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Study on Developments in the Aluminum Metal Matrix Composites using Different Reinforcement Particles

Ratna Deepika Manikonda[1], M.B.S. Sreekara Reddy[2] and Arul Raj K.[3]
[1]Research Scholar, Department of Mechanical Engineering, KLEF, Guntur, India.
[2]Associate Professor, Department of Mechanical Engineering, KLEF, Guntur, India.
[3]Professor, Department of Mechanical Engineering, Einstein college of Engineering, Tamilnadu, India.
(Corresponding author: Ratna Deepika Manikonda)
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ABSTRACT: The importance and value of composites materials as engineering construction materials is expressed in reality by various researchers in past. More than 200 from 1600 technological processes currently accessible in the market are also for composite materials. The analysis of various metal alloys and other type of alloys with contaminants and chemical impurities are already addressed in the various research investigations. This paper investigates the impact of silicon carbide on aluminium metal casting composite material. Aluminium Metal already lies in an advanced category of material used in aerospace, automotive, construction, underwater equipment's, and infrastructure devices. In this context, several investigators and experts have reviewed a numerous characteristic of the mechanical and physical performance. In this investigation silicon carbide enhanced Aluminum mechanical properties and its material composites is studied to determine the impact of this material on various properties. Al2014 has been shown to be useable with matrix material in almost studies when any research scientist examines the combination. Characteristics including certain wear and friction can be investigated through further experiments in the research project.

Keywords: Aluminium, silicon, metal matrix, reinforcement

Abbreviations: AMCs, Aluminum metal matrix; MMC, metal matrix composites.

I. INTRODUCTION

From the last several decades metal matrix composites (MMCs) have been main area of interest in many business sectors and companies. Previous works on MMCs focuses on the improvement in wide range of materials and its property. The article focuses mainly on mechanical characteristics and chemical composition of different MMCs. This is done in order to extend the applications of MMCs in various fields and for further eliminating conventional energy sources. Aluminium matrix composites also known as AMCs, are particularly used in aerospace and automobile companies. Machine block and aircraft engines, favors the use of MMCs due to their decreased density, high quality, durability, high resistance, and excellent tensile strength [1]. Aluminium and its alloys differ according to structure and quality while experimental implementations are performed on them. Various advanced methods have already been employed in past to improve the MMCs for different applications. The numerous different aluminium alloys and their widely accepted use of alloy are summarized in Table 1.

A. Theory

The objective and target of this research article is to choose aluminium metal for stronger sticky wear and to strengthen the wear dry sliding contaminants and toxins. A hypothesis of moving velocity, regular carry the density of the material described by Archard wear pressure as [2].

Archard developed the following expression for wear rate, W (volume of material worn):

$$W = \frac{KdP}{3H}$$

Where K = wear coefficient, d = sliding distance, P = applied normal load and H = bulk hardness of the material.

The hypothesis anticipated improvement and boost in wear strength and its toughness. Table 1. Illustrates numerous aluminum alloy along with their major applications and uses in the industries.

B. Manufacturing process

Strengthening and hardening process are executed in solid form or liquid phases (such as with powder metal casting). LSMs which are also known as liquid state methods have been used frequently in past studies. It is used for mechanical alloying, spray casting, and squeeze casting due to their technological and economic advantages in producing huge quantities [4]. SiC, B_4C, Al_2O_3, graphite, fly-ash etc. are some of the normally utilized strengthening materials [5]. It is indicated and stated in Table 2 shows that it is simple to produce most of the substance of aluminium alloy with different materials. Materials with their detailed properties are enlisted in the table for their selection. For delicate content, higher poison ratio is being used and with a strong matter the low ratio proportion was being used. SiC's poison ratio is 0.14 smaller than other materials demonstrated in Table 2. The toughness quality of materials is shown by this enhancement.

Table 3 summarizes the characteristics of the different chemicals for composite material of Alloy. Various Al Alloys with their chemical composition are enlisted in the table.

The characteristics of the various materials and chemical structure of the design depends on the composition of that material. Table 4 shown below shows various material used as an impurity for the composition of alloy with their abilities. These researches also revealed their applications according to their abilities. Work has already shown that mixing silicone or ceramic components to the aluminium results in outstanding composite efficiency.

The numerous contaminants in AMCs are listed in table 5 below. It is also mentioned to demonstrate the modifying strength and to improve its property with the latest composites produced. The usage of concrete and structural graphite has self-lubricating characteristics as Gr molecules are used as an lubrication in various applications. Graphiteis recognized among the strong lubricants in the product composition. SiC particles provide a reliably high toughness and outstanding thermal shock strength durability performance.

Table 1: Aluminium Alloy and their common use.

Aluminum Alloy	Common Use
1050/1200	Food and Chemical Industry
2014	Airframes
5251/5052	Vehicle panelling, structures exposed to marine atmospheres, mine cages.
6063	Architectural extrusions (internal and external) window frames, irrigation pipes.
6061/6082	Stressed structural members, bridge cranes, roof 6061/6082 trusses, beer barrels.
7075	Armoured vehicles, military bridges motor cycle and bicycle frames.
LM25	Applications of these composites are found in engine components like piston and cylindrical

Table 2: Mechanical property of materials.

Material	Density (kg/m3)	Tensile strength (MPa)	Melting point (ºC)	Poison ratio	Young's module	Source
6061-T6	2700	310	580℃	0.33	70	[19, 20, 21]
Graphite	1950	76	3800	0.21	12	[22]
Boron carbide	2550	500	3500	0.17	460	[22]
Graphene	2000				130	[7]
SiC	3100		2200-2700ºC	0.14		[23]
Al_2O_3	3690		2072ºC	0.21		[17, 23]
Pure Aluminium	2700	77				[24]
7075	2640	572		0.33	71.7	[25]

Table 3: Composition of chemical composition Al alloy.

Alloy	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al	Reference
6061	0.65	0.7	0.25	0.15	0.9	0.07	0.25	0.15	Rem.	[17]
2014	0.8	-	4.4	0.5	0.6	0.1	-	-	Rem.	[14]
6063	0.2-0.6	0.35	0.10	0.10	0.45-0.9	0.10	0.10	0.10	Rem.	[6]
A356	0.7	0.15	0.20	0.10	0.35	0.05	0.10	0.20	Rem.	[12]
LM25	7.33	0.43	0.10	0.09	0.38	-	0.07	-	Rem.	[10]
7075	0.07	0.18	1.4	0.04	2.4	0.18	5.8	0.06	Rem.	[4]

Table 4: Impurities and their impact.

Impurities	Ability	Author
Copper	Due to its capacity to rapidly evaporate heat	[6]
Gun metal	Its ability to with stand stresses.	[6]
TiO_2	Reduces the wear rate at room temperature.	
Boron carbide (B_4C)	After diamond and boron nitride, the third strongest material (3800 HV) has attractive mechanical characteristics such as high resistance; limited volume, extremely high strength, and excellent chemical and thermal stability are therefore classified and including SiC and Al_2O_3 for potential reinforcement.	[1]
SiC	Substances provide a relatively homogeneous strengthening production in the matrix with good consistency and outstanding temperature resistance	[27]
Zirconia	Zirconia, due to its excellent mechanical strength of character to break, it is one of the essential ceramics which is used as a bio and micro material. Graphite	[28]
Graphite	Self-lubricating properties, high strength, high hardness and excellent thermal shock resistance.	[14, 28]

Table 5: Impurities and their impact

AA+Impurities	Manufacturing process	Stirring speed	Temperature	
Al-SiC-Gr	Stir casting	450 rpm	800-850ºC	[12]
AA6061–B_4C	Squeeze casting	250 rpm	850ºC	[1]
LM25 + SiC & TiO_2	Stir casting	400 rpm	800-850ºC	[13]
Al2014+ B_4C	Stir casting	300 rpm	850ºC	[14]
Al 45+SiC	Powder injection	400 rpm	605ºC	[29]
Al-Si10Mg	Stir casting	350 rpm	700 ºC	[30]
Al+ ZIRCONIA	Stir casting	350 rpm	750ºC	[10]
7075+Si_3N_4	Stir casting	250 rpm	950ºC	[4]
AA6061 + Fly ash	Compo casting	500 rpm	610ºC	[18]

This indicates that the new compound and matrix will achieve excellent wear resistance and stiffness if silicon is applied to an aluminium base. Moreover, the substance may be used for dry sliding conditions with an aluminium foundation owing to the self-greasing properties of graphite.

II. LITERATURE REVIEWS

In the previous years, a number of studies were carried out mixing aluminium alloys with ideal contaminants to boost their performance. In the investigation of materials new combinations of impurities with base materials resulted in greater improvements of mechanical, chemical and microstructural properties. This material can greatly benefit to a lot of real life applications. Various researches in the past have been performed using different materials and techniques. It is done to present a suitable composition of material which can be readily used for real time applications. In a study Al 6063 is used as a base material. Impurities like copper and gun metal were added for further mechanical testing like hardness tensile strength which were done to find the outcome of this material composition. It was found from the study that when copper and gun metal powder were added in the Al 6063 base material tensile strength of material showed around 25% of improvement [6]. In another research study Titanium Oxide was used as an impurity with AA5050. This showed a higher growth in the tensile strength of composite material formed showing the better bonding capacity of material. Also the hardness of the composite material was improved by 16% [6]. Among various other research studies Al 2014 was mixed with Natural graphite particles [16], Ti_5Si_3-coated SiC_P [15], B_4C [14] and showed an improvement in electrical conductivity making its suitable for electrical applications [16], also there was better dispersion of particles and enhancement in interfacial bonding of Al 2014 with coating of SiC_P [15]. B_4C combined to form Al-B_4C composite showed high tensile and hardness for mechanical applications [14]. Aluminium LM25 alloy was considered in various studies and showed outstanding results in combinations with zirconia [10] SiC & TiO_2 [13]. In the study with LM25 & Zirconia results showed that wear rate has direct variation with applied load. Inverse variation with sliding distance and sliding velocity [10] while in combination of LM25 with SiC & TiO_2 coefficient of friction decreases with an increase in the particle reinforcement and load (for the fixed-sized SiC and TiO_2 particulates) [13]. B_4C when combined with AA6061 showed that when B4C amount is increased and squeeze pressure increases the hardness of the samples. This is due to the hardness of the B4C particles and improved densification, respectively [1]. The optical micrographs of composites produced by stir casting method shows fairly uniform distribution of SiC particulates in the 6061 Al alloy matrix [15]. In comparison from other studies, the SiC substance is not achieved with Al2014. This thus contains a number of studies to examine the characteristics of SiC particles in Al2014.

A. Parameter selection during casting process

Composite materials of the metal matrix are widely recognized as an extremely successful approach, presently it is professionally performed. The benefits of this would be its usability, versatility, and potential applications to broad output volumes. It is also desirable since it can be used in a traditional system of metallurgical processes and thereby significantly reduces the product's final expense [27]. The table below demonstrates that the method used is the stir casting technique in about each combination is also known to be the most suitable process for manufacturing composites. A high range of temperature can be utilized in this process as seen in the above table. This is the most frequently used method in the field of AMCs due to its flexibility and cost utilization. There are some of the influential and commercial paths for the production and manufacturing of composite materials. This makes the stir casting process, most suitable process for aluminium-based casting substances. These materials have a wide range of material properties as well as matrix enhancement variety. Particularly in comparison to other analytical methods, stir casting is extremely straightforward and less expansive. The features of the cast composites are also demonstrated to rely upon the consistency, weighting, and low casting deficiencies of dispersoids [31]. From the above table materials preheating temperatures can be determined and can be further selected according to their applications. Before combining the reinforcement content, the heating process is a major phase in production. The attachment characteristics of the strengthening and matrix components are consistently enhanced during preheating. The intensity for pre-heating is normally 600℃ to 1000℃. Originally heating and pouring the impurity or reinforcing content through a handle, the base metal matrix is formed in a molten state.

Table 6: Preheating temperature of different material.

Material	Preheating temperature	Reference
Silicon carbide	1000ºC	[12]
LM25	825ºC	[13]
Boron carbide	450ºC	[32]
Al-Mg	300-400ºC	[29]
ZIRCONIA	700ºC	
Alumina	700ºC	[33]

The difference in temperature influences the composition of the material and the application of the freshly developed substance. The heating process thus plays an important part in the measurement of friction or usage of any composite material [34]. A higher performance was observed in the samples at the testing of hardness, tensile strength and ductility. At higher temperature 1400^{o}C impurities mixes very well with Al6061. As a result it showed high mechanical characteristics [35]. When AL-7075 mixed at different proportion of SiC+Al_2O_3 a gradual increment in hardness and wear characteristics was seen till 10%. After further increasing the percentage there was a decrease in the harness as result of excess SiC+Al_2O_3 and week intermolecular bonding. Al 2014 when mixed with different percentage of Al- B_4C-Gr showed the best outcome at 1% as compared to other samples prepared with mixing 1.5% and 2% of Al- B_4C-Gr [14]. Flyash also increases the wear characteristics of aluminium alloys as in a study it was shown that 10%, 15% and 20% of flyash was added to the Al 6061 resulted in the increase of hardness in the samples [36].

III. CONCLUSION

Composite materials in aluminium matrix metal composites are widely acceptable. It is because of their absolutely vital properties, such as high hardness, low density, and good wear resistance in comparison to every other material. It is highly used in electric vehicles, aeronautics and for many other industrial uses. There were efforts to examine the various composite material mixtures and how they impact the characteristics of the aluminium. In order to include an overall assessment of composite material, the strongest and successful findings will be used for the future production of the strengthened compound of aluminium. Thorough information is also given for their proprieties. The key finding is that Al2014 in conjunction with SiC may be used further to shape a modern composite substance. The results were presented and that was shown in the literature. This type of matrix and reinforcement was not examined for characteristics like tensile strength, wear, or vibration. The research reveals that composite materials of the Al product matrix may be substituted with other regular metals to improve efficiency and higher quality of life.

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