Mechanical Properties of Particulate Periwinkle Shell- Aluminum 6061 Metal Matrix Composite produced by Two-Step Casting

Rambabu M[1*], Ravindra Babu P[2], Ranga Babu JA[3]

[*1]Pg Student, Mechanical Engineering Department, Gudlavalleru Engineering College, Gudlavalleru-521356 India,
[2] Professor and Principal, Mechanical Engineering Department, Gudlavalleru Engineering College, Gudlavalleru-521356 India.
[2]Associate Professor, Mechanical Engineering Department, Gudlavalleru Engineering College, Gudlavalleru-521356 India.

Abstract : Technological advancements and promotion of compact structures always raises challenging tasks to a design engineers. The innovative ideas and creative designs are demanding hybrid mechanical properties. However, the conventional material may not be able meet this demand. The current work aims to investigate the mechanical properties of Al-Particulate periwinkle shell(PPS) MMC and compared the properties of composites with the base material of aluminum 6061 (AA6061) alloy. Periwinkle shells were milled to particle sizes of 75µm and used to produce PPS-Al MMC at 1 and 2wt % filler loadings using two-step stir casting technique. The mechanical properties and microstructures of the composite materials were compared with AA6061. It was observed that the filler distributes uniformly in the matrix, it may due to due to two-step casting technique. The mechanical properties like hardness and Compression modulus was Improved when the filler was used to reinforce the alloy

Keywords: **Composites, Periwinkle shell, Aluminum, Mechanical properties, Microstructure**

I. INTRODUCTION"

Researchers have shown interests in the development of aluminum metal matrix composite (Al-MMCs) because of their potential applications in industries such as aerospace, automotive, thermal management, electrical and electronic as well as sports. Al-MMCs are engineered materials made by incorporating non-metallic reinforcement(s) into aluminum or its alloy so as to tailor the properties such as strength, hardness, stiffness, electrical and thermal conductivity as well as other properties of the material. Al-MMCs offer high strength to weight ratio and high stiffness to weight ratio [1]. In the composite, the good properties of the metal such as light weight, high ductility, electrical and thermal conductivities are combined with the properties of the reinforcement such as low coefficient of thermal expansion, high stiffness, and strength and abrasion resistance to produce material with desired properties. The reinforcement could be in the form of continuous and discontinuous fibres, whiskers or particulate [2]. The applications of Al-MMCs are limited by high cost and hence the search for cheap agricultural materials as reinforcements to enhance their applications [3]. Particulate Al-MMCs (PAl-MMCs) are less expensive compared to continuous fibre reinforced Al-MMCs.

(CFRAL-MMCs) and are usually produced by either the solid state (powder metallurgy processing) or liquid state (stir casting, infiltration and *in-situ*) processes [2]. The particulate ceramics materials used to reinforce aluminum are usually carbides, oxides and borides such as Sic, Al2O3, TiB, Tic, etc. [4]. The properties of the material are affected by factors such as the type of reinforcement, the method of production, the volume or mass fraction of reinforcement, the particle size of the reinforcement, the shape and distribution of the reinforcement in the matrix. For example, the impact strength and hardness of particulate Al-SiC MMC have been reported to increase with increasing weight fraction of reinforcement and at 25wt% of the reinforcement; there was over 100% increase in strength and about 90% improvement in the hardness of the composite over those of the pure aluminum. The method of stirring also affected the dispersion of the reinforcement in the matrix [5].

Prasad Reddy et al: Investigated In the samples of different sizes containing 10 wt. % SiCp has maximum compressive strength and among them 70 nm of size SiCp particles has maximum compressive strength of 601MPa.Without T6 treatment the nano composites were increased by 4.3% of yield strength and 6.25% of ultimate strength compared to base alloy but the elongation has decreased to 12.8 %. The T6 treated reformed components were increased by 11.4% of yield strength and 4% ultimate strength compared to the base alloy and the elongation decreased to 12.4%.[6]. Madhu kumar et al: Hardness value increases by increasing the glass particulates and maximum hardness value is obtained for 9 wt% glass particluate reinforced MMC. The tensile strength of MMCs is improved from 119Mpa to 192Mpa [7]. Himanshu kala et al: The density of AMC-AV is apparently lower than the base metal i.e., pure aluminium in comparison with AMC-FA. The ultimate tensile and yield strengths of AMC-AV are significantly higher than that of pure aluminium. tensile strength and ultimate yield strength were found for specimen AMC-FA are 104.21 MPa and 53.36MPa respectively. In the case of the specimen AMC-AV, the values of the properties are 119.83 MPa and 62.97 MPa respectively. The impact strength obtained for the specimens AMC-FA an AMC-AV are 1.775 J/mm2 and 1.8J/mm2 respectively. The impact strength of AMC-AV and AMC-FA was more or less the same. A substantial increase of hardness is observed in AMC-AV as compared to that of AMC-FA [8]. J.E. Oghenevweta et al: The addition of the carbonized maize stalk particulate in Al–Si–Mg alloy affects the microstructures and mechanical properties of Al–Si–Mg/carbonized maize stalk particle composites. The hardness values of Al–Si–Mg/carbonized maize stalk composites increase from 6.80HRF to 20.20HRF as the wt% carbonized maize stalk particulate addition increases. The tensile strength of the developed Al–Si–Mg/carbonized maize stalk particle composite increases from 50.86 to 85.60 N/mm2 as the carbonized maize stalk addition increases while the tensile modulus also increases from 43.42 to 70.25 N/mm2 as the carbonized maize stalk particles increases.

2. MATERIALS AND METHODOLOGY

2.1 MATERIALS

The major materials required for this work were aluminum 6061 alloy (AA6061) and periwinkle shells. **6061** is a precipitation-hardened aluminum alloy, containing magnesium and silicon as its major alloying elements. Originally called "Alloy 61S", it was developed in 1935. It has good mechanical properties, exhibits good weldability, and is very commonly extruded (second in popularity only to 6063 It is one of the most common alloys of aluminum for general-purpose use. The chemical composition of alloy is shown in Table 1.

Table.1 Chemical composition of 6061 Alloy

Alloy	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
6061	0.65	0.7	0.25	0.15	0.9	0.07	0.25	0.15	Reminder

Fig.1 Al-6061 Alloy

2.2 MATERIALS PREPARATION

Periwinkle shells were, washed, boiled in water at 100OC for 40 minutes, allowed to cool, thoroughly washed to remove sand particles and dirt and thereafter dried under the sun for two days and heated in an oven at 110oC for thirty minute to remove all moisture. The shells were crushed with hammer mill, pulverized with a our regular home cooked mixy jar and sieved to 75µm particle sizes using BS standard sieves.

Table. 2 Chemical composition of PPS

Element	Ca	Fe	Si	Mo	Al	P	S	Sn	Sb	Others
Content	70.3	0.50	0.07	0.23	0.19	0.27	0.39	0.45	0.45	27.0

2.3 Experimental Procedure

Two-step casting was used to produce the composite materials. The quantities of AA6061 and PPS required producing composites having 1 and 2 weight percent of the PPS were weighed out using digital electric balance based on charge calculations. The aluminum 6061 was charged into a gas-fired crucible furnace and heated to 730^{O}C which is above the liquidus temperature of the alloy and the liquid was allowed to cool in a furnace to a semi-solid state of temperature about 600^{0}C.

(a)

(b)

Fig .2 (a) Stir Casting setup, (b) Casted fingers

The calculated PPS was added at this temperature and the semi-solid mixture was stirred manually with a spindle for one minute. The composite slurry was re- heated to 730ºC and stirred vigorously for five minutes and the molten composite was cast in metallic die. Unreinforced AA6061 was also cast as the control specimen.

3. RESULTS AND DISCUSSION

3.1 Density

The particle density of PPS determined was 1.3g/cm^3 while the density of the AA6061 alloy was 2.7g/cm^3.Since PPS has lower density than AA6061 alloy, its addition to the produce composite will make the density of the composite to be less than that of the alloy. At the same volume, PPS-ALMMCs will weigh less than alumunium alloy. The average theoretical and measured density values of the AA 6061 alloy and its respective composites were given in table 3. It was observed that the addition of PPS into the AA 6061 alloy matrix significantly increased the density of the resultant composites in compare to the base alloy.

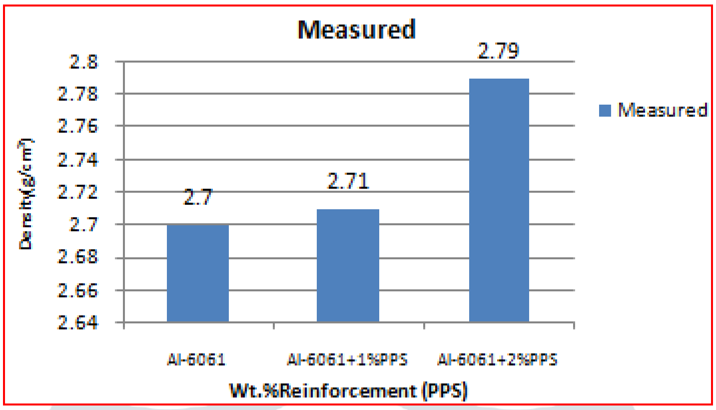


Fig.3 Density variation of Composites

3.2 Hardness

The hardness of the aluminium alloy and composites was determined with Vickers Hardness Tester (LECO AT 700 Micro hardness Tester). The dimension of each specimen for hardness testing was 10x10mm and each specimen was grinded and polished to obtain a flat smooth surface. During the testing, a load of 100gm was applied for 10s on the specimen through square based pyramid indenter and the hardness readings taken in a standard manner.

Fig.4 Hardness specimen

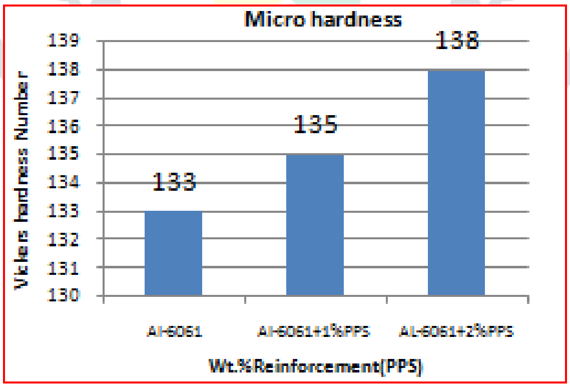
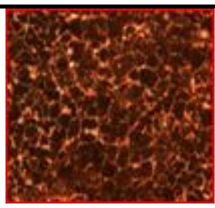


Fig.5 Graph of Percentage composition v/s Vickers Hardness Number

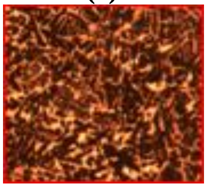
The readings were taken in three different points at the surface of the hardness specimen and the average computed as the hardness of the specimen. The hardness of AA6061 alloy and PPS-Al MMC are shown in Figure 14. In the composite with 75µm PPS, there was a increase in hardness at 1wt% filler addition followed by continuous increase in hardness at 2wt% in composite, the composite exhibited about 4% improvement in hardness over that of the alloy.

3.3 Microstructure

The optical micrographs of the AA6061 alloy and those of the composites are shown in Figures 6.Figure (a) shows the micrograph of the unreinforced alloy. It can be seen that the grains are coarse compared to Figures (b), (c) with finer grains when PPS of 75µm was used as the filer. PPS of smaller particle size with higher surface area refined the grains of the alloy. It was also observed that PPS dispersed in AA6061 alloy as seen from the homogeneity of the microstructures. Figures (b),(c) respectively show the micrographs of the composites reinforced with 1 and 2wt% PPS of 75µm particle size.



(a)



(b)

(C)

Fig.6. Microstructure of (a) pure 6061, (b) 1 % PPS (c) 2% PPS

3.4. Wear Properties

Dry sliding wear tests have been carried out on a pin-on - disc apparatus (Model: Ducom TR- 20 LE) by sliding a cylindrical pin against the surface of hardened steel disc (with a hardness value of HRC 62) under ambient condition. The Pin-on-disc wear testing experimental set up was shown in figure 8. The disc was ground to a smooth surface finish and renewed for each test. The wear test specimens were prepared from the alloy and composite castings in the dimensions of 8 mm ø and 25 mm length. Prior to testing, the test samples were polished with emery paper and cleaned in acetone, dried and then weighed using an electronic balance (Model: Sartorius Research R 200 D Germany) with a resolution of 0.1 mg.

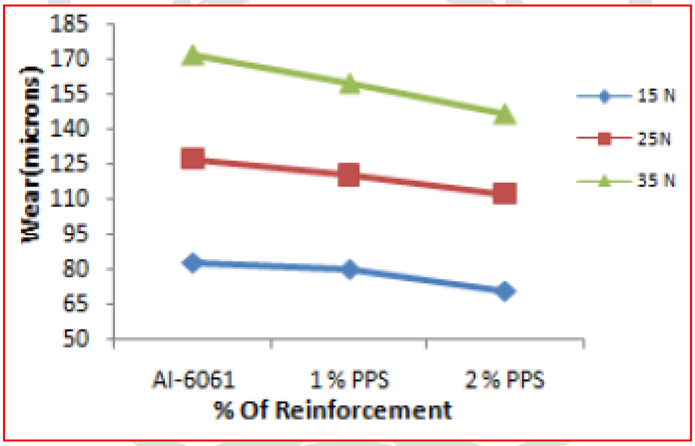


Fig.7. Shows Graph between wear vs. % of PPS

The variation of wear of composite and unreinforced Al-6061 with normal loads is shown in Fig. 7. In this work samples were placed on the wear disc and the sliding wear tests were carried out at various loads, time and sliding speed. The test was conducted in loads of 15N, 25N and 35N at a sliding velocity of 1.5m/s at 8 min. It is observed that the wear of the composite is lower when compared to unreinforced aluminum. Fig.8 reveals graph between frictional force and % of PPS composite. Composite have high frictional force compared to matrix material Al-6061 at various loads.

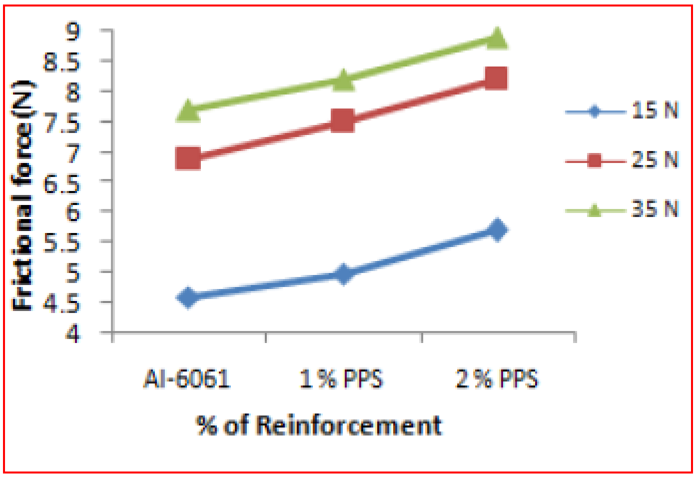


Fig.8.Shows Graph between Frictional force vs. % of PPS

4. CONCLUSION

In the present study investigations were made on the mechanical properties of aluminium6061/PPS composites and the conclusions are summarized below:

PPS can be effectively used as reinforcement as it possesses good interfacial bonding. The composites were fabricated with minimum porosity by stir casting method. Density of the composites increased to a maximum of 6% compared to the base aluminium alloy. Enhanced hardness of MMC's was found to be improved with increased weight fraction of PPS particle in AA6061 matrix. This indicates that the hard reinforcement have imparted strength to the matrix alloy. Hardness of composite the composites increased to a maximum 4.2% compared to the base alloy.

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