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An Assessment of Mechanical Characteristics of Al 6061 Reinforced with SiC and Bagasse Fly Ash Hybrid MMC

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Abstract*: Material is one or more substances that form an object. Due to an attractive mechanical characteristic, materials are commonly selected for structural applications. Recently, the hybrid MMC has been developed and highly an innovative trend in material science. The current study is concentrated on the formation of an innovative hybrid MMC by utilizing aluminum, silicon carbide and fly ash particulates of bagasse. In this study, the physical characteristics of Aluminum 6061 were evaluated by adding Sic, fly ash particulates of bagasse and observed that this is the hardest substance. The compositions were added until the final level and a method of stir casting has been utilized to fabricate Al MMC. XRD ie x-ray diffraction was utilized to analyze the structural characterization of MMC and optical microscopy was utilized to analysis the microstructure on MMC. In this study, the mechanical characteristics like hardness, elongation, yield strength, UTS and density have been performed on MMC. Aluminum was added with 5% of silicon carbide and 10% of fly ash particles of bagasse in one case and in other case aluminum was added with 10% of fly ash particles of bagasse and 10% of silicon carbide. As a result, it was detected that there is an improvement in the hardness and UTS and a reduction in the density and elongation of the composites in comparison to plain aluminum. This shows that the aluminum-silicon carbide-fly ash particles of bagasse MMC substantially differ throughout all characteristics.

Keywords: Hybrid MMC, Sic, Fly ash particles of bagasse, Aluminum.

I. INTRODUCTION

MMC is a mixture of two substances with dissimilar properties. When three substance is mixed then it is referred to as hybrid MMC. The current study was attempted for the fabrication of hybrid MMC by utilizing aluminum 6061 is in the form of a matrix, silicon carbide and fly ash particles of bagasse.

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Various methods like stir casting, squeeze casting, liquid metal infiltration, spray deposition, and powder metallurgy are available to fabricate the hybrid MMC. But in this study, due to easy manufacturing, plasticity and simplicity, a method of stir casting has been utilized for the production process.

The materials of MMC have a grouping of better characteristics when compared with an unreinforced matrix-like enhanced strength, more elevated modulus of elasticity, elevated service temperature, enhanced resistance to wear, excessive electrical and heat conduction, lower coefficient of heat enlargement and the high vacuum ecological durability. These qualities can be achieved with the correct selection of the reinforcement and matrix.

Fogagnolo (2004) produced materials of AMC that are reinforced with Aluminium Nitride, Zirconium di Boride, and Silicon Nitride and by powder metallurgical method and observed uniform distribution of reinforcement. Mechanical alloying increased the UTS and powder hardness in comparison to unreinforced aluminium alloy. The addition of reinforcement enhanced the UTS and rigidity of extrusions.

(Manoj Singla et al 2009) increased the rigidity, strength of impact and displacement of normalization through increasing the formulation of SiC in aluminium matrix. Standardized dispersion of particles silicon carbide in the aluminium matrix showed a growing trend in the tests made by the two-step technique of stir casting.

Zhou and Xu (1997) produced two separate AMC (A356 and 6061) reinforced with particles SiC by gravity casting and reported that a mixing technique in two-step has enhanced moisture absorption of the particles SiC and ensured good distribution of particle. The particles SiC are located predominantly in interdendritic regions as substrates of Si crystals in (A356-10%SiC) composites. Arda Cetin and Ali Kalkanli (2008) observed that adding Mg in alloy has enhanced moisture absorption of the particles SiC.

Tamer Ozben et al (2008) examined the effect of SiC reinforcement in aluminium (Al 6061/7Si/2Mg) and noted that increasing SiC has increased the UTS, hardness, and density of Al 6061/SiC composites, the impact toughness decreased with increase in SiC particles. The machinability of MMC was very less compared to traditional materials because of the abrasive reinforcement element.

Bayraktar et al (2008) examined the damage mechanism of aluminium reinforced silicon carbide composite materials in as received and conditions of heat-treated of the composites fabricated with various production methods. The rupture was started in the interface (matrix /SiC) with large debonding interfacial the matrix and particles SiC causes reduced fatigue strength.

The mechanical performance of these composite materials was associated with particulate geometric shapes, deployment and the number of reinforcement molecules in the matrix.
Chennakesava Reddy and Essa Zitoun (2010) reported that the strength of yield, UTS, and the plasticity of aluminium silicon carbide MMC are in the reverse order of Al 6061, Al6063 and Al7072 matrix alloys. The entire contents of alloy components like Fe, Si, Cu, and Mg play a significant role in the mechanical performance of SIC /Al composite materials. Mg enhanced wetness among the particles SiC and Al by lowering the layer of SiO_2 on the SiC surface. Fractured modes of composites are ductile in nature.
Hamouda et al (2007) reported that the UTS and modulus of elasticity of silica particles reinforced in aluminium alloy of LM6 composite materials gradually reduced over with the growth of silica. This was because of the predominant nature of the compression strength of silica particles reinforced in aluminum alloy of LM6 composite materials.
UTS, the strength of impact and fatigue properties of composite materials of aluminum reinforced with longitudinal steel fibers are higher compared to composites reinforced with transverse fibers (Agbanigo and Alowode 2008). This was due to the fact that transverse fibers created areas of stress concentration which aids initiation and propagation of cracks resulting in early commencement of deformation and fiber-matrix debonding.
Perez Ipina et al (2000) examined the fracture behavior of two MMC materials Al-Si alloy SiC and Al6061/Al_2O_3. Annealing heat treatments promoted an increase in fracture toughness and observed the formation of fatigue pre cracking after heat treatment.
Cepeda-Jime Nez et al (2008) developed a multilayered composite laminate of Al 7075 and Al 2024 alloys by hot roll bonding with high impact toughness. A post rolling tempering reduced the stresses around the interfaces and optimized the precipitation hardening during T6 treatment. The mechanism of interface pre-delamination was responsible for delamination and crack nucleation in every layer of the composite laminate.
Wang Weimin et al (2002) fabricated (TiB_2-Al_2O_3)/Al composites by high-temperature synthesis, self-propagating, and hot pressing. Fabricating processes parameters had a great influence on the ignition temperature of a synthesis reaction, reaction temperature and density of the synthesized products. The fracture toughness increased rapidly with an increase in the content of Al in composites. The bending strength augmented with the rise in the content of Al till about 30 vol% and then diminished with further improvement in the content of Al.
Roy et al (2006) manufactured aluminum matrix composites reinforced with Fe-alloy and aluminum oxide by process of in-situ and observed that the initiation temperature of reaction of in-situ decreased considerably with the usage of nano-sized Fe_2O_3 crystallites. Evolutions of strengthening are favored by increasing pressing temperature.
Adamiak (2006) added titanium aluminide intermetallics particles to aluminum matrix composites by the extrusion process and found that adding intermetallic strengthening particles to the composite material does not affect their characteristics of tensile. The higher content of strengthening resulted in the higher particle dispersal reinforcing.
Veeresh Kumar et al (2010) were successful in adopting the liquid metallurgical techniques in preparing Al7075-Al_2O_3 and Al6061-SiC composites and found that composites of Al6061-SiC exhibited excellent UTS performance in comparison of composites of Al7075-Al_2O_3. The resistance to wear of the composite materials are larger, SiC significantly improved the abrasive resistance of composite materials in comparison to composites of Al_2O_3.
Neelima Devi et al (2011) found that weight to the power proportion of Al SiC composite was approximately three times that of mild steel. The composite material of Al SiC was twice less on the mass in comparison to aluminum for equal size.
Abouelmagd (2004) reinforced by the various weight fractional numbers of Al_4C_3 and Al_2O_3 particles in pure aluminum by powder metallurgical process. Toughness and compression strength enhanced to approximately four times by adding Al_4C_3 and Al_2O_3. The addition of Al_4C_3 caused the ductile to brittle transition phenomenon and showed a large number of defects. The crack thickness augmented with the growth of deformation temperature.
Wodarczyk-Fligier et al (2010) noted the equal distribution of boron nitride in the aluminium matrix. The hardness of composites augmented with growth in BN. Precipitation strengthening was causing an extra rise in the rigidity of composites. The addition of boron nitride has reduced the UTS and corrosion resistance of composite materials.
The hardness of the Al6061 aluminum compound augmented with growth in the addition of frit particulate matter (Ramesh et al 2010). The addition of frit particles significantly improved the UTS and resistance to compression of Al6061 initially. UTS of composite materials decreased above by adding 6wt % of frit particulates. Above 8 wt % of frits, the resistance to compression of composite materials decreased with the rise in frit particles.

II. MATERIALS AND METHODS

A. Materials

In the current study, pure aluminum is utilized is in the form of a matrix and purchased from the local market. Silicon carbide and magnesium have also been available on the market. Fly ash particles of bagasse are obtained by burning the solid waste particles of sugarcane.

B. Experimental Work

In this study, the method of Stir casting is utilized to fabricate the hybrid MMC where a disperse stage blended with melted matrix metal with the help of mechanical mixing. Then the molten composites were cast through traditional casting techniques and also handled by traditional metal fabrication technology.

In this study, a method of stir casting was utilized to prepare the aluminum reinforced silicon carbide, aluminum reinforced fly ash particles of bagasse, aluminum reinforced with both 5% of silicon carbide and 10% of fly ash particulates of bagasse and aluminum reinforced with 10% of fly ash and 10% of silicon carbide. **Figure. 1** demonstrates this production process. The experimentation was performed by selecting 100 gm of pure aluminum and the required quantity of powder of fly ash particles of bagasse, silicon carbide, silicon carbide reinforced fly ash particulates of bagasse.

The moisture was removed by heating a fly ash particles and silicon carbide and their mix were heated for 3 hrs at 300°C. A resistance oven was utilized to melt the pure aluminum at 720°C and then the mild steel turbine stirrer was utilized to stir at a 200 rpm of velocity for 5 or 7 min. The wettability was increased by mixing 15% of magnesium to entire composite materials at 700°C of melting temperature. The method of the vortex was utilized to disperse the fly ash particles of bagasse and other particulates. The heated metallic mold was utilized in which the molten liquid with reinforced particles was poured at 680ºC. Molten was subsequently permitted to solidify in the mold. **Figure 2** demonstrates the solidification of molten liquid. Figure 3 illustrates the attained hybrid MMC.

C. Microstructural Characterization

In this study, optical microscopy was utilized to evaluate the produced composites and to examine the microstructure of the composites. A section has been trimmed from moldings, that is initially belt milled followed up by rubbing by a dissimilar grade of sanding papers. Then those have been cleaned with purified water and rubbed with a clean cloth. After carving, those specimens have been analyzed for microstructure in accordance with optical microscopy at various enlargements.

D. Analysis of X-Ray Diffraction

The technique of x-ray diffraction was utilized to examine produced composite materials in order to verify the existence of the various combinations in the composite materials.

E. Observation of Mechanical Characteristics

i. *Density*

The principle of Archimedes was employed to attain the density of the composite samples. As per the mass fraction reinforcement, the hypothetical intensity was computed by implementing the mixtures rule.

F. Tensile Behavior

According to ASTM E-8 standards, the tension testing was performed with the help of UTM at a 9.103 pts/sec of specimen speed and 5.0 mm/min of crosshead velocity. **Figure. 4 shows the** Standard specimens whose measuring length was 36 mm has been utilized to estimate the percentage elongation, Yield strength, and UTS. **Figure 5 illustrates the tension test specimens.**

G. Hardness

The measurements of bulk hardness have been performed on the parent metal and specimens of composite with the help of standard Brinell hardness testing apparatus by applying 10 kg of load. The measurements of bulk hardness have been performed to examine the impact of particle mass fraction on the hardness of the matrix. **Figure. 6 illustrates the** hardness test specimens.

Fig. 1. Stir casting device

Fig. 2. Specimens in mold

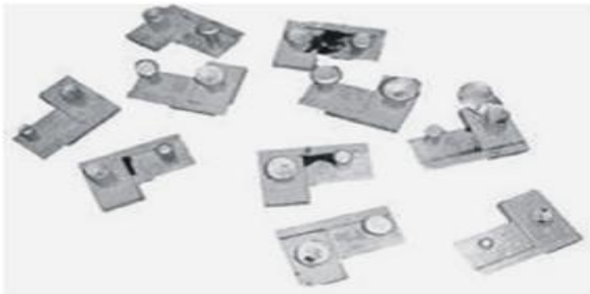

Fig. 3. Specimens

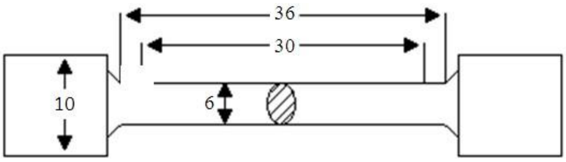

Fig. 4. Standard tensile specimen

Fig. 5. Samples for the tensile tests

Fig. 6. Specimens for the hardness tests

III. RESULTS AND DISCUSSION

A. Optical Micrographs of MMCs

Morphological structure, intensity, the kind of strengthening the particulates and their distribution significantly affect characteristics of the particle composite materials. The variables that regulate the distribution of particulate matter are the solidified velocity, fluidity, kind of reinforcement and the technique of incorporation. At the time of fabrication of particles, the particulates are distributed uniformly with the help of wettability throughout the casting and then segregation /agglomeration of particulates were presented at the time of pouring. The wettability was increased by adding magnesium. The particle distribution was analyzed by cutting the specimens of micro-structure from the casting plate at various positions. Figure 7 to 15 demonstrates the optical micrographs of hybrid MMC. From these figures, the boundary of grain was detected after the process of etching and the well-established modules had been detected before the process of etching. Therefore, in the circumstances of Al 6061 with 5% of silicon carbide, Al 6061 with 10% of silicon carbide, Al 6061 with 5% of fly ash particles of bagasse, and Al 6061 with 10% of fly ash particles of bagasse, there is a nonuniform distribution takes place because the segregation was controlled by gravity. While consistent distributions of particulate matter were detected in the micrographs of Al 1000 in the existence of a mixture of fly ash particles of bagasse and silicon carbide at different concentrations. The distribution of particles strongly affects the mechanical and physical characteristics of the composite materials. Consequently, the melt was added with magnesium, fly ash particles of bagasse and silicon carbide to improve the volume percentage of reinforcement.

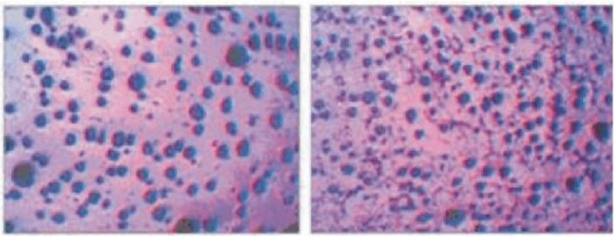

Fig. 7. Optical micrographic image (100X) of pure Al 6061. (a) before etching and (b) after etching

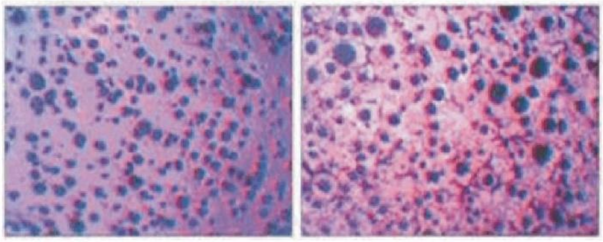

Fig. 8. Optical micrographic image (100X) of Al 6061/(5%SiC). (a)before etching and (b) after etching

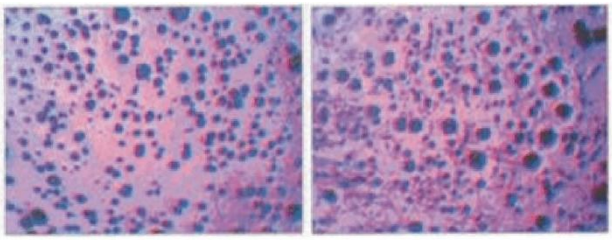

Fig. 9. Optical micrographic image (100X) of Al 6061/(10%SiC). (a)before etching and (b) after etching

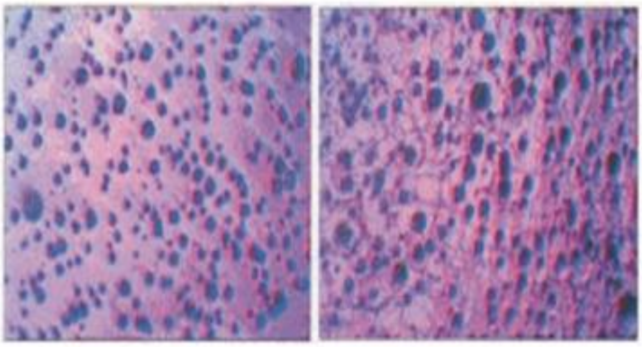

Fig. 10. Optical micrographic image (100X) of Al 6061/(5% fly ash). (a) before etching and (b) after etching

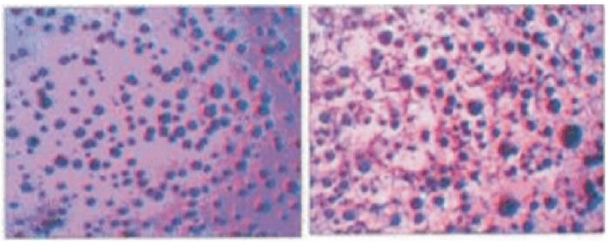

Fig. 11. Optical micrographic image (100X) of Al 6061/(10% fly ash). (a) before etching and (b) after etching

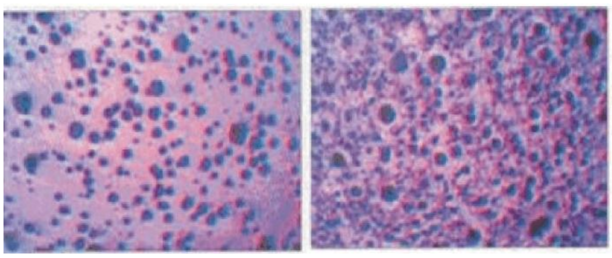

Fig. 12. Optical micrographic image (100X) of Al 6061/ (5%SiC+5%fly ash). (a) before etching and (b) after etching

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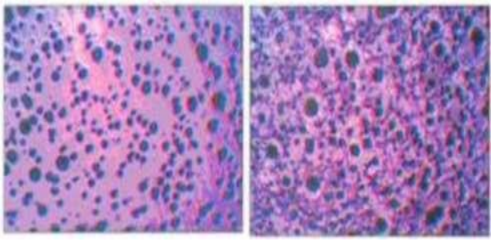

Fig. 13. Optical micrographic image (100X) of Al 6061/ (5%SiC +10%fly ash). (a) before etching and (b) after etching

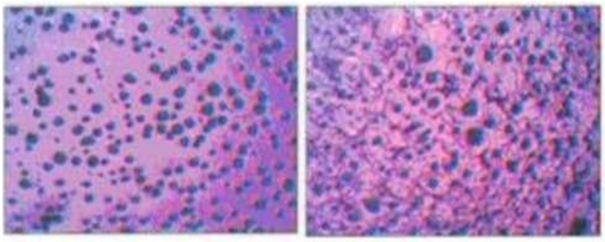

Fig. 14. Optical micrographic image (100X) of A6061/(10%SiC+5% fly ash). (a) before etching and (b) after etching

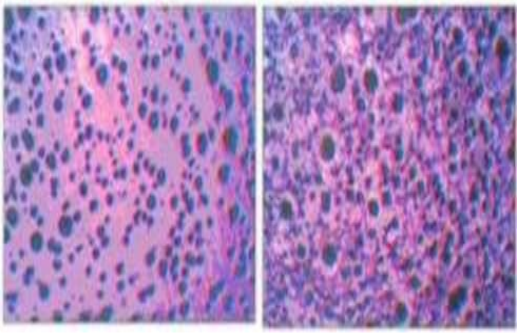

Fig. 15. Optical micrographic image (100X) of Al 6061/(10%SiC+10% fly ash). (a) before etching and (b) after etching

B. X-Ray Diffraction Analysis

The composite like fly ash particles of bagasse, silicon carbide, and its mixtures was added to respond with metallic liquid and to generate response products of different kinds. The reinforcement of the composite materials is affected due to the nature of the strengthening stage. Consequently, the mixture generated by the chemical reaction was identified by using an analysis of X-Ray diffraction. Figure 16 demonstrates the analysis of XRD of hybrid MMC of Al 6061 reinforced with the 10% mixture of fly ash particles of bagasse and silicon carbide composite because the possible reaction was taken place in these mixtures.

C. Mechanical Properties

Table 1 lists the findings of the mechanical characteristics of the hybrid MMC.

D. Density

Figure 17 illustrates the graphical representation of the experiment on the density of the composite materials in accordance with according to fly ash particles of bagasse, silicon carbide, and its mixtures.

Usually the fly ash particles of bagasse, silicon carbide contains low-density in comparison to aluminum. In this study, both fly ash particles of bagasse, silicon carbide has been utilized with the intensity not more than 2.2 g/cm^3. The principle of Archimedes has been employed to define the specific mass of the samples of the composite. Little pieces were cut from the samples were initially weighted in the air and then water and values of density have been computed by

$$\rho = \frac{\text{weight in air}}{\text{weight in the air - weight in water}} \text{ x}\rho \text{ water}$$

From Table 1 it was clearly detected that the experiment on the value of density was reduced for the Al 6061 reinforced silicon carbide, Al 6061 reinforced fly ash particles of bagasse and Al 6061 mixed with fly ash particles of bagasse and silicon carbide composite materials. The intensity was diminished because of the lower density of silicon carbide, fly ash particulates of bagasse composite and its mixtures in comparison to the plain Al 6061. It was also stated hypothetical values correspond closely with the empirical values. This suggests that there is a good interfacial adhesion among reinforcement and matrix. Therefore, the density was improved by adding the blend of silicon carbide and fly ash particulates of bagasse with Al 6061. The density was reduced with 2.06 g/cm^3 at elevated concentration ie Al 6061 reinforced with 10% of Silicon carbide and 10% of fly ash particulates of bagasse. This is about a 54% increase in comparison to pure Al 6061.

Table1.Mechanical characteristics of the hybrid MMC

Composition					Results				
Sample No.	Al(%) grams	Wt in % Mg	SiC	Fly ash	Density g/cm^3	Tensile strength N/mm^2	Yield strength N/mm^2	Elongation in %	Hardness (BHN)
1	100	1.5	0	0	2.6000	236	220	19.4	79.9
2	100	1.5	5	0	2.4660	248	236	19.0	85.3
3	100	1.5	10	0	2.3125	265	257	18.2	87.2
4	100	1.5	0	5	2.4400	245	233	16.3	80.6
5	100	1.5	0	10	2.2700	263	252	15.8	83.8
6	100	1.5	5	5	2.2000	276	262	14.4	88.2
7	100	1.5	5	10	2.1250	278	269	13.8	89.7
8	100	1.5	10	5	2.1170	285	275	12.8	93.9
9	100	1.5	10	10	2.0600	293	287	11.9	95.7

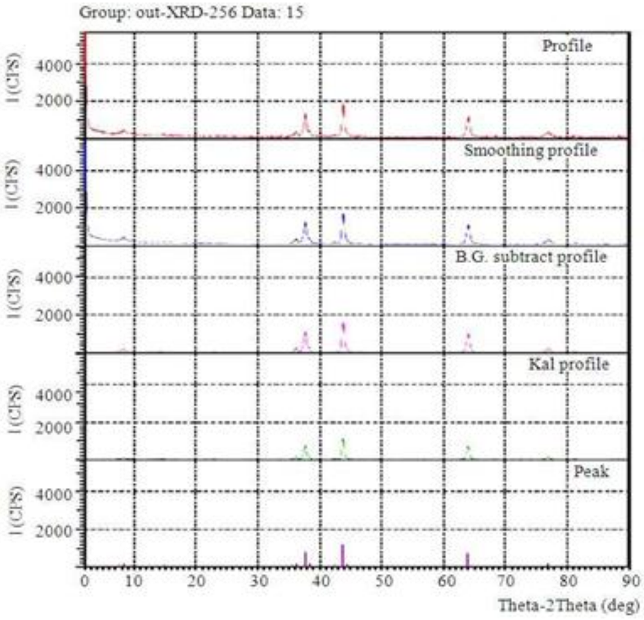

Fig. 16. XRD spectrum of the hybrid MMC[Al 6061/(10% fly ash of bagasse +10%Sic)]

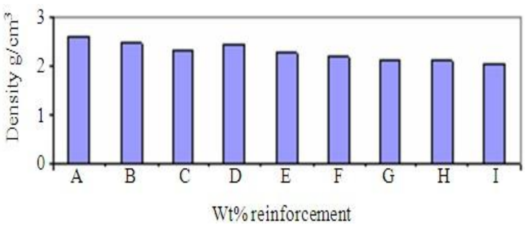

Fig. 17. Graphical illustration of the difference in density with various synthesis

E. Tensile Strength

Figure 18 demonstrates the graphical representation of the UTS of the composite materials as per the silicon carbide, fly ash particulates of bagasse and their mixtures. From the figure, it was observed that the UTS of composite materials is greater in comparison to plain Al 6061. UTS of plain Al 6061 is 236 N/mm^2 and this value will rise to 293 N/mm^2 for Al 6061/(10% silicon carbide +10% fly ash particulates of bagasse), 263 N/mm^2 for Al 6061/(10%fly ash particles of bagasse) and 265 N/mm^2 for Al 6061/(10% silicon carbide) composite which is approximately 57% enhancement in comparison to the plain Al 6061.

F. Yield Strength

Figure 19 demonstrates the graphical representation of the UTS of the composite materials as per the silicon carbide, fly ash particulates of bagasse and their mixtures.

From the figure, it was observed that the yield strength of composite materials is greater in comparison to plain Al 6061. Yield strength of plain Al 6061 is 220 N/mm^2 and this value improves to 287 N/mm^2 for Al 6061/(10% silicon carbide +10% fly ash particulates of bagasse), 252 N/mm^2 for Al 6061/(10% fly ash particulates of bagasse) and 257 N/mm^2 for Al 6061/(10% silicon carbide) composite which is approximately 67% enhancement in comparison to the plain Al 6061.

G. Elongation

Figure 20 demonstrates the graphical representation of the UTS of the composite materials as per the silicon carbide, fly ash particulates of bagasse and their mixtures.

From the figure, it was detected that the elongation of composite materials is inferior in comparison to plain Al 6061. Elongation of plain Al 6061 is stated as 19.4%, this value is reduced to 11.9% for Al 6061/(10% silicon carbide +10% fly ash particulates of bagasse), 15.8% for Al 6061/(10% fly ash particulates of bagasse) and 18.2% for Al 6061/(10% silicon carbide) composite which is approximately 75% with a decrease in comparison to plain Al 6061.

H. Hardness

Figure 21 demonstrates the graphical representation of the hardness of the composite materials as per the silicon carbide, fly ash particulates of bagasse and their mixtures.

From the figure, it was detected that there is an improvement in the hardness when weight fraction of silicon carbide, fly ash particulates of bagasse and their blends were increased. Consequently, the maximal hardness is detected at Al 6061/(10% silicon carbide +10% fly ash particulates of bagasse), which results in the deformity when exposed to strain. Embedding of fly ash particulate matter of bagasse with this greatly enhances the hardness and also deformity of the Al 6061. It is stated that the mixture of silicon carbide with fly ash particulate matter of bagasse has a superior hardness in comparison to the Al 6061.

Thus, it may be concluded that there is an improvement in the mechanical characteristics like hardness, yield strength, UTS and density of the composite materials when an improvement of silicon carbide, fly ash particulates of bagasse and their blends. . But there is a reduction in the elongation of the hybrid MMC in comparison to the plain Al 6061. The wettability has been enhanced by increasing the magnesium among the strengthening molecules and mechanical characteristics of the composites were improved by reinforcing the solid solution. Additionally, mechanical stirring in the semiconductor improves equal distribution among them.

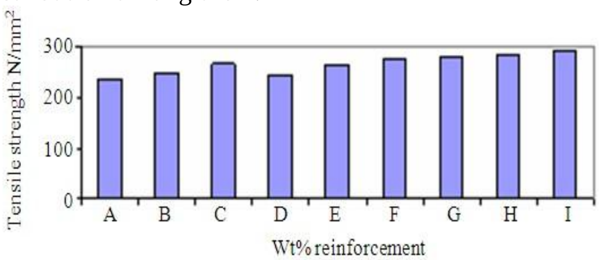

Fig. 18. Graphical illustration of the difference in UTS with various synthesis

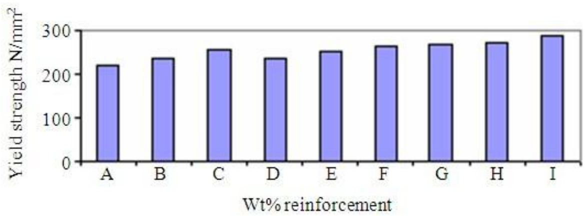

Fig. 19. Graphic example of the difference in yield strength with various synthesis

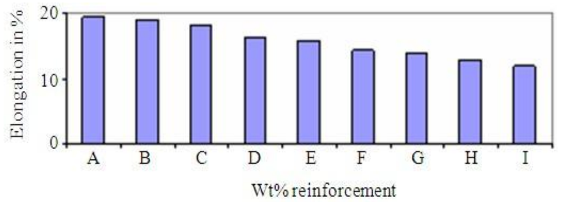

Fig. 20. A Graphic example of the difference in elongation with various synthesis

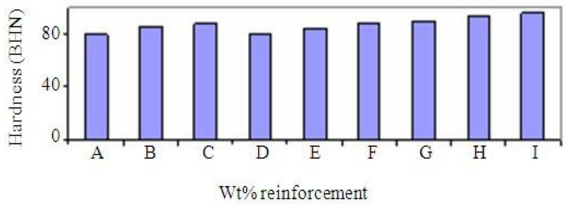

Fig. 21. Graphic example of the difference in hardness with various synthesis

IV. CONCLUSION

In this study, the method of stir casting was employed to fabricate the hybrid MMC like Al 6061 reinforced silicon carbide, Al6061 reinforced fly ash particulates of bagasse, and Al 6061 reinforced silicon carbide and fly ash particulates of bagasse with different concentrations. The purpose of this study is to develop the strengthening stage within the metal matrix with the reaction of silicon carbide, fly ash particulates of bagasse and their mixtures. The wettability was increased by adding 1.5% of pure magnesium. The composite materials were described by using optical microscopy and a method of x-ray diffraction.

According to empirical explanations, the following findings have been drawn: Optical micrographs have shown that both the fly ash particles of bagasse and silicon carbide have been well distributed throughout the aluminum matrix. The results of XRD have demonstrated inconsiderable changes occurring in the contents of components. The density of the composite materials was reduced by improving the reinforcement content. Therefore, it was discovered that the superior performance was attained in Al 6061 reinforced silicon carbide and fly ash particulates of bagasse in comparison to Al 6061 reinforced silicon carbide, Al6061 reinforced fly ash particulates of bagasse. An improvement in the percentage of reinforcement in the matrix leads to improvement in the hardness, yield strength, and UTS. The rate of elongation of the hybrid MMCs is had substantially reduced by adding a higher percentage of fly ash particles of bagasse and silicon carbide.

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