

A Review on Effect of Reinforcement Particles on the Mechanical Properties of Aluminium Based Composites

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ABSTRACT: This review considers the most important use and applications of aluminium because of its advanced properties like low density, ductility, electrical and thermal conductivity. Initially significant properties are discovered which investigate use of aluminium in numerous industrial applications observing the limitations in mind. So the composite materials fabricated by a number of methods like stir casting, powder metallurgy, squeeze casting, compo-casting by introducing different reinforcement particles are the healthier substitute with aluminium. In this literature improvement in mechanical properties like hardness, tensile strength, elongation and impact strength are reviewed of a number of researchers.

KEYWORDS: Composites, Aluminium, Hardness, Tensile strength, reinforcement.

I. INTRODUCTION

The growth of metal matrix composites (MMCs) has been one of the main innovations in the field of material science in the past 20 years [1]. The term Metal Matrix Composite (MMC) covers various types of system, and also a broad range of scales and microstructures. Common to them all is a metallic matrix, which is usually contiguous [2]. Though, while polymer matrix composites have obviously moved into commercial applications, the road to the application of metal matrix composites is meticulous when casting methods are employed, has been long and progress is slow. This is because of numerous troubles encountered in their processing and the lack of coherency in growth by the researcher and the manufacturers [3]. In AMCs one of the element is aluminium/aluminium alloy, which forms percolating arrangement and is known as matrix phase. The other constituent is mixed in this aluminium/aluminium alloy matrix and serves as reinforcement particles, which is generally non-metallic and generally ceramic such as SiC and Al₂O₃. Properties of AMCs can be customized by altering the nature of constituents and their volume fraction [4]. Al- alloy based composites have concerned attentions because of their processing flexibility, low density, high wear resistance, heat treatment capability and better elastic modulus and strength [5]. AMCs are manufactured by introducing reinforcement particles like SiC, B₄C, and Al₂O₃ with particle size of micron or nano-scale into Al-alloy matrix [6].

II. RELATED WORK

MATERIALS

A number of matrix cast aluminium alloy are used to manufacture composites based on different reinforcement particles depends on their applications in industries. Aluminium A356, A359 and A6061 are mostly used because of their application in defence, military, automobiles and general engineering purposes. The chemical compositions are given in table 1

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Table 1: Chemical composition of aluminium A356, A359 and A6061 [7, 8, 9]

Alloy	Si (%)	Zn (%)	Mn (%)	Fe (%)	Cu (%)	Mg (%)	Ti (%)	Ni (%)	Cr (%)
A356	7.2	0.02	0.35	0.12	0.01	0.02	0.01	0.04	
A359	8.5	0.1	0.1	0.2	0.2	0.5	0.2		
A6061	0.8		0.15	0.7		1.2	0.15		0.35

METHODS

Composite materials with a metal matrix are fabricated by casting and powder metallurgy route. By means of casting methods, composite materials reinforced by dispersion particles, platelets, non-continuous (short) fibres and continuous (long) fibres as well as composite materials with hybrid reinforcement composed of particles and fibres are manufactured. By powder metallurgy methods, composite materials reinforced by dispersion particles, platelets, non-continuous fibres and continuous fibres are manufactured [10,11].

1. Fabrication of composite materials by casting methods: Through mixing of reinforcing particles in molten matrix are produced composite materials reinforced by dispersion particles and short fibres. Usually incorporation method is performed under atmospheric pressure and reinforcing particles should be characterised by fine wettability by the molten metal alloy. Currently the most common route for fabrication of composites by casting are stir casting, squeeze casting, compocasting [12,13].

2. Fabrication of composite materials by powder metallurgy: Powder metallurgy routes are based on the conventional mixing of matrix powders and reinforcing particles and additional cold pressing and sintering followed by plastic working. Cold plastic working is usually functional when a green part is initial sintered and hot plastic working occurs when only cold pressing is applied [14]. A comparison of different fabrication methods are given in table 2

Table 2: Comparative evaluations of the different techniques used for MMCs fabrication [12,13,15]

Method	Range of shape and size	Range of volume fraction	Damage to reinforcement	Cost
Liquid metallurgy (Stir casting)	Wide range of shapes; up to 500 kg	Up to 0.3	No damage	Least expensive
Squeeze casting	Limited to perform shape	Up to 0.45	Severe damage	Moderately expensive
Powder metallurgy	Wide range; restricted size		Reinforcement fracture	expensive
Spray casting	Limited shape; large size	0.3-0.7		expensive

III. EFFECT OF REINFORCEMENT ON MECHANICAL PROPERTIES

1. EFFECT ON HARDNESS OF ALUMINIUM ALLOY:

The hardness of the aluminium have been considerably increased by the addition of CNTs [16]. It could moderately be recognized in the decrease in the grain size of A356 matrix of the composite materials. This figure described that hardness of composite samples have been considerably developed by casting in the semi-solid state. It is recognized that higher density, less gas and shrinkage is moulded in the compo-cast samples. The composite casting of A356-CNT with 0.3 solid fraction yields highest hardness [16].

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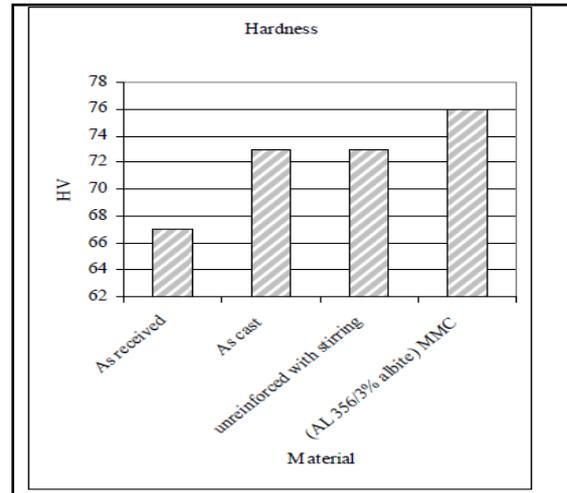
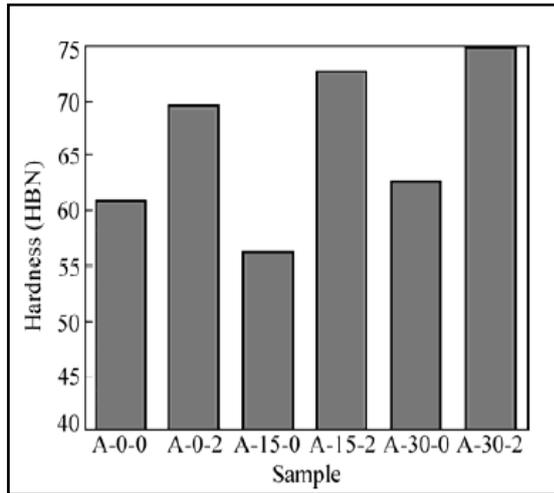


Fig1. Brinell hardness of Al with CNT particles [16] Fig 2. Vickers hardness graph Al A356 + albite composites [17]

The results of Vickers hardness results is shown in figure 2 when aluminium is reinforced with 3 wt. % albite [17]. An individual result is an average of 7 readings. A small increase in HV of (A356-3% Albite) MMC 's specified, 4 % more than unreinforced alloy where as hardness test showed on micro-hardness scale. The increment might be due to using of big particle size (90-150micro metre). It was observed that due to presence of Albite dispersions into the matrix alloy there is minor growth in hardness [17].

Increment in hardness of aluminium with purity of > 98% was observed when reinforced with 2, 5 and 10wt% of AlN. A remarkable growth in hardness of alloy matrix has seen with the addition of AlN reinforced powder [18]. It is shown in table 3.

Table 3: values of Al matrix and Al/AlN composites with 2-10% wt AlN at room temperature [18]

MATERIALS	HARDNESS VALUE (BHN)
Pure Al alloy	44 ± 7
Al-2% AlN	59 ± 3
Al-5% AlN	67 ± 5
Al-10% AlN	94 ± 5

The reading showed the higher value of hardness which indicates that the occurrence of particles in the matrix improved the on the whole hardness of the composites. Since aluminium is a soft material, property of hardness of reinforcement partilcles adds entirely to the hardness of composites. The enhancement in the hardness of composites has seen due to the dispersion of aluminium nitride particles close to Si phase [18].

Hardness of composites is reasonably large than that of A356 matrix when reinforced with nano- sized Al₂O₃-10% ZrO₂ [19]. The reason behind this was the existence of hard Al₂O₃-10% ZrO₂ nano particles. As the proportion was increased to 1wt% Al₂O₃-10% ZrO₂ the property of hardness was increased contrary the hardness of the samples

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containing proportion of 1.5 and 2 wt% of Al₂O₃-10% ZrO₂ decreased. This happened due to heterogeneous allocation of nano-particles and high porosity content. These results have been taken by the average of indentations. This indentations were carried out in different regions which might have contained no or low contents of reinforcing units or high porosity volumes [19].

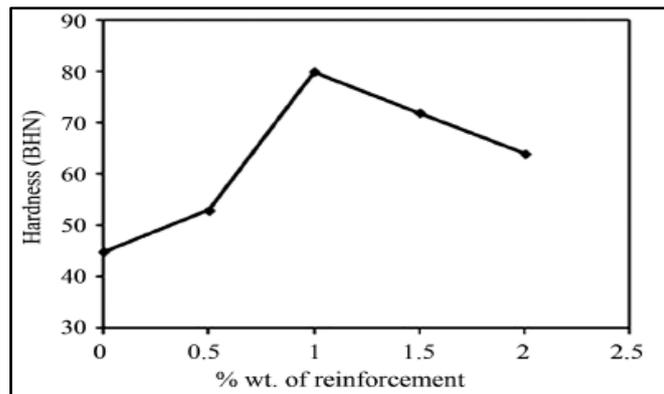


Fig 3: Measured values of hardness (BHN) vs. weight percentage of Al₂O₃-10% ZrO₂ for fabricated composites [19]

With the addition of % alumina the hardness was found to be 72 BHN that is 7.5% increased over the unreinforced alloy A6061. With the addition of Al₂O₃ particles it lead to notable increased in hardness. Overall hardness of the composites has got improved because attendance of the particulates in the matrix. The property of softness of aluminium and hardness property of reinforced particle particularly ceramic material lead to definitely hardness of the composites [20].

2. EFFECT ON TENSILE STRENGTH OF ALUMINIUM ALLOY:

Tensile and compressive strength tests are performs on Al specimens and composites by means of a computerized UTM testing machine as per the ASTM E-8 standards. Increased in tensile strength were observed when 99.5 % pure aluminium ingot is reinforced with flyash of particle size of 50-100µm [21].

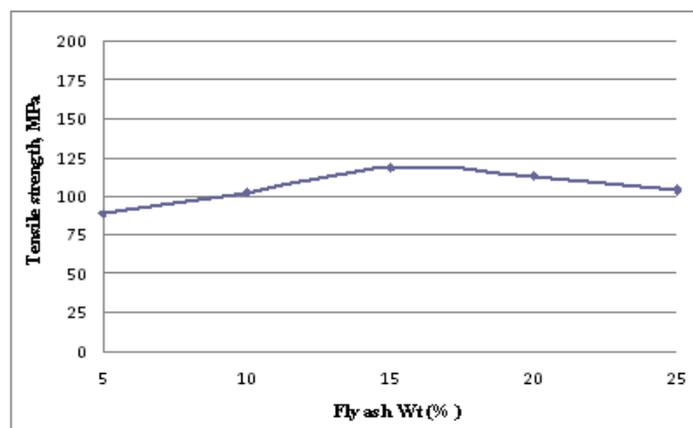


Fig. 4 Tensile strength of the Composites at various Wt% of fly ash particles [21]

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Tensile strength of unreinforced Al was observed 77 MPa and increase in tensile strength were observed to a maximum of 113MPa when reinforced with 15 wt% fly ash composite which is about 35% progress more than that of the unreinforced Al. matrix. When the fly ash wt. % increased from 20% to 25%, tensile strength decreased from 113 MPa to 104 MPa. It was observed possibly because of clustering of the reinforcement particles the composites having more than 15wt% of fly ash particles and rate of increase in tensile strength decreased notably [21].

Tensile strength of aluminum A356 was increased from 45 to 62 MPa when reinforced with fly ash 3 to 12.5 vol% which is much higher than that of base alloy (27.5 MPa) at 315 °C. The high temperature tensile strength decreased to some extent with increased fly ash content from 3 vol% to 12.5 vol% [b]. Additions of 8 vol% fly ash decreased the room temperature tensile strength of A356 by a magnitude of 28.9 MPa additions of fly ash lower than 8 vol% resulted in even lower decreased in strength [22].

Tensile strength of aluminium A356 increase when reinforced with 3 wt. % of AlN [c]. The average UTS altered from 102.5 MPa for the commercial conventional A356 alloy to 160 MPa for as cast alloy to 170 MPa with applying stirring into cast alloy to 200 MPa with 3% Albite addition . On the other hand the elongation % altered from 2 % for the received A356 alloy to 6% for both as cast and stirred alloy, and 7.5% with Albite addition [18].

The tensile strength of aluminium copper alloy increased with increase in percentage of flyash and SiC particles. Smaller cross-section castings showed more tensile strength than larger cross sections. This may be due to faster heat transfer from the mould resulting in finer grain structure of the castings [23].

3. EFFECT ON COMPRESSIVE STRENGTH OF ALUMINIUM ALLOY:

Compressive strength of aluminium alloy was increased when reinforced with 3% albite. Compressive yield values, (stress or strain) was increased in both cast as well as cast stirred alloy over the commercial alloy. Yet added enhancement have been achieved by adding particles to 150% for CYS and 157% for corresponding strain to that of commercial alloy. Achievement of high compressive yield strength and corresponding strain was observed in (A356-3%Albite) MMC as against unreinforced alloy with 17% and 37.5% [17].

4. EFFECT ON ELONGATION OF ALUMINIUM ALLOY:

Elongation of aluminium decreased with addition the 4 wt. % of reinforcement particle when reinforced with mono (SiC or Al₂O₃) and hybrid composites (SiC + Al₂O₃) [24]. This may be reason of larger agglomeration of reinforcement particles, brittleness and upper degree of micro-porosity there in the composite with higher SiC, Al₂O₃ and (Al₂O₃ + SiC) content. The increased wt. % of particles would reduce the effective slip distance of dislocations in the tensile deformation, which would lead to the reduce of the elongation. But in case of Al₂O₃ % elongation decreased at 12 wt. %. may be the result of greater agglomeration of particles [24].

Ductile property of a metal could be measured by the elongation or strain at definite point in the stress-strain curve. To analyse the effect of yttrium on the ductility of A356 strain at fracture is taken into attention. The tensile strain of original unprocessed alloy is 0.064. On the addition of TiB grain refiner which contain 0.1 wt% Ti and 0.02 wt% B, there is no significant improvement in ductility while its tensile strain is 0.069. With the addition of 0.1 to 0.5 wt%, there is a slow growth of tensile strain to the maximum value of 0.076 at 0.3 wt% yttrium. Continuous improvement in ductility is not seen on addition of yttrium exceeding 0.3wt% [25].

IV. CONCLUSION

For special application in military, defence, automobile and general engineering applications aluminium should have achieved certain properties like high hardness, high stiffness, high tensile strength. These properties can be altered by fabricating the aluminium composites by different fabrication routes like casting routes and powder metallurgy routes. So this literature covers the different routes and the effect of different ceramic particles on mechanical properties of

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aluminium. And from the literatures of different researchers we got to know that mechanical properties improves appreciably with increase in reinforcement particles.

REFERENCES

- [1] D. J. Lloyd, "Particle reinforced aluminium and magnesium matrix composites", International Materials Reviews 1994 Vol. 39 No.1.
- [2] T.W.Clyne, "Metal Matrix Composites: Matrices and Processing", Encyclopaedia of Materials: Science and Technology, Elsevier, 2001.
- [3] Mohamed A. Taha, "Practicalization of cast metal matrix compositesžMMCCs/ Mohamed A", Materials and Design 22Ž2001.431- 441.
- [4] M K SURAPPA, "Aluminium matrix composites: Challenges and opportunities", Sadhana Vol. 28, Parts 1 & 2, February/April 2003, pp. 319–334.
- [5] K. M. Shorowordi, T. Laoui, A. S. M. A. Haseeb, J. P. Celis and L. Froyen, "Microstructure and Interface Char-acteristics of B4C, SiC and Al2O3 Reinforced Al Matrix Composites: A Comparative Study," Journal of Materials Processing Technology, Vol. 142, 2003, pp.738-743.
- [6] G. Fu, L. Jiang, J. Liu and Y. Wang, "Fabrication and Properties of Al Matrix Composites Strengthened by In-situ Aluminum Particulates," Journal of University of Science and Technology Beijing, Vol. 13, No. 3, 2006, pp. 263-266.
- [7] Abhishek Kumar, Shyam Lal, Sudhir Kumar, "Fabrication and characterization of A359/Al2O3 metal matrix composite using electromagnetic stir casting method", j mater res technol. 2013;2(3):250–254.
- [8] S. Gopalakrishnan a, N. Murugan, "Production and wear characterization of AA 6061 matrix titanium carbide particulate reinforced composite by enhanced stir casting method", Composites: Part B 43 (2012) 302–308.
- [9] S.A. Sajjadi, H.R. Ezatpour , M. Torabi Parizi, "Comparison of microstructure and mechanical properties of A356 aluminum alloy/Al2O3 composites fabricated by stir and compo-casting processes", Materials and Design 34 (2012) 106–111.
- [10] S.F. Corbin, D.S. Wilkonson, The tensile properties of a particulate reinforced Al alloy in the temperature range 196±300 0C, Canad. Metall. Quart. 35 (1996) 189-198.
- [11] K.U. Kainer, Cast magnesium alloys reinforced by short Fibres, in: Proceedings of the International Conference on Magnesium Alloys and their Applications, Garmisch-Partenkirchen, DGM Informationsgesellschaft, Oberursel, 1992, pp. 415-422.
- [12] W. Ames, A.T. Alpas, Wear mechanisms in hybrid composites of graphite-20% SiC in A356 aluminium alloy (Al-7% Si-0.3% Mg), Metall. Mater. Trans. A 26 (1995) 85-98.
- [13] S. Skolianos, Mechanical behaviour of cast SiCp reinforced Al+4.5%Cu+1.5%Mg alloy, Mater. Sci. Eng. A 210 (1996) 76-82.
- [14] H. Kehler, R. Bode, H. Haddenhorst, PartikelverstaErkte Leichtmetalle, Metall 49 (1995) 191-195.
- [15] Muhammad Hayat Jokhio*, Muhammad Ibrahim Panhwar**, AND MUKHTIAR ALI UNAR, "Manufacturing of Aluminum Composite Material Using Stir Casting Process", Mehran university research journal of engineering & technology, volume 30, no. 1, january, 2011.
- [16] B. ABBASIPOUR, B. NIROUMAND, S. M. MONIR VAGHEFI, "Compcasting of A356-CNT composite", Trans. Nonferrous Met. Soc. China 20(2010) 1561-1566.
- [17] N. E. Elzayady, R. M. Rashad, and A. Elhabak , "Mechanical Behavior of A356/Albite Composite Material" , Journal of American Science 2012;8(6).
- [18] M. N. Wahab, A. R. Daud and M. J. Ghazali, "Preparation and characterization of stir cast-aluminum nitride reinforced aluminum metal matrix composites", International Journal of Mechanical and Materials Engineering (IJMME), Vol. 4 (2009), No. 2, 115-117.
- [19] Mohsen Hajizamani, HamidrezaBaharvandi, "Fabrication and Studying the Mechanical Properties of A356 Alloy Reinforced with Al2O3-10% Vol. ZrO2 Nanoparticles through Stir Casting", Advances in Materials Physics and Chemistry, 2011, 1, 26-30.
- [20] MadevaNagaral, BharathV and V Auradi , "Effect of Al2O3 Particles on Mechanical and Wear Properties of 6061al Alloy Metal Matrix Composites", J Material SciEng 2013, 2:1.
- [21] P. Shanmughasundaram, "Some Studies on Aluminium – Fly Ash Composites Fabricated by Two Step Stir Casting Method", European Journal of Scientific Research Vol.63 No.2 (2011), pp.204-218.
- [22] P. K. Rohatgi, "Applications of Fly Ash in Synthesizing Low Cost Metal Matrix Composites for Automotive and other Engineering Applications", JOM, Vol. 58, No. 11, 2006, pp. 71-76.
- [23] K. V. Mahendra and K. Radhakrishna, "Characterization of Stir Cast Al-Cu-(fly ash + SiC) Hybrid Metal Matrix Composites", Journal of Composite Materials, Vol. 0, No. 00/2009.
- [24] Bharat Kumar, Mr. Rohit S. Kamble, Mr. Mehul Chaudhari, Mr. Dhaval J. Darj, "Fabrication and Characterisation of aluminium based SiC and Al2O3 reinforced composites by stir casting", International Journal of Advance Research in Engineering, Science & Technology, Volume 2, Issue 6, June- 2015.
- [25] Y.P. Lim*, J.B. Ooi, X. Wang, " Microstructural and mechanical properties of gravity-die-cast A356 alloy inoculated with yttrium and Al-Ti-B grain refiner simultaneously", Volume 11 Issue 4/2011 77 – 82.