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Depiction of Aluminum-Fly ash hybrid Composites

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ABSTRACT: During revived backgrounds, strengthening metal matrix composites (MMC) with fly ash particulates have brought notable recognition due to their basic monotonous and Morphological response in the economic condition. Fly ash is an unavoidable product of power plant which creates pollution to the environment. Use full utilization of fly ash in MMC reduces the environment pollution. Besides this, fly ash has a low density, therefore by addition of fly ash in MMC results high strength to weight proportion to AMMC. It is collected from thermal power plants in enormous amounts being as solid waste by-product. The utilization of fly ash essentially as reinforcement reduces the requirement of its disposal and inhibits the environmental pollution. The existing article has attempted to proffer a complete record analysis of the overall achievement of these fly ash reinforced composites composed by different manifold methods. The current improve article has characterized into distinctive sections according to the expected execution of aluminum bolstered with fly ash particles such as Physical, microstructure and mechanical properties along with Surface Morphology.

Keywords: AMMC**,** Fly ash, Physical, Microstructure and Mechanical properties, Morphology.

I. INTRODUCTION

Aluminum Metal Matrix Composites (MMC) are leading of interest in various fields due to their attractive properties and among them, aluminum metal matrix composite (AMMC) has a distinctive priority because of its high potency and specific strength to weight proportion. These properties make it possible for its application in aircraft and automotive industries etc. [1-7]. However, these aluminum matrix composites are mainly bolstered with ceramic particles which are quite expensive and sometimes lead to an increase in the weight of composites [8-9]. So, there is a need for replacement of these reinforcements for economic and performance reasons. It is quite evident from the literature that fly ash can do this job in a very efficient manner along with the reduction of environmental pollution caused by it [10-12]. Many researchers till date have attempted various useful works in the field of fly ash reinforced MMC but still more work yet to be done regarding optimization of mechanical and tribological properties of different fly ash reinforced MMC.

A. Fly Ash

Fly ash is an industrial unintended but unavoidable product obtained from the flue gas by burning coal in an electrical power plant. The residue deposited after combustion is a complex substance that is obtained owing to the transform from mineral particles to existing coal particles at the time of combustion [13]. The chemical structure of fly ash changes clinging upon the kind of coal used in burning conditions controlling at the time of combustion as well as the efficiency of removal of air pollution control tool [14-15]. The combustion of sub-bituminous coal and lignite coal generate fly ash of the class C category whereas burning of bituminous coal and anthracite coal produces fly ash of the F class category. The total of Al_2O_3, Fe_2O_3, and SiO_2 with the amount in fly ash is more than 70% (fly ash of F category) along with the CaO less than 5% [16]. The class C category of fly ash is possessing less than 50% of combined SiO_2, Al_2O_3, and Fe_2O_3 with 20%-30% of CaO [16]. The fly ash can also be categorized into two different classes depending upon mass densities titles as cenosphere and precipitators. Cenospheres are hollow spheres having densities of less than 1 gm cm^{-3} (approximately 0.306gm cm^{-3}). These fly ash particles are utilized for the manufacturing of ultra-light composite materials because of their low density. Precipitators are the solid spheres from density ranging from 2.0 g cm^{-3} to 2.5 g cm^{-3}. Adding of precipitator fly ash possesses distinctly developed strength, wears resistance and stiffness in the properties of matrix materials. Coal fly ash is utilized in many advanced industries like cement and concrete. Nowadays fly ash is used for the fabrication of MMCs.

II. LITERATURE REVIEW

A. Ultimate Tensile Strength versus Fly ash (wt. %)

Supplementing fly ash at varying percentages with aluminum alloy under various methodologies to improve the tensile strength of the metal matrix is presented under Fig. [1] by several researchers [20, 21, 24, 28, 30, 31, 38, 39]. However, the reasons for improving the tensile strength of MMC are due to good bonding with a distinct interface within the metal matrix including fly ash as presented by Selvam [24]. The difference in thermal co-efficient (between fly ash and metal matrix) introduced a strain field. Dislocation and refinement of grain are accountable for acquiring more areas in the strain field to arrest crack propagation during tensile loading. Orowan mechanism supports to define the rising of ultimate strength because of the uniform scattering of fly ash throughout the matrix. Narasaraju and Raju have analyzed the mechanical properties

AlSi10Mg aluminum alloy including fly ash and rice husk ash. They have found that tensile strength increases due to poor wettability [28].

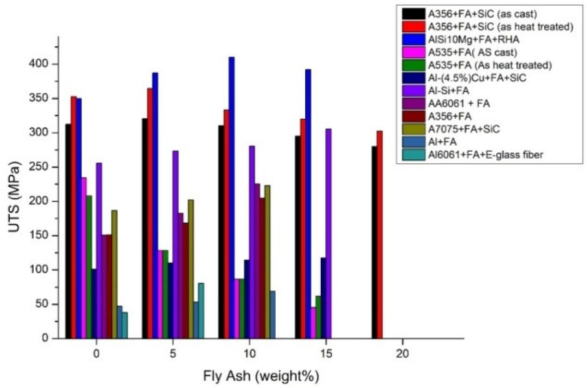

Fig. 1. Ultimate Tensile Strength of Various Aluminum Matrix Composite including weight percentage of fly ash.

Nevertheless, few other researchers [18, 26] observed that the increase of fly ash reduces the ultimate strength in different AMMCs. Gikunoo *et al*., (2005) have conferred their work using A535 alloy with varying composition of fly ash [18]. They presented that the cause of reducing the tensile strength of MMC is due to segregation and non-uniform spread of fly ash adjacent to the boundaries of aluminum dendrite making adverse porosity. Dwivedi *et al*., (2014) investigated their research work using A356 with fly ash by utilizing electromagnetic stir casting. They have taken both casts as well as heat treated MMCs [26]. They observed that at a lower percentage of fly ash, the tensile strength reduces both in a cast and heat-treated MMC as shown in Fig. 1. Nevertheless, tensile strength decreases at a higher percentage, of SiC/fly ash due to work hardening [18, 26]. The clustering about ash particles around the A356 makes the MMC more brittle. All issues of the current investigation are presented covering the following conclusion about the fly ash reinforced AMMC.

– Uniform distribution of fly ash in MMC can avoid segregation and clustering, which results in improvement of the tensile strength.

– Addition of fly ash in a moderate percentage can improve the tensile strength of MMCs

– An increase in percentage of fly ash content in MMC is responsible for increasing porosity which may harden the MMC.

B. Percentage Elongation

The percentage of elongation is an approach to express the ductile behavior of MMC applying for material design. AMMC whose elongation exceeds 5% is termed as ductile material. Fig. 2 is reported for the variation of percentage elongations of diversified AMMC accompanying fly ash over the distinctive Research paper [18, 24, 27, 31, 39]. The increasing in fly ash percentage reduces the rate of elongation for a given MMC as indicated in Fig. 2.

The number of fly ash grains in a distributed AMMC develops the grain boundaries. Therefore, dislocation is moved and disrupted the grain boundaries with the application of external load. Atomic planes are approaching closer and closer due to internal resisting force and the AMMC changes its behavior from ductility to brittleness. Besides that, the percentage elongation is also depending on the composition of alloy ingredients such as Mg in AA6061 alloy and Cu in AA2024 alloy. For a given percentage of Fly ash, Cupper has a notable impression on elongation than Mg.

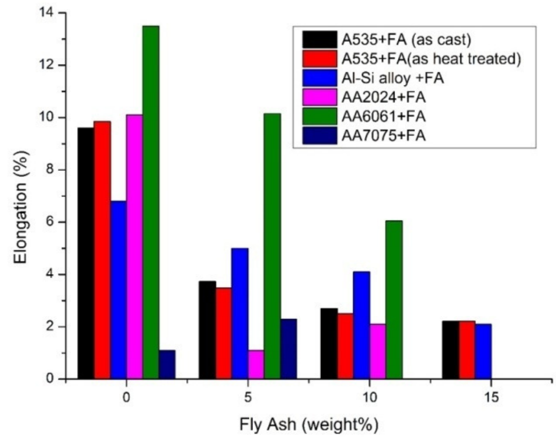

Fig. 2. Elongation of Various Aluminum Metal Matrix Composite with varying fly ash weight percentage.

The subsequent outcomes can be represented from the preceding results.

– The 5% elongation can be accepted for a given AMMC for its practical application in designing a composite metal matrix.

– Proper selections of Aluminum alloys with fly ash can solve the requisite design application such as elongation.

C. Density

The basic physical property which indirectly controls the porosity of an MMC is density. Few percentages of fly ash present in different metal matrix composite can able to light the entire weight of AMMC. Different researchers [21, 26, 29, 33, 38, 40, 41, 42, 39] have used fly ash with their MMC in different percentages [ranges from 0-6%/0-8%/0-12%/0-25%] is presented in Fig. 3. The measurement of density for AMMC can be implemented by the Archimedes drainage method [38] or density measurement kit [42]. The standard formulas for calculating densities are followed by the relations.

$$\mathrm{P} = \frac{m}{V}. \quad (1)$$

$$\rho_{mmc} = \frac{m}{m-m_1} \times \rho_{H2O} \quad (2)$$

$$\rho_{mmc} = V_r\rho_r + (1 - V_r)\rho_m \quad (3)$$

The adding up the percentage of fly ash has reduced both ductility and density of MMC [39]. The reason is the density of constituents as the reinforcement with fly ash (2.09 gm/cm^3) is more cramped than the density of aluminum alloys [42]. Bharathi e*t al.,* (2017) presented their research work taking LM25 (silica and alumina) with fly ash. They stated that if both constituents (silica and alumina) are harder material than AMMC provide a better weight to strength ratio than any other MMC which can be used for bearings and other related components in mechanical design [41].

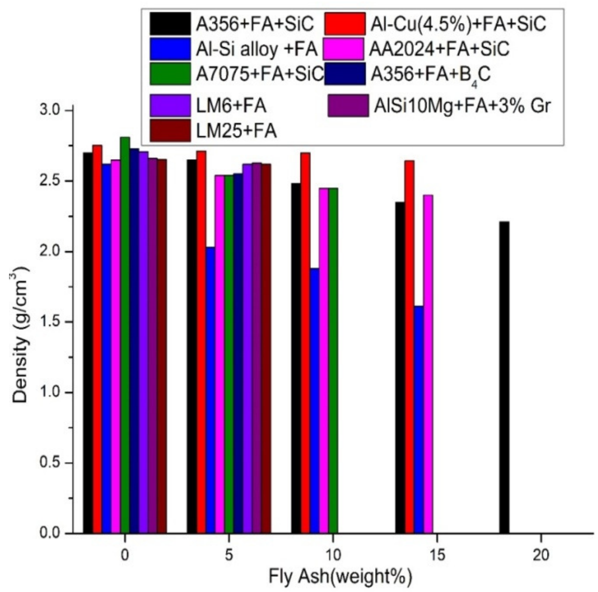

Fig. 3. The density of various AMMCs with a varying weight percentage of fly ash.

Dwivedi *et al*., (2014) presented their research work on A356 including SiC and fly ash. The porosity of AMMC increases with raising fly ash percentage due to homogeneous MMC. The clustering of ash particles at higher percentages leads to specimen failure [26].

$$\% \text{ porosity} = \left[1 - \frac{\text{Measured density}}{\text{Calculated density}}\right] \times 100 \quad (4)$$

Bhaskar *et al.,* (2017) analyzed AA2024 that is strengthened with SiC including fly ash. They observed that the difference in calculated and theoretical density is due to porosity [33]. Efzan *et al.,* (2016) studied about the reinforcement of LM6 (A closed pack aluminum alloy) with 0-6% by weight of fly ash adopting compo casting technique. Few particles of LM6 had been replaced by fly ash and AMMC become stronger and for which reduces the density [29].

D. Ultimate Compressive Strength

The material continues compressive deformation due to compressive load and deforms permanently at maximum compressive stress. The method of failure may happen due to clasp, crick or crush due to high compressive strength. Typically composites have greater tensile strength than compressive strength when loaded in compression. The failure in a fiber-reinforced composite is due to axial compressive load which depends on the individual property or defects of the ingredient [23, 30]. Especially, in civil aircraft, 80% of its structure is subjected to critical compressive load with estimated minimum axial load of 1034 MPa at 82℃. Consequently, special attention must be considered to choose support material along with its metal matrix for a selected purpose.

Fig. 4 presents a significant curve between UCS with a distinctive composition of fly ash by several researchers [21, 23, 30, 31, 32, 34]. Ultimate Compressive Strength concerning AMMC increase with raising fly ash for different methodologies is presented in Fig. 4. Some principles of possibilities of increasing UCS are shown.

The compressive strength of AMMC is improved by addition of fly ash particles as reported by Mahendra and Radhakrishna; Razzaq *et al.,* [21, 32]. Rao *et al*., (2011) [23] worked on AA2024 with fly ash (0% to 10%) in their MMC. By analyzing results from the load-displacement curve, they interpreted the increasing of Ultimate compressive strength during compression testing. A comparative investigation represented by Kulkarni *et al*., (2016) introducing three types of reinforcements (12% Al_2O_3, 12% fly ash and 6% Al_2O_3 and 6% fly ash) with AA356 in AMMC. All hybrid reinforcements were used for examining their mechanical properties [30]. It was observed that 12% of Al_2O_3 reinforcement is producing better UCS than the other two as shown in Fig. 4.

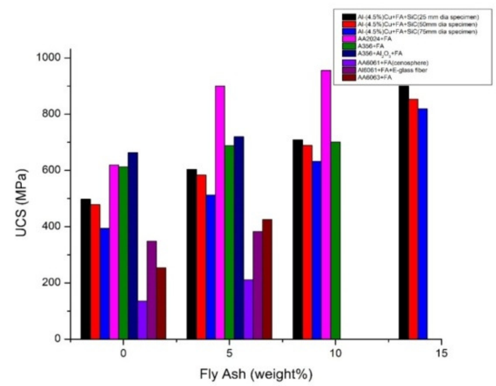

Fig. 4. Ultimate Compressive Strength vs. fly ash on different AMMCs.

Ilandjezian and Gopalakannan (2017) [34] experimented on adding 5% of the cenosphere (made of silica and alumina) with Aluminum. Notably, they observed that adding the cenosphere promotes the compressive strength because of its spherical nature. The voids generated by cenosphere are quite responsible for the improvement in the compressive strength with high capacity. The concepts of waste to wealth adopted by Patel *et al*., (2017) [31] have taken E-glass fiber with fly ash for Al6061 metal matrix composite. They rendered that E-waste reinforcement contributes better compressive strength than that of the cenosphere as shown in Fig. 4.

The resulting outcomes for compressive strength can be brought concerning the fly ash reinforced AMMC of the present study.

– A blending of fly ash accompanying with glass fiber, plant waste and aluminum oxide can improve the compressive strength of the AMMC.

– A moderate leading percentage of fly ash content is responsible for getting better the compressive strength of the AMMC.

E. Hardness

(i) Brinell Hardness Number

Hardness is a step to measure plastic deformation produced by mechanical indentation and/or abrasion. Macroscopic hardness is usually defined by large intermolecular force. However, the response due to the complexity of force, the material hardness can be measured in a different way such as indentation hardness, rebound, and scratch hardness.

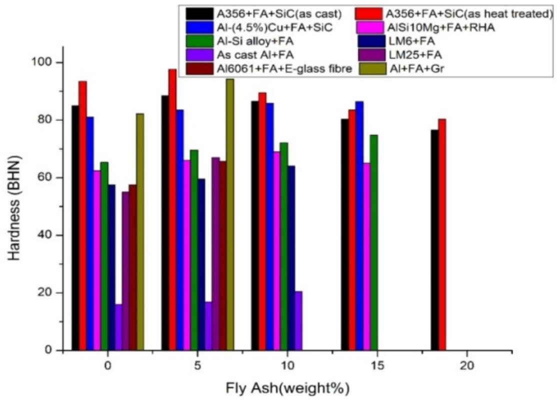

Fig. 5. Hardness (BHN) of various AMMCs with varying fly ash weight percentage.

Indentation hardness is mostly applied for various manufacturing and metallurgical applications. Normally indenter (harden steel ball) is allowed to impress on the material sample to deform by the constant load. The hardness of the present specimen is determined by the area and depth of indentation as given by the formula.

$$BHN = \frac{2P}{\pi D_i\left(D_i - \sqrt{\left(D_i^2 - d_i^2\right)}\right)} \qquad (5)$$

BHN = Brinell hardness number (Kgf/mm^2)
P = Theoretical load in (Kgf)
D_i = Diameter of indenter (mm)
d_i = Impression diameter (mm)
Test-retest reliability of Brinell hardness procedure has well accuracy. Increasing the hardness refers to enhances the wear resistance.
Hardness (BHN) values for different AMMCs varying with a weight percentage of fly ash from some Researchers [21, 26, 28, 31, 35 and 39] are revealed in Fig. 5.
Silicon carbide along with fly ash (5% to 15%) as reinforcement in MMC Al-4.5% Cu increases the hardness by conventional foundry techniques presented by Mahendra and Radhakrishna [21]. Implementing the stir-squeeze casting technique, Prasad and Ramachandra (2018) examined the impact of fly ash as reinforcement with LM6 Al alloy. They presented that the consolidation between metal matrix and SiC with fly ash intensify squeeze pressure to operate as a load-bearing material [35].
Increasing fly ash above 5% of the metal matrix in an A356 the reinforcement between SiC and fly ash decreases the hardness of AMMC is presented by Dwivedi *et al.*, (2014) [26]. The cause of decreasing hardness above 5% of fly ash in the specified sample is due to a further increase of porosity percentage. However, 15% SiC with 5% fly ash is represented as the best combination (BHN 88.8) among all samples in A356/SiC with fly ash as shown in Fig. 5. Dwivedi *et al.*, (2014) [26] extended their work on implementing heat treatment on the same samples and found an increase of 9.42% more hardness than that of without casting as shown in Fig. 5. Adopting liquid metallurgy method, Ramachandra and Radhakrishna [39] noticed that the hardness of Al-Si alloy by 15% adding up of fly ash improved from 65.3 BHN to 74.8 BHN on the prepared composite.
Common similar efforts were made by [28, 31] utilizing agro-waste (RHA), E-Glass fiber as well as industrial waste (fly ash) for preparing a strong reinforcement with a metal alloy like AlSi10Mg and AL6061 respectively. A 20% weight of MMC [AlSi10Mg] was used as reinforcements to study the mechanical properties like hardness. Three sets of reinforcements (15% FA with 5 % RHA, 10% of both FA and RHA and 5 % of FA with 15% RHA) were added with AlSi10Mg aluminum alloy using the stir casting technique. AlSi10Mg with 10% FA and %10 RHA composite exposed the optimum hardness due to increase in surface area of MMCs which offers more resistance to plastic deformation. On the contrary, a sample with 5% FA and 15% RHA put together poor reinforcement due to wettability. Similarly, AL6061, Glass fiber in addition to fly ash was prepared to increase hardness. It is found that the hardness increases in all cases except at a 6% fly ash sample as shown in Fig. 5.
The follow-on for Brinell hardness Tester can be drawn pertaining to the fly ash reinforced AMMC of the present study.
– Increasing (by percentage) of Fly ash results in better hardness than parent MMC.
– Industrial waste (Fly ash), Agro waste and E-Glass fiber can steps forward to Brinell hardness of the AMMC.
– Suitable % choice of non-metal such SiC, Al_2O_3 with fly ash can improve the hardness of the AMMC.

(ii) Vickers Hardness Number

Vickers hardness test is one of the modified versions of Brinell hardness test which from micro load to macro range of load (from 1 gm force to 120 kg force).
The hardness of this coating present on the surface of the matter can be measured with Vickers hardness tester. The indenter is made up of a diamond square base pyramid whose impression area on the specimen is calculated by determining the diagonal of the square pyramid with apex angle 136° by high powerful resolution by an optical method. The testing results produce high accuracy with prone to crack after testing the specimen.
Nevertheless, the surface of the specimen should be well polished before apply to Vickers hardness testing. The optical system present in VHN testing is more expensive and slower as compared to Brinell hardness tester. Numbers of researchers [18, 23, 24, 34 and 36] have preferred to test hardness of AMMC using Vickers hardness tester using fly ash as one of the reinforcements. The summarized results are presented in Fig. 6. A good number of research work [23, 24, 34 and 36] claimed that % of fly ash increases the hardness in MMC due to following causes.
– Homogeneous distribution of fly ash
– Presence of silicate and mullite, Alumina and silica
– Grain refinement due to the incongruity in thermal expansion coefficient within MMCs and fly ash during solidification.
Gikunoo *et al.,* (2005) reported that the presence of fly ash develops porosity and degraded mechanical properties like hardness. It is expected to the non-uniform arrangement of fly ash which accumulates around aluminum dendrite creating clusters at the boundaries [18]. Conversely, the micro hardness is improved by effective heat treatment as shown in Fig. 6.

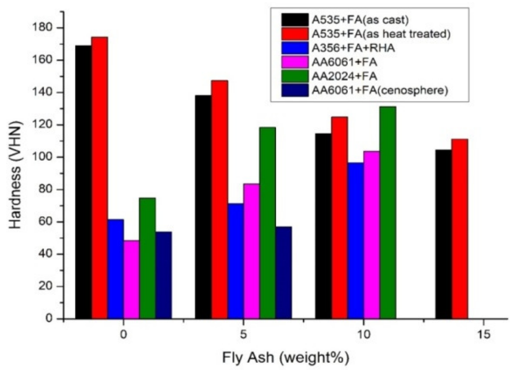

Fig. 6. Hardness (VHN) value for various AMMCs with varying fly ash weight percentage.

(iii) Sintered Hardness

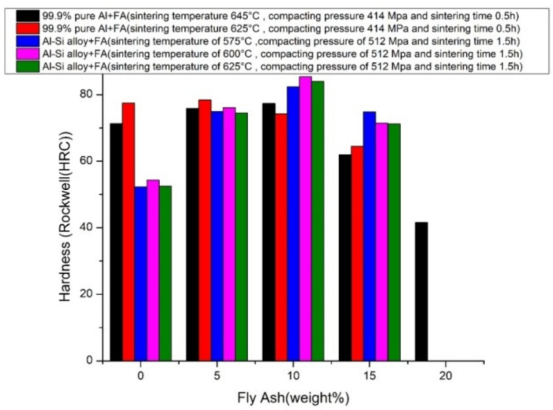

Fig. 7. Sintered hardness for different AMMCs vs. fly ash percentage.

Sintering is the method regarding compacting and settling some substantial mass like metal with heat energy preferentially pressure before melting at the time of liquefaction. The atoms in the corporealities distribute over the boundaries of the particles and combining with other particles producing a regular piece.

The Rockwell hardness tester is one of the simplest methods to determine the hardness of given specimen without its sample preparation. It is quick, cost-effective and non-destructive test which directly measures the hardness without optical instruments in different scales indicated as HRA, HRB, and HRC dimensionless numbers. Indenter of cone type is used to penetrate the specimen surface under a considerable load and related to penetrating prompted by a minor load. This hardness value is accepted to correlate with tensile strength for various applications. Fig. 8 represents the impact of percentage in fly ash (by weight) with Rockwell hardness number in AMMCs at different sintering temperatures. Guo *et al.,* (1997) prepared AMMCs taking pure aluminum with fly ash at different percentage by powder metallurgy [17]. The hardness of the specimen in increases as sintering temperature changes from 625℃ to 645℃ with addition of fly ash from 0% to 5% keeping both compacting pressure (414 Mpa) and sintering time (0.5h) as constant. But the hardness of AMMCs limits on raising the percentage of fly ash. Fig. 7 shows a variation between the Rockwell hardness and substantial percent of fly ash for different sintering temperatures (575^{0}C, 600^{0}C, 625^{0}C and 645℃) respectively. Hardness increased a little, up to 10 wt. % and then decreases in aluminum fly ash compacts MMCs. In a similar way Siddhi Jailani *et al.*, [22] have prepared aluminum silicon composite alloy reinforced with fly ash (5%-15%) by powder metallurgy and sintered it up to 625℃ from 575℃ (512Mpa). It is concluded that the hardness of the AMMCs composites improves with increase in fly ash content (up to twelve percentages) while the sintering temperature rises from 575℃ to 600℃. However, the hardness of the specimen is limited to 12% of fly ash irrespective of sintering temperature [22]. Consequently, it is revealed that results for improved hardness required higher long times with higher sintering temperature.

The characteristic of sintering decreases due to a higher percentage of fly ash (12%) which generates clustering around the metal matrix and pointing to reduce the hardness of the composites. Deterioration of property of sintering is accountable for more % of fly ash particles in the present MMCs. That is also remarked that the best hardness of the composites transpires at twelve percentage of fly ash as presented in Fig. 7. Results from sintering hardness in the performance of fly ash as reinforcement can be drawn about the AMMC from the present study.

– Increasing (by percentage) of Fly ash in MMC, more useful hardness enhances from that of parent MMC.

– Sintering temperature and sintering time perform a significant role in improving hardness for a given fly ash percentage of the AMMC.

– Clustering of fly ash around the metal matrix can be depreciated by suitably choosing the sintering temperature and time.

F. Sintered Compression strength

Here subdivision is based on the analysis of sintering compressive strength of AMMC (Pure aluminum with fly ash and Al-Si alloy with flay ash) with % of fly ash as presented in Fig. 8. Taking sintering temperature (625℃), both Guo *et al.,* [17] and Siddhi Jailani *et al.*, [22] have developed a relation connecting the compressive strength of composites with fly ash percentage on different weight fractions through powder metallurgy process. The consequence of fly ash amounts covering the compression strength of metal matrix powder compacts at the pressure of 414 MPa and 512Mpa for the duration of 0.5 h is showing in Fig. 8.

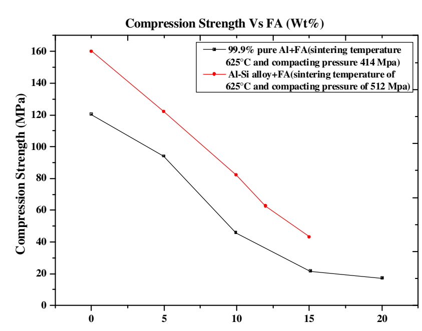

Fig. 8. Sintered compressive strength of AMMC over % of fly ash.

The figure exposes that the sintered compression strength degenerates with developing weight % of fly ash. It is especially low strength subsequent at 10 percent of fly ash. The weak interfacial bonding within the fly ash particles including the aluminum matrix is the cause of the decrease in compression strength in aluminum-fly ash sintered composite. The grain size is controlled by Fly ash particles situated in grain boundary that affect strength and toughness as described by Siddhi Jailani *et al.*, [22] may another cause of the reduction in compressive strength. Under the present Fig. 7 indicate the nature of the curve sharply decreasing due to the increase of fly ash percentage. It observed by comparing the two results [17, 22], the sintered compression strength decreases with an increase in fly ash amount. Pure aluminum with Fly ash composite had shown less sintered compression strength than that of Al-Si alloy with Fly ash composite.

Conclusions from sintering compressive vs fly ash from the presence study can be drawn about the AMMC as presented below.

– Increasing (by percentage) of Fly ash content can reduce the sintering compressive strength.

– Inadequate bonding is responsible for decreasing in the sintering compressive strength.

– Pure Al with Fly ash composite provides less compressive strength than Al alloy with Fly ash for a given sintering Temperature.

G. Densification Parameter

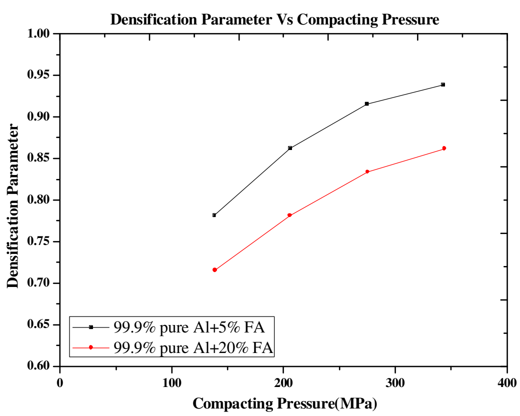

Fig. 9. Influence of compacting pressure vs. Densification parameter.

The influence of compacting pressure on aluminum fly ash composite based on the densification parameter is studied by Guo *et al.*, [17]. They developed a new composite taking Al-fly ash with varying weight fractions of fly ash by powder metallurgy route. The density during sintering decreases with raising the fly ash percentages. It was noted that the Metal matrix with 5% Fly ash reinforcement results 0.95 densification limits whereas 20% Fly ash reinforcement reduces to 0.85 for the same Metal matrix with settled compacting pressure (414Mpa) [17]. The higher results of the densification parameter are near to unity which justifies the compacting pressure of pure metal matrix as 414Mp.

– Densification is a function of compacting pressure

– The density of MMC decreases by increasing fly ash percentages (by weight) during compacting.

H. Green Density along with Compacting Pressure

The compatibility is measured by the rate of change in volume with respect to external compacting pressure followed by the equation given below

$$\frac{V_0 - V}{V_0} = \frac{xyP}{1+yP} = C \qquad (6)$$

Initial volume of powder V_0, V is volume at given pressure P, C is the compressibility and both x and y are constant for given powder.

Powder compaction is the method of compacting similar/dissimilar metal particles in a die by high pressure and getting a compacted solid piece ejected from the die cavity. The pressure involved in this process is called compacting pressure. The density obtained after compacting from the pattern is called as green density. Saheb (2007) *et al.*, described the cause of reducing the green density at consistent compaction pressure. They mentioned that the low density of fly ash is responsible for reducing the density of the product and make the specimen light. The density of every specimen improved with developing compaction pressure [19].

Aluminum silicon alloy reinforced with fly ash (5-15%) prepared by Siddhi Jailani *et al.*, [22] using powder metallurgy. It is clear from the composition of AMMC that the green densities in the case of alloy with fly ash remained below the density of the metal matrix. The green density of the AMM improves with rising of pressure and approaches to the highest density of 2.62 g/cm^3 (theoretical value of density, 97.8%) at 512MPa. The cause of decreasing green density is due to the low density of fly ash porosity. However, the porosity is decreased by raising the compacting force that leads to an improvement over the green density of AMMC as shown in Fig. 10(a) and (b).

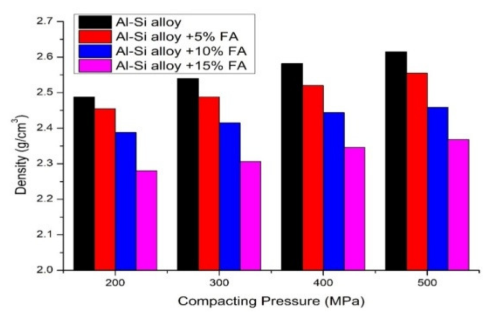

Fig. 10 (a) Compacting pressure vs. Green density for AMMCs of Al-Si alloy.

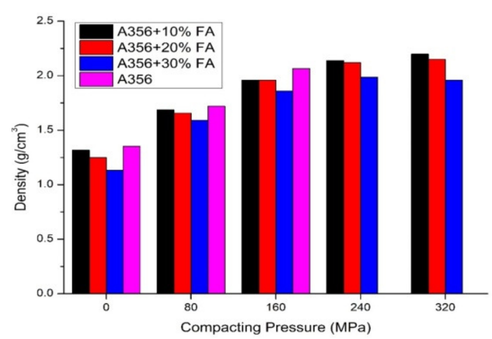

Fig. 10 (b) Compacting pressure vs. Green density for AMMCs of A356 alloy.

I. (Green Density and Sintered Density) Vs Fly Ash Weight Percentage

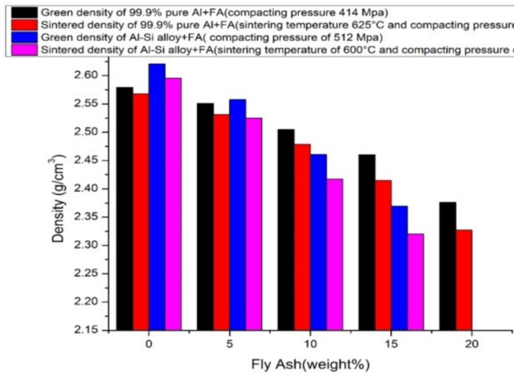

Fig. 11. Result of percentage of weight fly ash on sintered density of various AMMCs.

Strength and integrity are achieved by the powder compact through the sintering process which is basically a heat treatment process. Sintering process is an integral method included in powder metallurgy process where temperature is kept below the melting point of major components. The density of compact is known as green density and after application of high temperature it is known as sintered density.

A good comparison between green density and sintering at different pressure and temperature for different fly ash composition have presented in Fig.11. Both Siddhi Jailani *et al*., [22] and Guo *et al*., [17] prepared their noble work based on metal aluminum silicon-fly ash composite (5-15%) and pure aluminum-fly composite respectively using powder metallurgy. The green, as well as the sintered density of Aluminum alloy-fly ash composites, degenerated with the composition of fly ash in the existing composites as pointed in Fig. 11. The presence of fly ash particles (having a lower density than matrix) in the matrix and the behavior of porosity decrease the green densities of the metal matrix composites. The sintered density is found to be some extent below than the green density despite the increasing of the compacting pressure. The gap among the calculated and observed experimental density indicates that porosity is present in the sintered compact. This gap rises with rising wt. % of fly ash which indicates that the increase in fly ash weight percentage increases the porosity in the sintered aluminum-fly ash compacts [17, 22]. The green density is found to be higher than that of sintered density. From the above research work, the following conclusion may be drawn

– Fly ash amount in the composite strongly affects the green and sintered density as its amount decides the porosity and it has less density than the matrix

– On sintering the powder, the volume of the compacts increases thus decreasing the sintered density.

J. Ultimate compression strength Vs dimension of fly ash particle

The dimension of fly ash particles (in µm) plays a significant role in deciding the solubility of reinforcement in the lattice structure of the Metal matrix. Consequently, it has influenced the several characteristics of metal matrix composite including the mechanical characteristics.

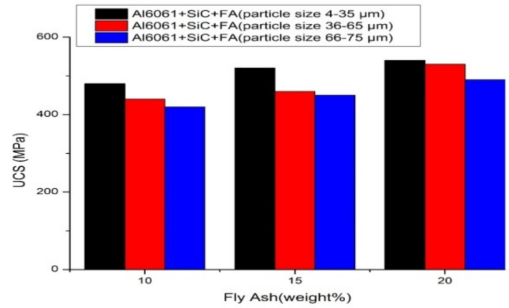

Fig. 12. End result of fly ash particle size on Ultimate Compression Strength of AMMC.

Particle sizes with its distribution enhance the mechanical straight. Materials forms into powder and pressed into a die with desired pressure and temperature may contain voids which creates stress concentration. Therefore, uniform distribution of particle in metal particle avoids porosity and improves mechanical properties such as tensile as well as compressive strength.

Shukla *et al*., (2018) reported that the influence of the size of fly ash (in microns) to strengthened aluminum matrix composite. The results revealed that fly ash addition enhances the compressive strength. The higher particle size of fly ash reduces the compressive strength. The narrow range particles enter into the atomic vacancy in the lattice structure of matrix thus enhancing mechanical properties like Ultimate Compression Strength [37].

The following conclusion can be derived from the above research work

– Particles size should be chosen perfectly desired results of AMMC.

– Synchronized size of particles may produce homogenous mixture which will have a choice of impact on all properties

– The distribution of fly ash particles affects the behavior of the reinforcements as well as in the aluminum metal matrix thus improves properties of whole composite.

III. SURFACE MORPHOLOGY

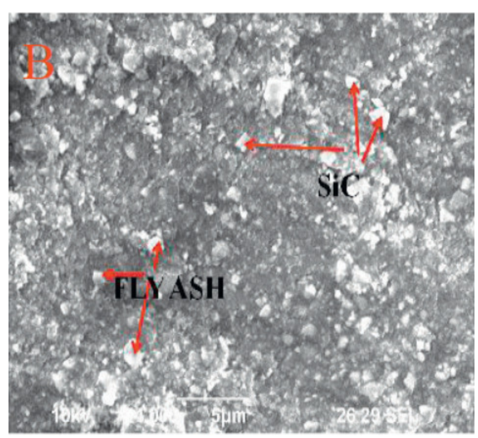

Fig. 13. Study of Comp casting of Aluminum AA6061 with silicon carbide (7.5%) and fly ash (7.5%) as reinforcement using SEM.

The distribution of the FA and SiC particles appears to be uniform throughout the aluminum matrix as well as absence of porosity as revealed by Selvam [25] presented their SEM taking AA6061 along with fly ash and silicon carbide. The uniform distribution of metal matrix with its reinforcement produced a homogeneous mixture which can control process parameters and develop mechanical properties.

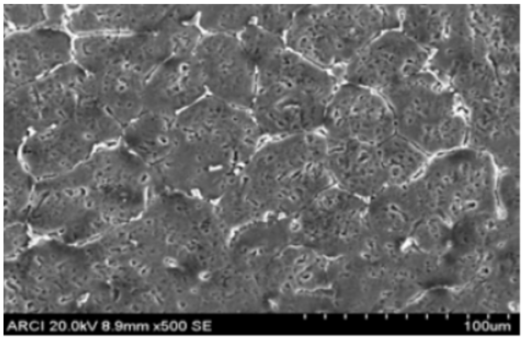

Fig. 14 (a). At 100 × magnification, the microstructure of AA 2024 with 10% FA and 10%/SiC.

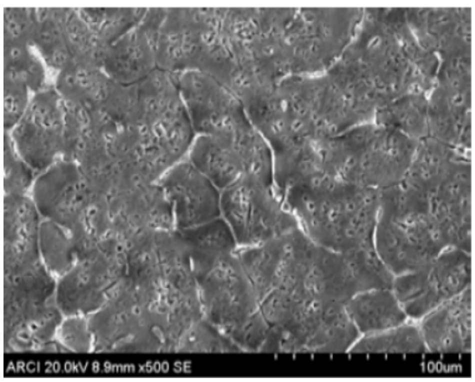

Fig. 14 (b). At 100 × magnification, the microstructure of AA 2024 with 15% FA and 15%/SiC.

Fig. 14(a-b) displayed the SEM of AA2024 hybrid composites varying with 10% and 15% of fly ash by weight. Bhaskar *et al.,* (2017) prepared the composite through stir casting taking AA2024 as metal matrix with silicon carbide and fly ash reinforcement. It is found that Uniform distribution of SiC with fly ash enhanced the mechanical properties [33].

IV. CONCLUSION

We are highly thankful to the relevant authors as presented in reference whose contributions give us to review this article specially meant for aluminum/aluminum alloy using fly ash one of the reinforcements. Mechanical properties, Physical properties, Effects of microstructure along with surface morphology are presented which make a good relationship between the metal matrix composites with one of its reinforcement such as fly ash. The conclusion drawn from different authors is summarized at the end of each part of the review.

However, the above literature it is considerably distinct that fly ash can be utilized as support in aluminum matrix appearing in improved mechanical properties, microstructure properties, etc. and can be a future perspective for commercial production in industries. Thus, industrial waste can be converted into industrial as well as social wealth. This also resolves the problem of fly ash disposal leading to an eco-friendly and economical solution

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