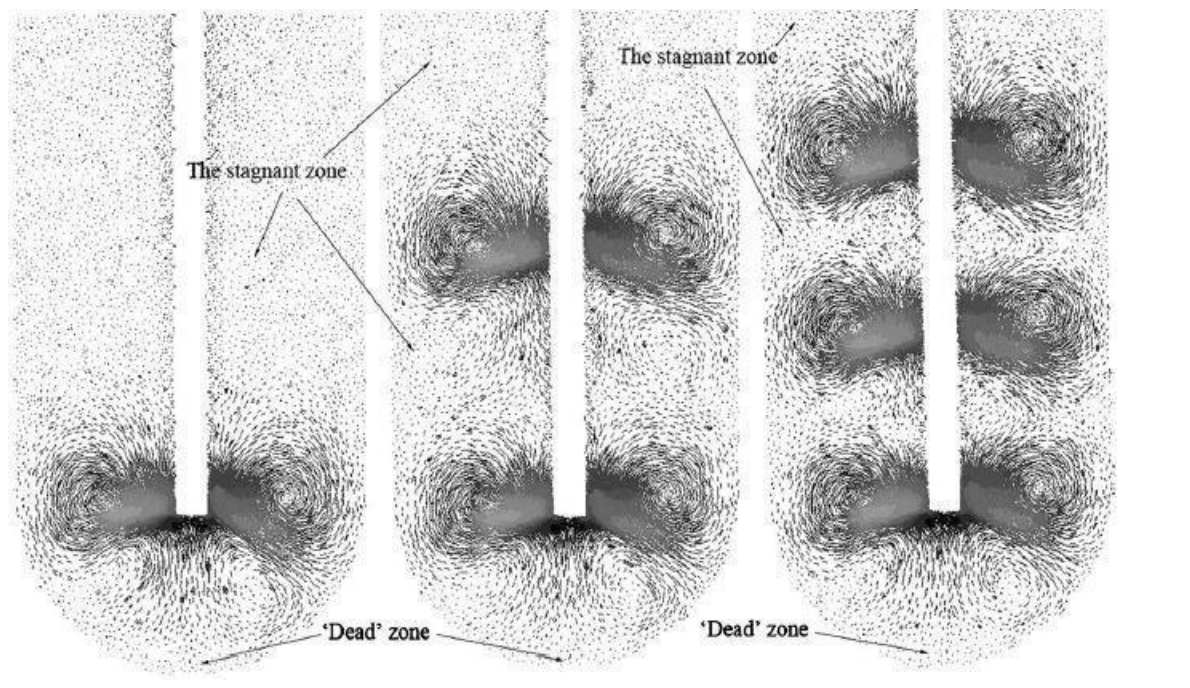

a. Single blade stirring	b. double blade stirring	c. multi-impeller stirring

Fig. 14 Reinforcement distribution in molten metal with different blades at 500 rpm

Table. 4: Various operating parameters proposed by the researchers to get enhanced mechanical properties to Al-MMCs.

S. No	Matrix Material	Reinforcing Material	Reinforcing Material %	Stirring Speed (RPM)	Stirring Time (Min)	Feed Rate(g/s)	References
1	Al-356	Nano sized Al_2O_3	1, 2, 3, 5 wt.%	200 300	10	-	[38]
2	Al-384	SiC	10 Wt.%	450500 600	5, 10,	-	[39]
3	Al-6061	SiC/Fly ash	7.5-10 wt%, 7.5 wt %	700 350	15 10	1.2-1.6	[40]
4	Al-6061	TiC	3-7 wt.%	Manual	-	-	[41]
5	Cast Al-Ti-Zr	B_4C	5 Vol. %	600 700	5, 10	1/60%	[42]
6	Al7075	TiC/Graphote	5 wt.%/1-4 wt.%	550	15	0.9-1.5	[43]
7	Al-7075	Basalt	-	600	10	-	[44]
8	Al-7075	B_4C/Fly ash	-	500 550	-	-	[45]
9	Al-1050	SiC	18 wt %	600470 380	15	-	[46]

5.2 Stirring speed:

Stirring speed is the pivotal parameter that influences the distribution of reinforced particles in the composite material. Prabhu et al. [47] conducted an experimental survey to analyze the stirring parameters with Al-MMC reinforced with SiC. For the instant, they chose three stirring speeds as 500 rpm, 600 rpm and 700 rpm with the stirring durations of 5 min, 10 min and 15 min respectively. However, they noticed that for their considered composite 600 rpm stirring speed for 10 min of stirring would gave better homogeneity in composite. From their analysis, the resulting composite exhibits better metallurgical structure and mechanical behaviour. Elsayed et al. [48] studied the Al-MMC reinforced with manganese dioxide reinforcement and discussed the optimized mechanical properties of resultant composite. They observed that the optimizing parameters for their considered composite is 300 rpm to 1100 rpm with 300 sec duration. The impact of churning speed with the same number of blades are presented in Fig. 15. One can observe from the Fig. 15 that the pattern of particle dispersion with different stirring speeds and the dispersion is more uniform at higher blade speeds.

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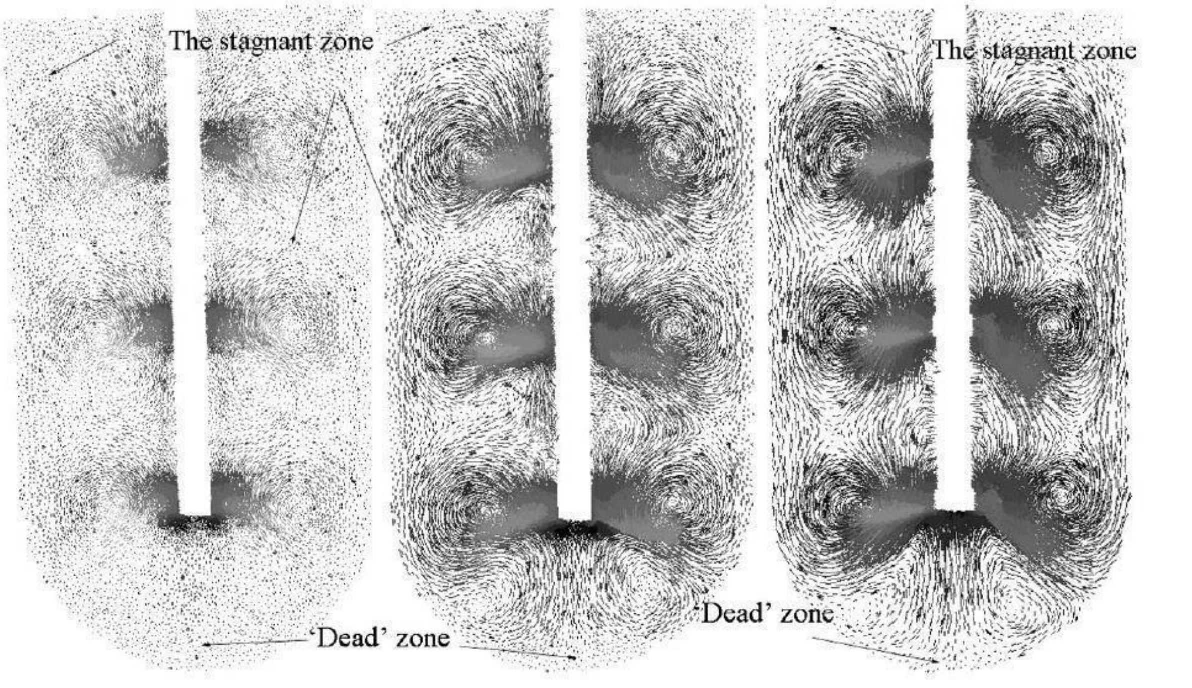

(i) 300 rpm	(ii) 600 rpm	(iii) 1000 rpm
F	ig. 15Particle distribution patter	ns

5.3 ***Blade angle of impeller:***
The homogenous distribution of reinforced particles is resulted from the whirl motion of that can impart to molten metal by churning action. This churning in molten metal can be created by the motion of stirring blades. The agitating forces that are imparted to the molten metal are judicated by other stirring parameters viz., number of blades and blade angles, stirring speed and its duration as well. The whirl motion of molten metal is able to pull the reinforced particles from the outer surface to matrix metal to generate the uniform dispersion of particles [49]. Single set of impeller blade with primary blade angle is presented in Fig. 16. This swirl motion also provides the shearing action to the particles so as to avoid the agglomeration and sedimentation of reinforcement particles, nevertheless the angles of impeller blade possess a significant role in dispersion of secondary phase reinforced particles in composite material.

Numeral approach facilitates the researcher to do an analytical survey with no experimental expenses, however the trueness of the results is closely depended on the percentage of closeness to real environment. A few research investigations using computational fluid dynamics platform analyze the various stirring parameters those have higher impact on the characterization of resultant composite are discussed. The range of stirring speeds for this numerical pseudo approach is from 200 rpm to 700 rpm, stirring duration varies from 120 sec to 900 sec while the blade angles are ranging from 15^{o} to 90^{o} with a step size of 15^{o} [45].

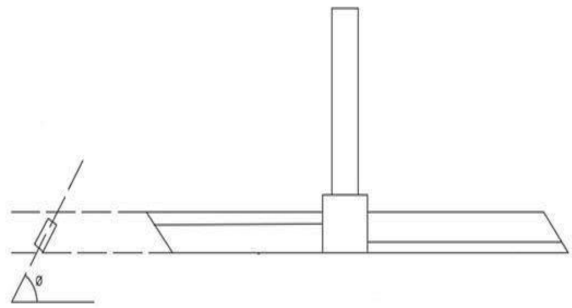

Fig. 16 Schematic presentation of single set impeller blade angle

5.4 ***Stirring Duration***
Time of stirring is the other critical parameter that control the homogeneity, physical, metallurgical and mechanical properties of resultant composite. Period of stirring is may be about few minutes that churns the molten metal. Churn duration would define and decides the uniform dispersion of reinforcing agent in base material, that would also avoid the sedimentation of particles as an agglomeration at a particular location. However, the ill-effect of over stirring period may cause for the plastic deformation of reinforcement and

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matrix materials as the molten metal possess lower yield properties. Along with the period of churn, mechanical properties of individual constituents, blade material, blade angles and operating temperatures are also influence the homogenation of composite. Stirring at such high temperature with high blade angle may results in deformation of the impeller [14].

It can notice from the open literature that, higher stirring time not only causes for the plastic deformation but also responsible for higher power consumption and even uneconomical as well. Therefore, one has to find the optimum stir duration for a particular composite so as to get the desired mechanical properties. However, along with duration blade geometry also possess considerable influence on quality of the composite.

6 Review on Mechanical Properties of Al-7075 metal matrix hybrid composites

Amit Raturi *et al.* [50] fabricated the Al-7075 based Al_2O_3 Nano fillers reinforced (at 3, 5 and 7Wt.
%) composites by stir casting method to study the mechanical, tribological and structural behavior. The hardness values of the composites/compounds are improved with the increase in addition of Al_2O_3 filler and the maximum value of 129 BHN is observed in the composites filled with 7Wt. % of Al_2O_3. The Tensile Strength, Flexural Strength and Impact Strength of the compounds/ composites have been improved with the increase in wt. % of the filler up to 5 Wt. % and the properties are decreased with the further addition of Al_2O_3 at 7Wt.%. This may be due to presence porosity at high levels, uneven distribution of fillers and cluster formation.

R Pramod *et al.* [51] have done the experimentation work on Al_2O_3 reinforced Al-7075 based composites and the mechanical properties were enhanced with the accumulation/ addition of filler when compared with pure Al-7075 alloy.

Diptikanta Das *et al.* [32] did the investigations to find mechanical properties of SiC filledAl-7075 composites. It is observed that with the increase in addition of filler content from 0 to 25Wt. % and decrease in particle size of the filler at four levels (0, 5, 15 and 25Wt. % of SiC fillers) the micro hardness has been enhanced with the reduction in ductility. Reduction in yield strength is observed with the rise in filler content as well as improvement in yield strength is observed with the reduction in particle size of the reinforcement/ strengthening filler. The ultimate tensile strength (UTS) is increased with the addition/accumulation of reinforcement filler up to 15Wt. % and reduced at 25Wt. % and with the reduction in particle size of the reinforcement filler. All the above properties were enhanced for the heat treated samples compared to casted Al-7075 composites.

Manoj Singla *et al.* [49] varied the SiC reinforcement with 10Wt. % and 15Wt. % to prepare the composite by stir casting method and observed that the mechanical properties were enhanced but density is reduced with the increase in addition of the reinforcement filler.

Chandana Sri S. *et al.* [52] have done the work on manufacturing and characterization of SiC (at 5Wt. %) and Graphite (at 2 Wt. % and 4Wt. %) reinforced Al-7075 hybrid composites. It is observed that the micro hardness of hybrid composite at 2 Wt. % of the Graphite has been improved by 64% compared to the base Al-7075 alloy, but the hybrid composite filled with 4Wt. % of the Graphite has shown only 16% increase in hardness over Al-7075 alloy. Here the decrease in hardness value is due to high level of porosity. The same trend of improvement is observed for impact strength also with 55% and 40% improvement in hybrid composites/ compounds strengthened/ reinforced with 2Wt. % and 4Wt. % Graphite filler over Al-7075 base alloy.

Atla Sridhar *et al.* [53] successfully prepared the Al-7075 based hybrid composites/ compounds strengthened/ reinforced with SiC/ mixture of SiC and Graphite by 'powder metallurgy' technique and they found the mechanical and then wear properties. The hardness of the Al-7075 composite reinforced with 5Wt. % SiC is enhanced compared to Base Al-7075 alloy but it is reduced when the hybridization of composite is done with the addition of 5Wt. % of Graphite to Al-7075 composite (Al-7075+ 5% of SiC+5% of Graphite). Increase in addition of graphite to composite reduces the mechanical properties where as more SiC content in composite results in difficulty in machining.

K. Maruthi Varun *et al.* [54] made the investigation on mechanical properties of SiC (3, 6 and 9Wt. %) and MoS_2 (1Wt. %) reinforced hybrid composites with Al-7075 as base metal and they observed that the values of 'Tensile strength' and 'hardness' were enhanced with the rise in Wt. % of SiC reinforcement from 3% to 9%. S. Suresh et

al.[15] produced Al-7075 based hybrid composites reinforced with Al_2O_3 and SiC in same proportions of 1 to 4Wt. % by liquid state process and it is observed that the hardness as well wear resistance has been increased with the escalation in content of reinforcement/ strengthening element compared to Al-7075 base alloy.
Uvaraja and Natarajan [55] carried out the work of fabrication and finding the hardness for SiC (at 0-15Wt. %) and B_4C (at 3Wt. %) reinforced Al-7075 hybrid composites. It is detected that the hardness of composites has been improved with the accumulation of B_4C strengthening element/ reinforcement at 3 Wt. % compared to the base Al-7075 alloy. The improved hardness may be due to harder reinforcements which are the obstacles to the wave of displacement in composite. Further enhancement in hardness is obtained with hybridization effect to the B_4C reinforced composites with SiC reinforcement from 5 to 15Wt. %. The maximum hardness value of 88BHN is observed in hybrid composite of reinforcements SiC (at 15Wt. %) and B_4C (at 3Wt. %).

In the experimentation work done by B. Jayendra *et al.* [56] the results of mechanical properties have been reported for the hybrid composites of Al-7075 with boron carbide (2, 4 and 6 Wt. %) and graphite (1, 3 and 5 Wt. %) reinforcements at three fixed levels of boron carbide and graphite compositions for total of 9 trials. It is found that the hardness values are improved for the hybrid composites compared to un-reinforced Al-7075 base metal. Hardness value is in increasing manner with the increase in addition of graphite and the peak value of rigidity/ hardness is 159 for 95-Al-70752-B_4C-3-Gr hybrid composite. The impact strength is also increased with the increase in addition of graphite and the maximum value of 4 joules is observed in the composites filled with 3 and 5 Wt. % of the graphite reinforcement at 2, 4 and 6 Wt. % of the B_4C reinforcement. The UTS value is also in increasing trend with the increasing weight percentage of Graphite due to the good bonding strength provided by boron carbide.

Al-7075 based metal matrix composites reinforced with Si_3N_4 (0, 4, 8 and 12Wt. %) reinforcement are prepared by the researchers S. Arun Kumar *et al.* [57] through stir casting method. The Vickers micro hardness number of composites has been enhanced/ improved with the increase in addition of silicon nitride filler compared to parent metal alloy and the authors suggested that the further enhancement in hardness can be achieved by heat treatment of samples at above 550^0C so that the porosity in specimens can be reduced for hardness enhancement.

TiC (at 0, 2.5, 5 and 7.5Wt. %) Reinforced Al-7075 based metal matrix composites (MMC) are contrived by K. R. Ramkumar *et al.* [18] using stir casting method. In their research work they found the hardness (RHN) and bending strength of the composites and they have been improved with the TiC filler addition from 0 to 7.5Wt. % compared to the unfilled Al-7075 composite. The extreme values of hardness (248HRC) and bending strengths (730MPa) were observed in the composites filled with 7.5Wt. % of TiC. The enhancement in mechanical properties may be due to the presence bonding in between matrix and reinforcement, grain refinement, uniform distribution, shape and size of the reinforcement (TiC).

R. Manikandan *et al.* [15] prepared the hybrid composites reinforced with boron carbide (at interval of 2.5Wt. % up to 10Wt. %) and Cow dung ash (at interval of 2.5Wt. % up to 10Wt. %) reinforcements with Al-7075 as matrix at fixed weight percentage of 90. They reported that the hardness results/values of composites have been increased with the growth in addition of B_4C from0Wt. % to 10Wt. % and at 10Wt. % of Cow dung ash minimum hardness was observed. The maximum value of hardness is 152BHN observed in the composite filled with B_4C at 10Wt. % (Cow dung ash at 0Wt. %). The minimum value of hardness is 102BHN for the composite filled with Cow dung ash at 10Wt. % (B_4C at 0Wt. %) whereas the pure alloy is having the hardness of 110BHN. The 'tensile strength' of the composites also improved with the increase in the addition of boron carbide-B_4C from 0Wt. % to 7.5Wt. % (at 10Wt. % of the B_4C the slight decrease in tensile strength is observed) and at 10Wt. % of Cow dung ash minimum tensile strength is observed. The maximum tensile strength of 288.38MPa observed for the composite 'Al-7075-7.5B_4C-2.5Cow dung ash' and the minimum tensile strength of 184.8MPa is observed for pure Al-7075 alloy. Impact strength of the composites has been decreased with the increase in addition of B_4C from 0Wt. % to 10Wt. % and at 10Wt. % of Cow dung ash the peak value of 'impact strength' was detected compared to other filled composites whereas unfilled Al7075 alloy has exhibited the maximum impact strength of 3.2 J. The flexural strength of the composites has been augmented with the increase in B_4C from 0Wt. % to 2.5Wt. % (Cow dung ash from 10Wt. % to 7.5Wt. %) further increase in addition of B_4C reinforcement from 5 to 10Wt. % resulted in decrease in flexural strength. The maximum and minimum values of flexural strengths of 358MPa and 300MPa are observed in the composites'Al-7075-2.5B_4C-7.5Cow dung ash' and 'Al-7075-10B_4C-0Cow dung ash'.

Al-7075 based composites reinforced with TiB_2 at different Wt. % of 0.8, 1.2, 1.6 and 2 are fabricated by stir casting method. It is perceived that with the rise in addition of reinforcement/ strengthening content the mechanical properties like micro hardness, compressive strength and tensile strength were improved compared to Al-7075 base alloy [58]. R. Keshavamurthy *et al.* [33] also selected the same Al-7075 base alloy to fabricate the composites with TiB_2 reinforcements at 4, 6 and 8 Wt. % and they found the increasing trend of hardness values with the increase in reinforcement addition.

Many researchers have done the work on fabrication and mechanical characterization of Al-7075 based Al_2O_3 reinforced composites having weight percentages of 0%, 2%, 4%, 6%, 8%. They reported that through the increase in addition of Al_2O_3 reinforcements the progress in Tensile strength, hardness, compression strength and impact strengths is observed. The extreme values of mechanical properties are obtained at 8Wt. % of Al_2O_3 reinforcement [32], [36]. Al-7075 hybrid composites are prepared with the reinforcement of 5 Wt. % of Graphite along with Al_2O_3 reinforcement with the above compositions ranging from 2% to 8% and all the mechanical properties are increased with reinforcement addition [31].

Balasubramani Subramaniam *et al.*[14] prepared the hybrid composites reinforced with boron carbide Wt. % of 0, 3, 6, 9 and 12 and coconut shell fly ash (at 3Wt. %) reinforcements with Al-7075 as matrix. They reported that the hardness values of composites are improved with the increase in addition of B_4C.The maximum hardness of 169BHN is obtained for the composite 'Al-7075-12%B_4C-3%CSFA' and the maximum tensile strength of 189MPa for the composite 'Al-7075-9%B4C-3%CSFA'.

Ashiwani Kumar *et al.* [35] fabricated the marble dust (at 0, 2, 4 and 6Wt. %) reinforced Al-7075 based composites. In their experimental work they found that with the rise in marble dust addition the hardness/ impact strength values were increased and the maximum value of hardness and impact strength are 48HRB and 21.4 KJ/m^2 respectively. Maximum compressive strength of 512MPa is observed for the composite filled with 2Wt. % marble dust and high flexural strength of 528MPa is acquired for the composite reinforced with 6 Wt. % of marble dust.

Mani Sambathkumar *et al.* [37] have done the fabrication of Al-7075 composites reinforced with Red mud an industrial waste at volume fractions of 0, 5, 10, 15 percentages by double stir casting method. It is observed that with the addition or red mud the hardness values are increased and the maximum hardness value of 181.86VHN is observed at 15 Vol. % of red mud. The values of ultimate tensile strength are also increased compared to unfilled composite and the maximum strength of 326MPa is observed for the composite reinforced with red mud at 5 Vol. %.326MPa is observed for the composite reinforced with red mud at 5 Vol. %.S. Rajesh *et al.* [47] used the fly ash and SiC reinforcements to fabricate the Al-7075 based composites. The reinforcement content ranges from 0 Wt. % to 10 Wt. %. As shown in below Table 5.

Table 5 Composition of the Al-7075 based hybrid composites

S.No.	Wt. % of Al-7075	Wt. % of SiC	Wt. % fly of ash	S.No.	Wt. % of Al-7075	Wt. % of SiC	Wt. % fly of ash
1	100	0	0	6	90	0	10
2	95	5	0	7	90	5	5
3	95	0	5	8	90	2.5	7.5
4	95	2.5	2.5	9	90	7.5	2.5

5	90	10	0	-	-	-

It is witnessed that the hardness/ tensile strength results/values of composites were enhanced through the accumulation of fillers when compared with the unfilled composites. The extreme tensile strength and hardness values are 601.9MPa for the composite having '90% Al-7075+7.5% SiC+2.5% fly ash' and 184.67BHN for the composite having '90% Al-7075+5% SiC+5% fly ash' respectively.

In a mechanical performance study of the four Al-7075 hybrid composites reinforced with silicon nitride at (2, 4 and 6 Wt. %), rice husk ash (at 5 Wt. %) and snail shell powder (2, 4 and 6 Wt. %), it is observed that the tensile strength, impact strength and hardness values are improved compared to the unfilled composites.

The highest values of hardness, tensile strength and impact strength are 78.6HRB at 91% Al-7075 + 2% $S_{i3}N_4$ + 2% Snail shell powder (SPP) + 5% Rice husk ash (RHA), 154.64MPa at 83% Al-7075 + 6% $S_{i3}N_4$ + 6% Snail shell powder (SPP) + 5% Rice husk ash (RHA) and 12J at 87% Al-7075 + 4 % $S_{i3}N_4$ + 4 % Snail shell powder (SPP) + 5% Rice husk ash (RHA) respectively [21]

The Tensile strength and yield strength of the Al-7075 based composites reinforced with Short basalt fiber at 2, 4 and 6 Wt. %'s were enhanced when compared with the pure Al-7075 alloy. The extreme values of tensile strength and yield strength are 215 MPa and 185MPa respectively for the composites reinforced with 6 Wt. % short basalt fibers [34]

Al-7075 based hybrid composites reinforced with boron carbide at 0, 3, 6 and 9 Wt. % and Titanium diboride at 3 Wt. % are fabricated by stir casting technique. The hardness/ Impact strength/ tensile strength/ compressive strength values are improved with the rise in addition of weight percentage of boron carbide. The extreme values of hardness, Tensile strength and compressive strength are 76Hv; 233MPa and 231MPa respectively are obtained for the Al-7075 based hybrid composite reinforced with 9 Wt. % boron carbide and 3 Wt. % Titanium diboride. But the Impact strength value is maximum at 3% boron carbide and 3% titanium diboride reinforcement and the further addition of boron carbide reinforcements leads do decrease in the values of impact strength [59].

From the literature it is observed that all most all the industrial wastes are used as reinforcements in combination with metal oxide, nitride and carbide reinforcements to the Al-7075 matrix and so many combinations of reinforcements can be added to the Al-7075 to enrich the individualities of the composites.

The usage of various agro wastes are reported in a review article in detailed manner written by Bisma Parveez *et al.* [27]. Hidayat *et. al.* [60] Prepared the Gd added Al-18%Si Alloy for the applications of Automotive and they observed the enhancement in mechanical properties with the addition of Gd. The usage of agro wastes as reinforcement to Al-alloys enhanced the all characteristics compared to Al-base alloy.

Along with this the optimization techniques like taguchi method can be implemented for CNC Turning parameters for cutting Al alloy based composites to achieve good surface roughness [60].

Influence of reinforcement on properties of composites:

Composites exhibits ameliorated properties than the monolithic materials such as higher strength to density and stiffness to density ratios, better fatigue and wear resistance and high thermal stabilities. However, these are suffering from immature fabrication and service technologies.

Fiber reinforced:

Tungsten fibered alloys are suitable for jet turbine engines to operate at elevated temperatures.

Titanium hybridized with SiC can be exceptionally improves the skinning properties of aero-vehicles. Adding the titanium carbide in tool steel, and Inconel can ameliorate the thermal stability and corrosive resistance. Properties of copper and graphite composites can be tailored and can be used for high temperature applications, and also gives good mechanical properties along with the refined electrical and thermal properties. These composites are easy to fabricate than tungsten and offers lower density than ferrous. Copper reinforced composites can be used as heat sinks of electronic gadgets as well.

7 Research Gap

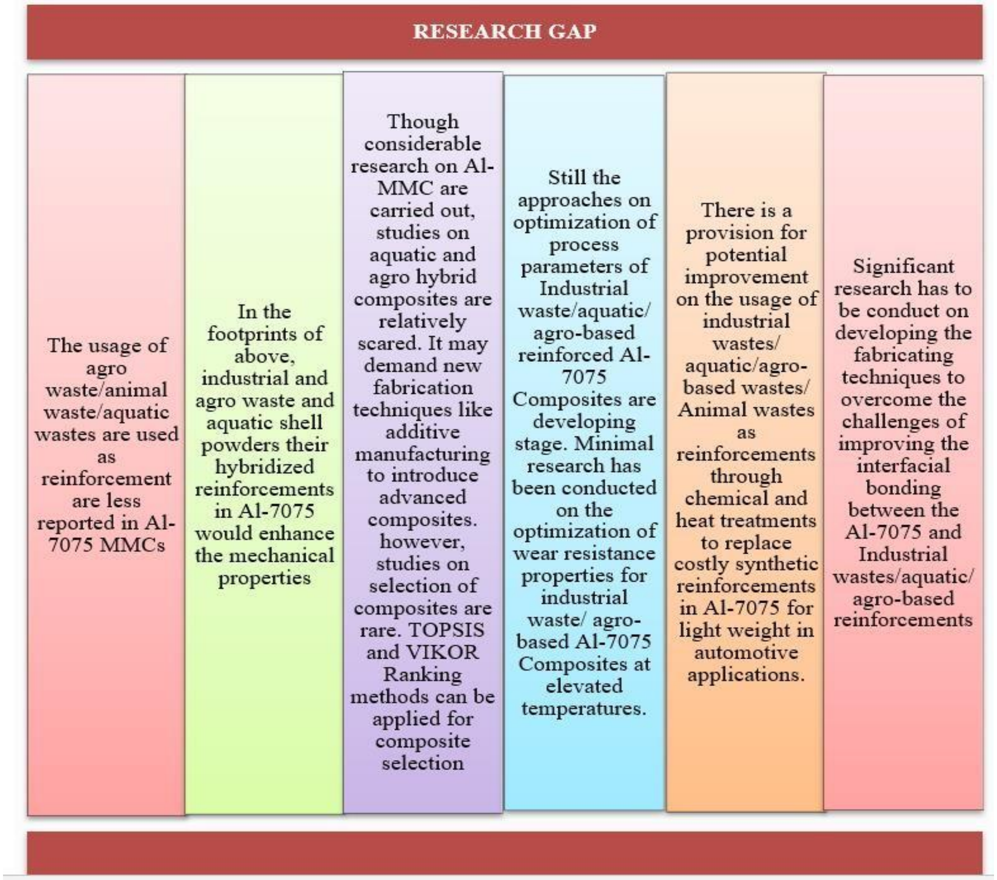

Fig. 2: Knowledge Gap present in the Previous Research Investigations

From the literature presented in this article we found some of the gaps presented in the Fig. 2 as shown below. Based on the knowledge gap present in the earlier investigations the objectives for future work are framed. The first objective of the work is selection and preparation of filler materials to prepare Al-7075 based metal matrix composites. The selected filler materials are surplus crab shell powder, oyster shell powder, Pearl shell powder and their mixture. The second objective is to fabricate the Al7075 based composites filled with the above fillers as per the designated compositions by stir casting method. The third objective is mechanical characterization and selection of composites w.r.t their attributes. The fourth objective of the work is estimation of erosion wear behaviour and implementation of optimization techniques.

8 Conclusions

This review has thoroughly discussed various costly ceramic reinforcements and agro-based strengthening elements as reinforcements as well as their effects on mechanical properties along with the manufacturing procedures involved. The key findings are:

1. The addition/ accumulation of strengthening elements as reinforcements to the Al-7075 base alloys are enhancing their mechanical properties.
2. The cost of fabrication of Al based composites can be reduced by the usage of naturally available industrial wastes, agro wastes and aquatic animal shells/ bones as reinforcements. The usage of these fillers can reduce the environmental pollution and disposal problems.
3. The usage of these industrial wastes, agro wastes and aquatic animal shells/ bones as reinforcements in various combinations in Al alloys can reduce the weight of the composites. So to achieve weight reduction one can use these reinforcements.
4. These Agro wastes can be used as potential materials for the manufacturing of automotive parts with Al-alloys.

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References

1. Z. Liao, A. Abdelhafeez, H. Li, Y. Yang, O. G. Diaz, and D. Axinte, “State-of-the-art of surface integrity in machining of metal matrix composites,” *Int. J. Mach. Tools Manuf.*, vol. 143, pp. 63–91, 2019, doi: 10.1016/j. ijmachtools.2019.05.006.
2. M. D. Hayat, H. Singh, Z. He, and P. Cao, “Titanium metal matrix composites: An overview,” *Compos. Part A Appl. Sci. Manuf.*, vol. 121, no. April, pp. 418–438, 2019, doi:10.1016/j.compositesa.2019.04.005.
3. S. K. Lalmuan, S. Das, M. Chandrasekaran, and S. K. Tamang, “Machining Investigation on Hybrid Metal Matrix Composites- A Review,” *Mater. Today Proc.*, vol. 4, no. 8, pp. 8167– 8175, 2017, doi: 10.1016 /j.matpr.2017.07.158.
4. M. Rosso, “Ceramic and metal matrix composites: Routes and properties,” *J. Mater. Process.*
5. *Technol.*, vol. 175, no. 1–3, pp. 364–375, 2006, doi: 10.1016/j.jmatprotec.2005.04.038.
6. C. C. Bozarth and W. L. Berry, “Measuring the congruence between market requirements and manufacturing: A methodology and illustration,” *Decis. Sci.*, vol. 28, no. 1, pp. 121–150, 1997, doi: 10.1111/j.1540-5915.1 997.tb01305.x.
7. V. Rao and S. Iyengar, “An Affordable composites lab to bridge the gap between Industry and Academia,” no. September, 2015.
8. R. S. K and R. C. M, “A Survey of Al7075 Aluminium Metal Matrix Composites,” 2013. [Online]. Available: www.ijsr.net.
9. S. D. Saravanan and M. S. Kumar, “Effect of mechanical properties on rice husk ash reinforced aluminum alloy (AlSi10Mg) matrix composites,” *Procedia Eng.*, vol. 64, pp. 1505– 1513, 2013, doi: 10.1016/j. proeng .2013.09.232.
10. M. Sambathkumar a, P. Navaneethakrishnan, and S. K. S. . Ponappa.K, “Mechanical and Corrosion Behavior of Al7075 (Hybrid) Metal Matrix Composites by Two Step Stir Casting Process,” *Lat. Am. J. Solids Struct.*, vol. 7075, pp. 243–255, 2016.
11. B. C. Kandpal, N. Johri, N. Kumar, and A. Srivastava, “Effect of industrial/ agricultural waste materials as reinforcement on properties of metal matrix composites,” *Mater. Today Proc.*, vol. 46, no. xxxx, pp. 10736–10740, 2021, doi: 10.1016/j.matpr. 2021.01.575.
12. B. Vijaya Ramnath, C. Parswajinan, R. Dharmaseelan, K. Thileepan, and K. Nithin Krishna, “A review on aluminium metal matrix composites,” *Mater. Today Proc.*, vol. 46, no. xxxx, pp. 4341–4343, 2020, doi: 10.1016/ j.matpr.2021.03.600.
13. S. Ahamed, R. J. D, and S. P. C, “A LITERATURE REVIEW ON ALUMINIUM -7075 METAL MATRIX COMPOSITES,” *Int. Res. J. Eng. Technol.*, p. 1384, 2008, [Online]. Available: www.irjet.net.
14. T. Anandaraj, P. P. Sethusundaram, C. Chanakyan, S. Sakthivelu, and M. Meignanamoorthy,
15. “Influence of different reinforcements on properties of metal matrix composites: A review,” *Mater. Today Proc.*, vol. 37, no. Part 2, pp. 3480–3484, 2020, doi: 10.1016/j.matpr. 2020.09.386.
16. B. Subramaniam, B. Natarajan, B. Kaliyaperumal, and S. J. S. Chelladurai, “Investigation on mechanical properties of aluminium 7075 - boron carbide - coconut shell fly ash reinforced hybrid metal matrix composites,” *China Foundry*, vol. 15, no. 6, pp. 449–456, 2018, doi: 10.1007/s41230-018-8105-3.
17. R. Manikandan, T. V. Arjunan, and A. R. Akhil, “Studies on micro structural characteristics, mechanical and tribological behaviours of boron carbide and cow dung ash reinforced aluminium (Al 7075) hybrid metal matrix composite,” *Compos. Part B Eng.*, vol. 183, no. Al 7075, p. 107668, 2020, doi: 10.1016/j.compositesb.2019.107668.
18. N. E. Udoye, G. E. Ezike, O. S. I. Fayomi, and J. O. Dirisu, “The Study on Mechanical and Electrical Properties of AA6061/Snail Shell Composites,” *Int. J. Chem. Eng.*, vol. 2022, 2022, doi: 10.1155/2022/9711761.
19. S. Suresh, G. H. Gowd, and M. L. S. Devakumar, “Wear behavior of Al 7075/Al2O3/SiC Hybrid NMMC’s by Stir Casting Method,” *Mater. Today Proc.*, vol. 24, pp. 261–272, 2020, doi: 10.1016 /j.matpr.2020.04.275.
20. K. R. Ramkumar, S. Sivasankaran, F. A. Al-Mufadi, S. Siddharth, and R. Raghu, “Investigations on microstructure, mechanical , and tribological behaviour of AA 7075–x

wt.% TiC composites for aerospace applications," *Arch. Civ. Mech. Eng.*, vol. 19, no. 2, pp. 428– 438, 2019, doi: 10.1016 /j.acme.2018.12.003.
21. P. Sivaraman, T. Nithyanandhan, M. Karthick, S. M. Kirivasan, S. Rajarajan, and M. S. Sundar, "Analysis of tensile strength of AA 2014 and AA 7075 dissimilar metals using friction stir welding," *Mater. Today Proc.*, no. xxxx, 2020, doi: 10.1016/j.matpr. 2020.04.895.
22. R. Vasanth Kumar, R. Keshavamurthy, C. S. Perugu, M. Alipour, and C. Siddaraju, "Influence of hot rolling on friction and wear behaviour of Al6061-ZrB2 in-situ metal matrix composites," *J. Manuf. Process.*, vol. 69, no. July, pp. 473–490, 2021, doi: 10.1016/j.jmapro.2021.07.058.
23. P. S. Raghavendra Rao and C. B. Mohan, "Study on mechanical performance of silicon nitride reinforced aluminium metal matrix composites," *Mater. Today Proc.*, vol. 33, no. 14, pp. 5534–5538, 2020, doi: 10.1016 /j.matpr.2020.03.495.
24. P. Sakthivel, V. Manobbala, T. Manikandan, Z. M. A. Salik, and G. Rajkamal, "Investigation on mechanical properties of dissimilar metals using MIG welding," *Mater. Today Proc.*, no. xxxx, 2020, doi: 10.1016/j.matpr.2020.05.488.
25. C. Sri *et al.*, "No 主観的健康感を中心とした在宅高齢者における 健康関連指標に関する共分散構造分析 Title," *Mater. Today Proc.*, vol. 47, no. 1, pp. 3–5, 2021, doi: 10.1016/j.matpr.2021.06.430.
26. C. Hima Gireesh, K. G. Durga Prasad, K. Ramji, and P. V. Vinay, "Mechanical Characterization of Aluminium Metal Matrix Composite Reinforced with Aloe vera powder," *Mater. Today Proc.*, vol. 5, no. 2, pp. 3289–3297, 2018, doi: 10.1016 /j.matpr. 2017.11.571.
27. M. Imran and A. R. A. Khan, "Characterization of Al-7075 metal matrix composites: A review," *J. Mater. Res. Technol.*, vol. 8, no. 3, pp. 3347–3356, 2019, doi: 10.1016/j.jmrt.2017.10.012.
28. M. Satheesh and M. Pugazhvadivu, "Investigation on physical and mechanical properties of Al6061-Silicon Carbide (SiC)/Coconut shell ash (CSA) hybrid composites," *Phys. B Condens. Matter*, vol. 572, no. August, pp. 70–75, 2019, doi: 10.1016/j.physb.2019.07.058.
29. B. Parveez, M. A. Maleque, and N. A. Jamal, "Influence of agro-based reinforcements on the properties of aluminum matrix composites: a systematic review," *J. Mater. Sci.*, vol. 56, no. 29, pp. 16195–16222, 2021, doi: 10.1007/s10853-021-06305-2.
30. S. Pradeep Devaneyan, R. Ganesh, and T. Senthilvelan, "On the Mechanical Properties of Hybrid Aluminium 7075 Matrix Composite Material Reinforced with SiC and TiC Produced by Powder Metallurgy Method," *Indian J. Mater. Sci.*, vol. 2017, pp. 1–6, 2017, doi: 10.1155/2017/3067257.
31. T. Prasad, P. Chinna, S. Rao, and B. V. Kiran, "'Investigation of Mechanical Properties of Al 7075 with Magnesiumoxide Nano Powder Mmc,'" *IOSR J. Mech. Civ. Eng.*, pp. 60–65, [Online]. Available: www.iosrjournals.org.
32. K. Shrivastava, K. K. Singh, and A. R. Dixit, "Tribological properties of Al 7075 alloy and Al 7075 metal matrix composite reinforced with SiC, sliding under dry, oil lubricated, and inert gas environments," *Proc. Inst. Mech. Eng. Part J J. Eng. Tribol.*, vol. 232, no. 6, pp.693–698, 2018, doi: 10.1177/13506 5011 7726631.
33. Baradeswaran and A. Elaya Perumal, "Study on mechanical and wear properties of Al 7075/Al2O 3/graphite hybrid composites," *Compos. Part B Eng.*, vol. 56, pp. 464–471, 2014, doi: 10.1016/j.compositesb.2013.08. 013.
34. D. Das, M. Sharma, C. Samal, and R. K. Nayak, "ScienceDirect Investigation of mechanical properties of SiC p reinforced Al 7075 metal matrix composites: a case study," 2019. [Online]. Available: www.sciencedirect .com.
35. R. Keshavamurthy, S. Mageri, G. Raj, B. Naveenkumar, P. M. Kadakol, and K. Vasu, "Microstructure and Mechanical Properties of Al7075-TiB 2 in-situ composite," *Res. J. Mater. Sci.*, vol. 1, no. 10, pp. 6–10, 2013.
36. R. Karthigeyan, S. Ezhil Vannan, G. Ranganath, S. Paul Vizhian, and K. Annamalai, "Effect of coating parameters on coating morphology of basalt short fiber for reinforcement preparation of al/basalt metal matrix composites," *Int. J. Electrochem. Sci.*, vol. 8, no. 8, pp. 10138–10148, 2013.
37. Kumar, V. Kumar, A. Kumar, B. Nahak, and R. Singh, "Investigation of mechanical and tribological performance of marble dust 7075 aluminium alloy composites," *Mater. Today*

Proc., vol. 44, pp. 4542–4547, 2020, doi: 10.1016/j.matpr.2020.10.812.

38. Hariharan Vaggeeram, V. Mohankumar, and P. Gnaneswaran, “A Review on Tribological And Mechanical Behaviors of Aluminium Metal Matrix CompositesTitle,” *Int. J. Mech. Eng. Robot*, vol. 2, no. 6, 2014.
39. M. Sambathkumar, P. Navaneethakrishnan, K. S. K. Sasikumar, R. Gukendran, and K. Ponappa, “Investigation of Mechanical and Corrosion Properties of Al 7075/Garnet Metal Matrix Composites By Two-Stage Stir Casting Process,” *Arch. Metall. Mater.*, vol. 66, no. 4, pp. 1123–1129, 2021, doi: 10.24425/amm.2021.136432.
40. S. A. Sajjadi, H. R. Ezatpour, and H. Beygi, “Microstructure and mechanical properties of AlAl2O3 micro and nano composites fabricated by stir casting,” *Mater. Sci. Eng. A*, vol. 528, no. 29–30, pp. 8765–8771, 2011, doi: 10.1016/j.msea.2011.08.052.
41. S. B. Prabu, L. Karunamoorthy, S. Kathiresan, and B. Mohan, “Influence of stirring speed and stirring time on distribution of particles in cast metal matrix composite,” *J. Mater. Process. Technol.*, vol. 171, no. 2, pp. 268–273, 2006, doi: 10.1016/j.jmatprotec. 2005.06.071.
42. T. P. D. Rajan, R. M. Pillai, B. C. Pai, K. G. Satyanarayana, and P. K. Rohatgi, “Fabrication and characterisation of Al-7Si-0.35Mg/fly ash metal matrix composites processed by different stir casting routes,” *Compos. Sci. Technol.*, vol. 67, no. 15–16, pp. 3369–3377, 2007, doi: 10.1016/j. compscitech.2007.03.028.
43. S. Gopalakrishnan and N. Murugan, “Production and wear characterisation of AA 6061 matrix titanium carbide particulate reinforced composite by enhanced stir casting method,” *Compos. Part B Eng.*, vol. 43, no. 2, pp. 302–308, 2012, doi: 10.1016/j. compositesb.2011.08.049.
44. M. Raei, M. Panjepour, and M. Meratian, “Effect of stirring speed and time on microstructure and mechanical properties of Cast Al–Ti–Zr–B4C composite produced by stir casting,” *Russ. J. Non-Ferrous Met.*, vol. 57, no. 4, pp. 347–360, 2016, doi: 10.3103 /S1067821216040088.
45. R. A. Kumar, A. Devaraju, and S. Arunkumar, “Experimental Investigation on Mechanical Behaviour and Wear Parameters of TiC and Graphite Reinforced Aluminium Hybrid Composites,” *Mater. Today Proc.*, vol. 5, no. 6, pp. 14244–14251, 2018, doi: 10.1016 /j.matpr.2018.03.005.
46. M. Ayyanar Raja, V. Manikandan, P. Amuthakkannan, S. Rajesh, and I. Balasubramanian, “Wear resistance of basalt particulate-reinforced stir-cast Al7075 metal matrix composites,” *J. Aust. Ceram. Soc.*, vol. 54, no. 1, pp. 119–128, 2018, doi: 10.1007 /s41779-017-0133-8.
47. M. K. Sahu and R. K. Sahu, “Optimization of Stirring Parameters Using CFD Simulations for HAMCs Synthesis by Stir Casting Process,” *Trans. Indian Inst. Met.*, vol. 70, no. 10, pp. 2563–2570, 2017, doi: 10.1007 /s12666-017-1119-5.
48. S. M. L. Nai and M. Gupta, “Influence of stirring speed on the synthesis of Al/SiC based functionally gradient materials,” *Compos. Struct.*, vol. 57, no. 1–4, pp. 227–233, 2002, doi: 10.1016/S0263-8223(02)00089-2.
49. S. Rajesh, R. S. Kumar, S. Madhankumar, M. Sheshan, M. Vignesh, and R. S. Kumar, “Study of the mechanical properties of Al7075 alloy, silicon carbide and fly ash composites manufactured by stir casting technique,” *Mater. Today Proc.*, vol. 45, pp. 6438–6443, 2020, doi: 10.1016 /j.matpr. 2020. 11.278.
50. Elsayed, A. Nofal, and G. Attia, “Optimization of stir casting process parameters for producing mmc aluminum sacrificial anode incorporated with manganese dioxide concentrate powder,” *Int. J. Eng. Res. Technol.*, vol. 13, no. 10, pp. 2651–2659, 2020, doi: 10.37624/IJERT /13.10.2020.2651-2659.
51. M. Singla, D. D. Dwivedi, L. Singh, and V. Chawla, “Development of Aluminium Based Silicon Carbide Particulate Metal Matrix Composite,” *J. Miner. Mater. Charact. Eng.*, vol. 08, no. 06, pp. 455–467, 2009, doi: 10.4236/jmmce.2009.86040.
52. Raturi, K. K. S. Mer, and P. Kumar Pant, “Synthesis and characterization of mechanical, tribological and micro structural behaviour of Al 7075 matrix reinforced with nano Al2O3 particles,” *Mater. Today Proc.*, vol. 4, no. 2, pp. 2645–2658, 2017, doi: 10.1016/j.matpr.2017.02.139.
53. R. Pramod, G. B. Veeresh Kumar, P. S. S. Gouda, and A. T. Mathew, “A Study on the Al2O3 reinforced Al7075 Metal Matrix Composites Wear behavior using Artificial Neural Networks,” *Mater. Today Proc.*, vol.

5, no. 5, pp. 11376–11385, 2018, doi:10.1016 /j.matpr.2018.02.105.
54. C. Sri, S. Saravanamurugan, A. Shanmugasun daram, and S. Mohapatra, "Effect of SiC and Gr particles on the mechanical properties and dynamic characteristics of AA 7075 hybrid metal matrix composite," in *Materials Today: Proceedings*, 2021, vol. 46, pp. 390–398, doi:
55. 10.1016/j.matpr.2020.09.217.
56. Sridhar and K. P. Lakshmi, "Evaluation of mechanical and wear properties of aluminum 7075 alloy hybrid nanocomposites with the additions of SiC/Graphite," *Mater. Today Proc.*, vol. 44, pp. 2653–2657, 2021, doi: 10.1016/j.matpr.2020.12.675.
57. K. Maruthi Varun and R. Raman Goud, "Investigation of mechanical properties of Al 7075/SiC/MoS2 hybrid composite," *Mater. Today Proc.*, vol. 19, no. xxxx, pp. 787–791, 2019, doi: 10.1016/j.matpr.2019.08.131.
58. V. C. Uvaraja and N. Natarajan, "Optimization of Friction and Wear Behaviour in Hybrid Metal Matrix Composites Using Taguchi Technique," *J. Miner. Mater. Charact. Eng.*, vol. 11, no. 08, pp. 757–768, 2012, doi: 10.4236 /jmmce. 2012.118063.
59. B. Jayendra, D. Sumanth, G. Dinesh, and M. Venkateswara Rao, "Mechanical Characterization of Stir Cast Al-7075/B 4 C/Graphite Reinforced Hybrid Metal Matrix Composites," 2020. [Online]. Available: www.sciencedirect.comwww.materialstoday. com/proceedings.
60. S. Arun Kumar, J. Hari Vignesh, and S. Paul Joshua, "Investigating the effect of porosity on aluminium 7075 alloy reinforced with silicon nitride (Si3N4) metal matrix composites through STIR casting process," *Mater. Today Proc.*, vol. 39, no. xxxx, pp. 414–419, 2020, doi: 10.1016/j.matpr. 2020.07.690.
61. B. P. Sahoo, D. Das, and A. K. Chaubey, "Strengthening mechanisms and modelling of mechanical properties of submicron-TiB2 particulate reinforced Al 7075 metal matrix composites," *Mater. Sci. Eng. A*, vol. 825, no. June, p. 141873, 2021, doi: 10.1016/j.msea. 2021.141873.
62. M. V. Raja and K. Manonmani, "Mechanical and Tribological Characteristics of Aluminium Hybrid Composites Reinforced With Boron Carbide and Titanium Diboride," *Ceram. - Silikaty*, vol. 66, no. 3, pp. 396–406, 2022, doi: 10.13168/cs.2022.0035.
63. N. A. Mahbubah, M. Nuruddin, S. S. Dahda, D. Andesta, and E. Ismiyah, "Optimization of CNC Turning Parameters for cutting Al6061 to Achieve Good Surface Roughness Based on Taguchi Method," vol. 1, no. 1, pp. 1–9, 2022.