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EFFECT OF DATE SEED PARTICULATES ON MECHANICAL PROPERTIES OF ALUMINIUM ALLOY

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Abstract: The results of an experimental investigation of mechanical properties of date seed particles reinforced aluminium alloy composites, processed by stir casting method are reported in this paper. Two sets of composites with date seed of 300 and 500 µm particle sizes were used. The ranges of particle size used were based on the weight fraction when sieve analysis was conducted on the sample collected for the work. Each grain size had four types of composite samples with the reinforcement weight fractions of 5, 10, 15 and 20%. The mechanical properties considered were the tensile strength, Impact and hardness behaviors. Unreinforced aluminium alloy samples were also tested for the same properties. It was found that the hardness and tensile strength increases with the increase in the weight fraction and the fracture toughness decreases with increase in the weight fraction of reinforced date seeds particles. It was concluded that the improvement in the mechanical properties can be well accredited to the high dislocation density.

Keywords: aluminium alloy; date seed particle late; mechanical properties; metal matrix composites; reinforcement

INTRODUCTION

Metal matrix composites (MMCs) have found application in many areas of daily life for quite some time these materials are produced *in situ* from the conventional production and processing (Karl 2006). According to Chaudhary et al, 2015, the growth of MMCs has been one of the main innovations in the field of material development in the past 2 decades. MMCs is a new generation of engineering materials in which particle reinforcement is incorporated into a metal matrix to improve its strength, specific stiffness, wear resistance, excellent corrosion resistance and high elastic modulus. MMCs are the forerunners amongst different classes of composites. Over the past two decades metal matrix composites have been transformed from a topic of scientific and intellectual interest to a material of broad technological and commercial significance (Ron and Alcan 1994, Kok and Ozdin 2006). Aluminium based metal matrix composites have received increasing attention in recent years as engineering materials with most of them possessing the advantages of high strength, hardness and wear resistance (Kok and Ozdin 2006). Particulate reinforced aluminium alloy composites have shown a significant improvement in tribological properties, including sliding and abrasive wear resistance and seizure resistance (Kok 2003). In aluminium alloy matrix composites reinforced with ceramic particles, it has been generally agreed that increasing the particle content can enhance wear resistance (Kok 2003, Kok and Ozdin 2006). Al2O3 and SiC particles are the most commonly used reinforcements in MMCs and the addition of these reinforcements to aluminium alloys has been the subject of a considerable amount of research work (Udomphol 2007).

(Anilkumar, H.S. et al. 2010) studied mechanical properties of fly ash reinforced aluminium alloy (Al6061) composites using stir casting technique. It was reported that the tensile strength, compression strength and the material hardness increased with increase in the weight fraction of reinforced fly ash and decreased with increase in particle size of the fly ash. The alloy ductility decreased with increase in the weight fraction of reinforced fly ash and decreased with increase in particle size of the fly ash (Kok and Ozdin 2006). (Charles and Arunachalam 2004) and (Anilkumar, H.S. et al. 2010) studied the properties of aluminium alloy hybrid composites (Al-alloy/Silicon carbide (SiC)/fly ash). They reported that the wear and hardness were enhanced by increasing volume fraction of SiC. They also reported that the tensile strength was high at 10 volume fraction of SiC and decreased as the volume fraction increased. A further study was carried out by (Manoj, Deepak et al. 2009) on the development of aluminium based silicon carbide particulate metal matrix composite, where stir casting method was used to form metal matrix composite. Their result shows that an increase in the composition of SiC, increased the hardness and impact strength of the composite. It was also reveal that the best results was obtained at 25% weight fraction of 320 grit size SiC particles (Saravanana and Senthil 2013).

The mechanical properties of aluminum alloy (Al2024) reinforced with SiC and graphite particles ware investigated by (Basavarajappa, Chandramohan et al. 2004). Their results revealed that the mechanical properties such as hardness, yield strength, ultimate tensile strength and compressive strength of the composite increased predominantly with the increase in volume fraction of the reinforcement. However, the investigation of the abrasive wear behavior of an Al–4.0Cu–0.75Mg alloy composites reinforced with SiC, Si3N4, Al2O3 produced by stir casting techniques by (Sato and Mehrabian 1976) showed that the wear rates of particulate composites were lower than those of the matrix aluminium alloy by a factor of 4. (Kok and Ozdin 2006) investigated the wear resistance of aluminium alloy reinforced with Al_2O_3 particles fabricated by a vortex method, their result reveal that the abrasion wear resistance and wear resistance increased with increase in Al_2O_3 particle size and content. The effect of Al_2O_3 particle size on the wear resistance was more significant than that of the particle content.

The work of (Kok 2003) on the effect of Al_2O_3 particle content and size on the porosity and mechanical properties of Al_2O_3 particle-reinforced 2024 aluminium alloy composites and examination of the wettability problem during the incorporation of Al_2O_3 particles into the aluminium alloys. The result of the investigation shows that the density of the composites increased with increasing weight percentage and size of particles, whereas the porosity of the composites increased with decreasing size and increasing weight percentage of the particles. The wettability and the bonding force between Al alloy/Al_2O_3 particles were improved by the applied pressure after the casting. The tensile strength and hardness of MMCs increased while elongation decreased with decreasing size and increasing weight percentage of the particles (Udomphol 2007). The work of Ramesh et al, (2014) titled "Effect of reinforcement of natural residue (Quarry Dust) to enhance the properties of AMMCs, reported that here is significant improvement in the tensile strength and the hardness with addition of quarry dust particulates, having the tensile strength of matrix alloy and Al-quarry dust composites improved from 150 MPa to 172 MPa

(Ameh, Isa et al. 2015) worked on "Effect of particle size and concentration on the mechanical properties of polyester/ date palm seed particulate composites". They achieved optimum tensile strength of 16.7619 N/mm^2 and elastic modulus of 343.8 N/mm^2 at 15wt% and 10wt% loading respectively with 0.5mm particles. The percent water absorption was found to be least for 0.5mm particle size while hardness was enhanced to the maximum of 74 HRF (Rockwell Hardness Factor) by 2mm particle size at 25wt% loading. In a related work of (Alaa 2015) titled "Investigation of tensile and impact of composite materials reinforced with natural materials." He concluded that the composite specimens reinforced with olive seeds powder gives high mechanical than composites specimens reinforced with dates seeds powder. He recorded value of modulus of elasticity and tensile strength at 18 wt% and grain size of 300μm for two types of powder. Effects of MoSi2 reinforcement and aging treatment on hardness and wear properties of AA 2024-MoSi2 nanocomposites were investigated by Sameezadeh et al, 2011. They reported that, with increased volume fraction of nano MoSi2 up to 3-4%, the hardness of the composites continuously increased and that the particle agglomeration reduced the amount of effective nano particulate available and the particle strengthening effect diminished.

It can be observed from the aforementioned literature reported that addition of date seed as reinforcement in aluminium alloy is rarely available. Hence there is need to investigate the effect addition of date seed particles in aluminium composite. According to (Souhail, Christophe et al. 2004), date fruit has been an important crop in arid and semiarid regions. This fruits plays an important part in the economic and social lives of the people of these regions. The fruit of the date palm is well known as a staple food composing of a fleshy pericarp and seed. The pits of date palm (seed) are a waste product of many industries, after transformation of the date fruits. It has been reported by (Mohammad, Mostafa et al. 2014) and (Mohamed, Souhail et al. 2013) that in some date-processing countries, such as Tunisia, date seeds are discarded as wastes or used as fodder for domestic farm animals.

In most parts of northern Nigeria where date fruit is been heavily consumed, the seed is usually discarded as wastes after the fleshy pericap of the date has been eaten. More importantly, these date seeds turn out to be wastes after the date fruit has been consumed (eaten). Furthermore, the aluminium alloy used as melt in this work is off-cuts from the production of aluminium doors and windows. The addition of date seeds particles as reinforcement in aluminium composites was achieved through stir casting process with various weight fractions and grain sizes of date seeds particles. The effect of the reinforcing material on mechanical property of the aluminium composite was investigated and reported in this work.

MATERIALS AND METHOD

— Reinforcement Material

The materials (date seeds) used in this work (Figure 1) was sourced from local vendor, with fleshy pericarp of the date fruits removed to obtain the seeds (Figure 1a). The seeds were sundried for one week to reduce and maintain the moisture content in other to aid the pulverizing process. After drying, local grinding machine was used to pulverize the date seeds, the pulverized seed particles (Figure 1b) were sieved using standard sieve sizes of 600, 500, 420 and 300 μm successively.

(a) (b)

Figure 1. Date Seed Used in this Work (a) Raw Date Seeds and (b) Pulverized Date Seed

— Matrix Material

In this work, the matrix phase of the composite is aluminium alloy. The aluminium was cast from aluminium scrap. The scraps (Figure 2) that was used for the melt were sourced from aluminium window frame and door fitters as off-cuts from aluminium alloy 6063 commonly referred to as architectural alloy which are normally used in window frames and doors as well as extrusions of parts. To minimize the level of impurity in the melt, the scraps were cleaned using steam and hand towel to removed dirt and colored inscriptions on the aluminium scraps. Table 1 gives the elemental composition of the aluminium scrap used.

Figure 2. The Scrap (off-cuts) from Aluminium Alloy 6063

Table 1. Elemental Compositions of the Aluminium Used

Element	Mg	Si	Fe	Cr	Cu
wt. %	0.45-0.9	0.2-0.6	0.35	0.10	0.10
Element	Ti	Mn	Zn	Al	
wt. %	0.10	0.10	0.10	Bal	

EXPERIMENTAL PROCEDURE

— Sample Preparation

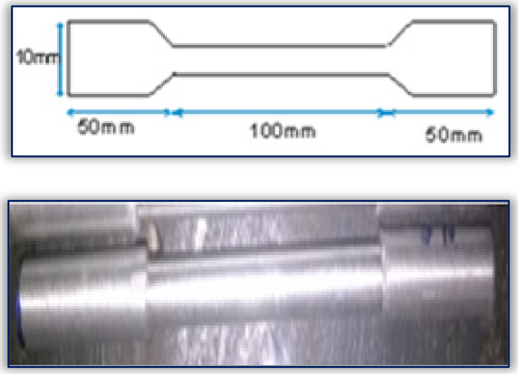
The quantity of Aluminium scrap and date seeds particles required to produce composites having 5, 10, 15, and 20% weight of date seeds particles were evaluated using charge calculations. The date seeds particles were initially preheated at a temperature of 180°C for 20 minutes to help improve wettability with the aluminium alloy. Aluminium alloy was weighed and charged into the crucible. The loaded crucible was put into the heating chamber of the electric furnace and the temperature of the furnace was set to 850°C (150°C above the liquidus temperature of aluminium).

The preheated date seeds particles was added at this temperature and stirring of the slurry was performed manually for 2 minutes. The composite slurry was then reheated to 850°C and a further stirring was carried out for another 2 minutes to help improve the distribution of the date seeds particles in the molten aluminium alloy. The molten composite was then cast into prepared sand molds. Unreinforced aluminium alloy was also prepared by casting for control experimentation.

— Testing for Mechanical Properties

≡ Tensile Test

The tensile test was conducted according to ASTM E8/(E8M) (ASTM 2016) on each of the cast sample using Testometric Universal Testing Machine (TUTM) model FS50AT, with maximum load capacity of 50KN. The tensile test samples (Figure 3) were 10mm diameter and gauge length of 100mm, machined from the cast aluminium composites. Average of three readings was taken for each sample prepared from the cast aluminium alloy. Analyses of the tensile results were generated and obtained from the machine.

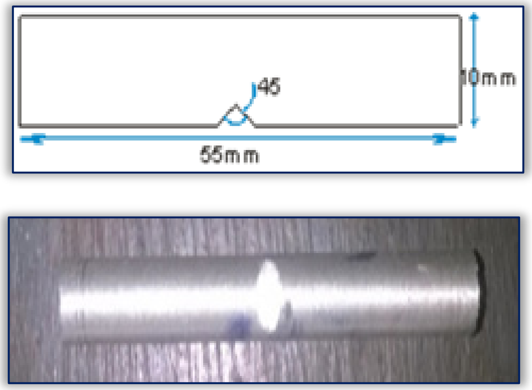


(a)

(b)

Figure 3. Prepared Samples for Tensile Test (a) Schematic and (b) Sample Piece

Figure 4 shows the impact test workpiece sample. In line with the ASTM E23-16b, the test was carried out on Avery-Denison Izod impact testing machine (model: 6705U/33122). The samples were prepared with gauge length of 55mm, diameter of 10mm, and notch depth and angle of mm and 45°C respectively machined from the cast aluminium composites.



(a)

(b)

Figure 4. Sample for Izod Impact Test (a) Schematic and (b) Sample piece

≡ Hardness Test

The permanent depth of indentation was carried out on 30 mm height samples (Figure 5) cut out of the as-cast aluminium composite for hardness test according to ASTM B647-10. The sample surfaces were prepared by grinding on emery paper of 400 grits thereafter polished to obtain flat and smooth surface before setting the samples on Rockwell hardness machine of model MCT-381DS. Average of three readings was taken for each sample.

Figure 5. One of the Prepared Samples with Indentations

RESULTS AND DISCUSSIONS

≡ Tensile Test

Figure 6 shows the variation of tensile strength of the composites with different weight fractions of date seeds particles. It can be noted that the stress at upper yield increased with increase in the weight percentage of date seeds particles. Therefore the date seeds particles act as barriers to the dislocations when taking up the load applied (Basavarajappa, Chandramohan et al. 2004). The date seed particles obstruct the advancing dislocation front, thereby strengthening the matrix (Anilkumar, H.S. et al. 2010).

Also, as the size of the date seeds particles increased, there was increase in tensile strength. Poor bonding of smaller size date seeds particles with the matrix could be the reason for this behavior. The observed improvement in tensile strength of the composite is attributed to the fact that the filler date seeds particles possess higher strength. The decrease in the tensile strength of the samples with date seeds particles weight fraction beyond 10% is due to the poor wettability of the reinforcement with the matrix.

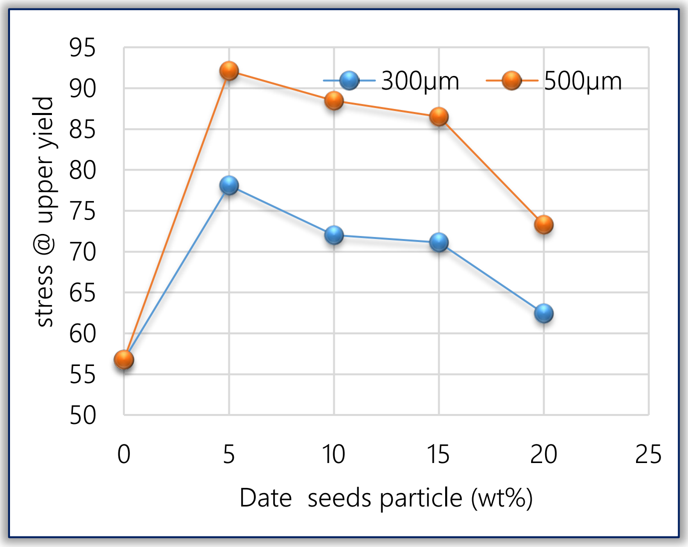


Figure 6. Variation of Tensile Strength with Weight Fraction of Date Seeds Particles

— Impact Test

The relation between weight fraction of date seeds particles reinforcement and impact energy of cast aluminium alloy composites at different grain sizes of 300µm and 500µm is shown in Figure 7. The fracture toughness (which is a measure of the composites resistance to crack propagation) was observed to decrease with increase in weight fraction of date seeds particles which is consistent with the trend in most hard particle reinforced metal matrix composites (Saravanana and Senthil 2013). The increased sites (particles, particle/matrix interfaces, and particle clusters) for crack nucleation with increasing weight fraction of the date seed particles were likely to be responsible for this observed trend, similar to the work of (Saravanana and Senthil 2013).

Also as it was observed in tensile test result (Figure 6), increase in date seed particles size from 300 to 500 *µm* (Figure 7) gave a corresponding increase in impact energy of the aluminum composite.

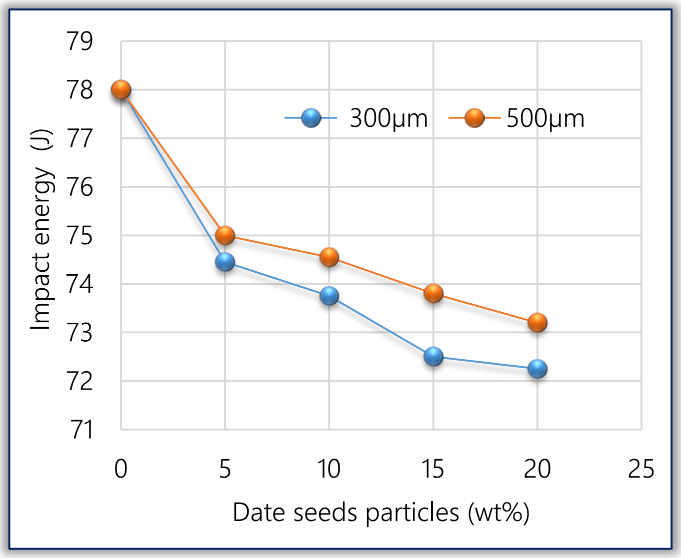


Figure 7. Variation of Impart Energy (J) with Weight Fraction of Date Seeds Particle

— Hardness

The behaviour of weight percentage of date seeds particles reinforcement on hardness of cast aluminium alloy composites at different grain sizes of 300 and 500 µm is shown in Figure 8.

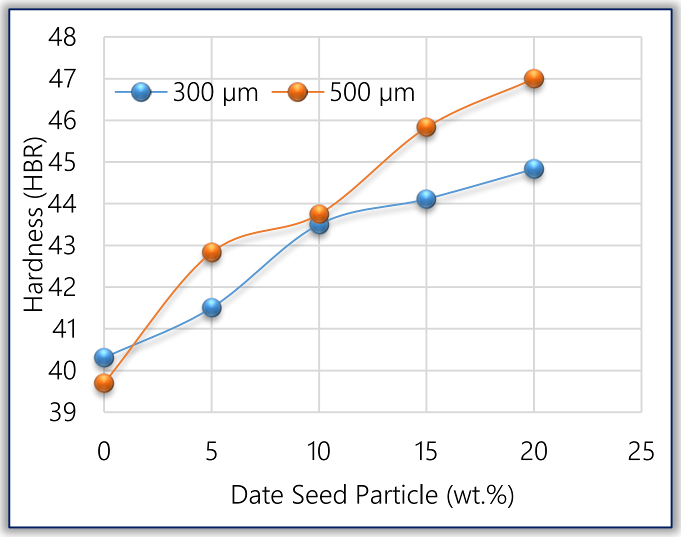


Figure 8. Variation of Hardness with Weight Fraction of Date Seeds Particles

It can be observed that the hardness of the composite increase steadily with increase in weight fraction of the date seeds particles up to 10%wt before the two size particles show a slight reduction in their hardness.

However, the particle size of 500 µm has higher hardness values of 47 HBR as against that of 300µm particle size that has 44.83 HBR. This hardness behavior occurs due to increases in surface area of the matrix as a result of reduced grain size of the aluminium. Thus the presence of such hard surface area offers more resistance to plastic deformation which leads to increase hardness. Similar finding was reported by Saravanan, et al, 2015; Saravanana and Senthil 2013 and Swamy, et al, 2011 Miracle 2005.

CONCLUSIONS & FUTURE WORK

The conclusions drawn from the present work can be summarized as follows:

- The date seeds particulate as reinforcement in aluminium alloy composite can be used to improve the mechanical properties of aluminium alloy composite.
- The hardness and tensile strength increase with increase in the weight fraction while the impact strength of the aluminium alloy decrease with increase in the weight fraction of reinforced date seeds particles.
- It can also be concluded that the improvement in the mechanical properties can be accredited to high dislocation density of the material

The following future works have been planned for this research: The effects of heat treatments on the various weight fractions (5, 10, 15 and 20%) of the compositions and the microstructural analysis of the various weight fraction of the compositions

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