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Mechanical Performance of Heat Treated AA7075/E-Glass/Cenosphere Composites

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Abstract

The influence of heat treatment on the mechanical characteristics of cenosphere/aluminum alloy/E-Glass fibre hybrid composites is discussed. To synthesize hybrid composites, the stir casting process was employed. Tensile properties and characteristic hardness of the alloy and its composites have been determined under both heat treatment and as cast conditions. Microstructure exhibits consistent particle spreading in both cast and heat treatment settings. When compared to unheat treated counterparts, heat treated alloys and composites exhibit a significant improvement in tensile and hardness characteristics. Heat treatment significantly reduces the ductility of composites. Scanning electron microscopy was used to examine tensile cracked surfaces in the presence of hybrid reinforcements in order to determine possible fracture processes.

Keywords: Aluminium composites, Cenosphere, E-Glass fiber, Mechanical properties.

1. Introduction

Compared to traditionally available alloys the Aluminum composites are suitable in majority of the applications due to it's beneficial properties of such as very low density, greater strength, and fatigue resistance. For this reason, the Aluminum composites tends to be most appropriate or even suggested for the utilization in automobile and aerospace sectors because the components experiences repetitive loads[1-5]. Especially in automobile parts as well as aerospace the Aluminum based hybrid composites usually needs exceptional requirements which can be appropriately addressed because of their enhanced as well as excellent properties. SiC, Boron nitride, Silicon Nitride, fly ash, Graphite, ZrB_2, TiB_2, TiC, Al_2O_3, TiO_2 etc are classified as the most commonly reinforcements form as well as they are obtainable in the type of particulates, fibers as well as whiskers[6-15]. Amith kumar etal [16] have analyzed, the impact of graphite as well as TiO_2 hybrid reinforcement on microstructure and studied the AA7075 alloy's Mechanical behavior. By employing stir-casting as well as hot rolling techniques, the samples of AA7075 and hybrid composites of its have been fabricated. A great dispersion of reinforcement's particles of graphite as well as Titanium dioxide was shown by the examination of Microstructure also the particles with exceptional bond with AA7075 matrix alloy. Inclusion of hybrid reinforcements in both hot rolled as well as cast condition, leads to a noticeable improvisation in the tensile strength as well as micro hardness of hybrid composites. Pradeep kumar et al [17] synthesized an Al-based hybrid composites material using Titanium dioxide and silicon carbide as reinforcements and AA7075 as matrix using the stir casting process. Tensile and hardness evaluations, as well as SEM tests, have been performed on the produced composites. Silicon carbide and titanium diboride particles are dispersed equally throughout the matrix. The specimens of AA7075+ TiO_2 +SiC composites demonstrated higher tensile strength as well as high hardness. The authors further confirm that there is a strong connection between the hybrid reinforcement and the aluminium alloy as observed by the microstructure. Kumar et al [18] used liquid metallurgy to fabricate composites of Aluminum 6061 alloy and Titanium diboride. To hot forge the composites and metal, a temperature of 500^0 C was used. Tensile property evaluations, microstructure research, and micro hardness testing have been performed on matrix alloy, cast, and forged composites. The author verifies that the TiB2 particles in the matrix alloy are distributed uniformly, as proven by cast and forged composites, with forged composites exhibiting much greater homogeneity than cast composites. In terms of ultimate tensile strength and microhardness, composites beat unreinforced alloys. Composites have a lesser ductility than matrix alloys. Gajakosh et al. [19] investigated the mechanical properties of AA7075-based composites reinforced with Titanium diboride. Following the casting process, composites and alloys were also hot rolled. Microstructure analysis indicates a great dispersion of titanium diboride particles and a strong connection between the particles and matrix. Under hot rolled circumstances, the composites shown a considerable improvement in ductility, strength, and micro hardness. To achieve superior mechanical qualities, a mix of fibre and particle type phases was tested in the current study. E-Glass fibre and cenosphere were joined in different ratios due to their exceptional and unique material features, and an attempt is being made to improve the mechanical properties of hybrid composites by applying the stir casting process [20-22]. Stir casting is one of the simplest processes for creating metal matrix composites. Furthermore, an attempt was made using heat treatment to perform mechanical assessments in order to create composites with improved characteristics [23-25]. According to published data, the majority of experts have shown a significant interest in improving the properties of MMCs by applying optimum heat treatment. Even now, data on the characteristics of heat-treated hybrid composites are poorly available. In light of recent advancements, this work focuses on the production and evaluation of mechanical characteristics of cast and heat-treated AA7075/Censophere/E-Glass fibre metal matrix composites.

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2. Materials and Process

Among engineering materials, the AA7075 alloy has a huge range of applications as a consequence of it AA7075 alloy has been selected as matrix. AA7075 alloy ingots have been obtained from M/s PMC Corporation, Bengaluru, India. The AA7075 has the chemical composition as described in Table 1. The cenosphere particles with dimensions 10 to 30 microns were considered as primary reinforcement and E-Glass fiber of length 4-6 mm size was utilized as secondary reinforcement was procured from M/s Tesppo International, Bangalore, INDIA. SEM and EDS of Cenosphere and E-Glass fibers are presented in Fig.1a-b and 2a-b respectively. By stir casting route the AA7075/Cenosphere/E-Glass fiber composite was manufactured by using 6-kilowatt electrical resistance furnace utilizing graphite based crucible. Ceramic coated mechanical stirrer with motor facility was adopted to uniformly mix the hybrid reinforcements by mechanical stirring. Prior to composite preparation, the reinforcement particles were preheated to a temperature of 200^0 C to remove the moisture and to activate the surface in order to obtain the best wettability [26-27]. The entrapped gases were thrown out by adding Hexachloroethane degassing billets. The mechanical stirrer was used to mix cenosphere and E-glass fiber particles in aluminium alloy by rotating at an rpm of 250 in the molten aluminum. Before pouring aluminium composite mixture into cast iron moulds, the slag was taken out of the molten mixture. Solidified composite materials were machined as per standards for various tests.

Table: 1

Composition of Aluminum 7075 alloy

Element	Cu	Cr	Mn	Mg	Si	Ti	Zn	Fe	Al
Wt. %	1.8	0.2	0.4	1.9	0.5	0.15	3.25	0.5	Balance

In a muffle furnace, the composite and matrix alloy were both heated to 520^0 degrees Celsius for two hours, resulting in a solutionizing temperature of 520^0 degrees Celsius. Quenching was performed on both solutionised alloys and composites utilizing water as the quenching medium. The ageing process was carried out at a temperature of 190o C for a total of two to ten hours, with the duration varied. Hardness was determined by the use of Brinell hardness testing. In this test, a 10 kg weight was applied to the polished surface of the aluminum alloy 7075 and its hybrid composites. It was decided to conduct the inquiry by using an average of five hardness testing data. A universal testing machine (UTM) was used to evaluate the tensile properties of the material at room temperature, in line with the ASTM E8-82 methodology. Diagram of a tension sample with dimensions is depicted in Figure 3 (right). The examination was carried out by obtaining an average of three tensile samples from each of the compositions under consideration. When it came to examining broken surfaces, scanning electron microscopy was utilized.

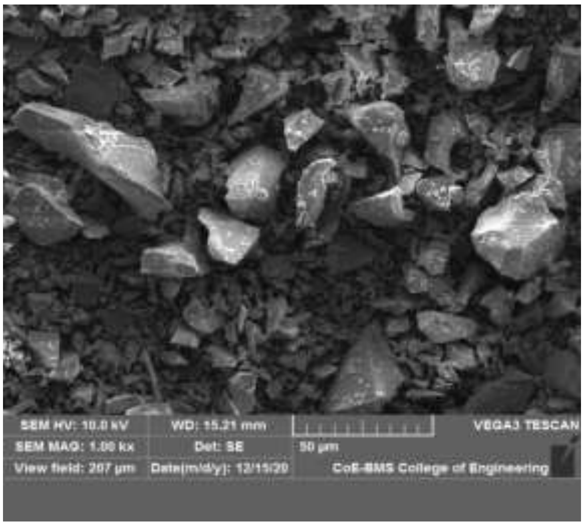


Fig.1a SEM of Cenosphere

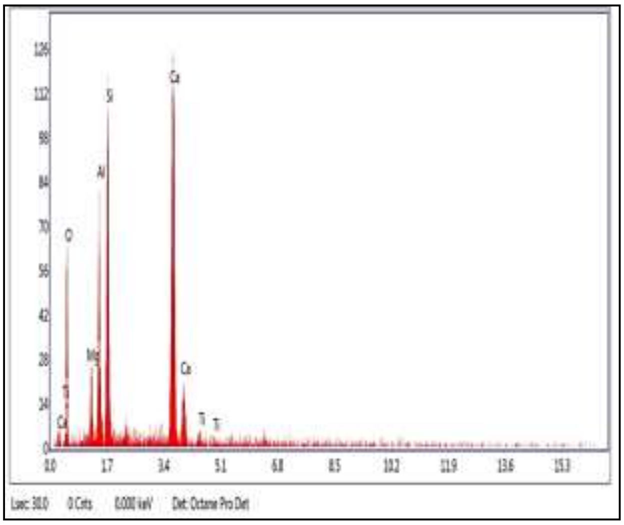


Fig.1b EDS of Cenosphere

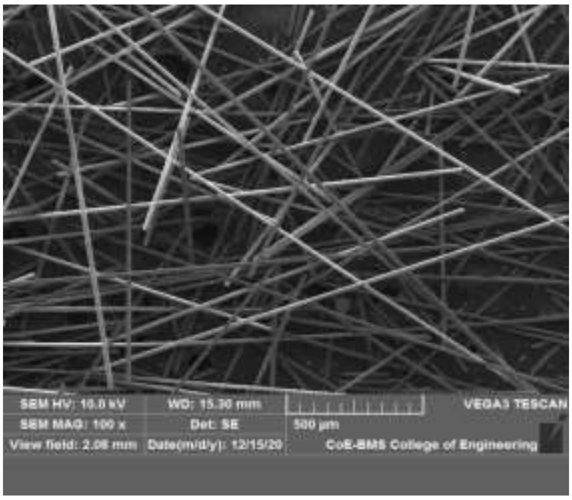


Fig.2a SEM of E-Glass fiber

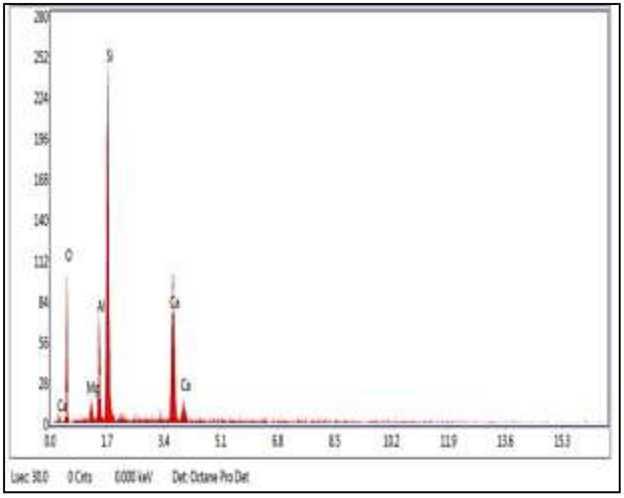


Fig.2b EDS of E-Glass fiber

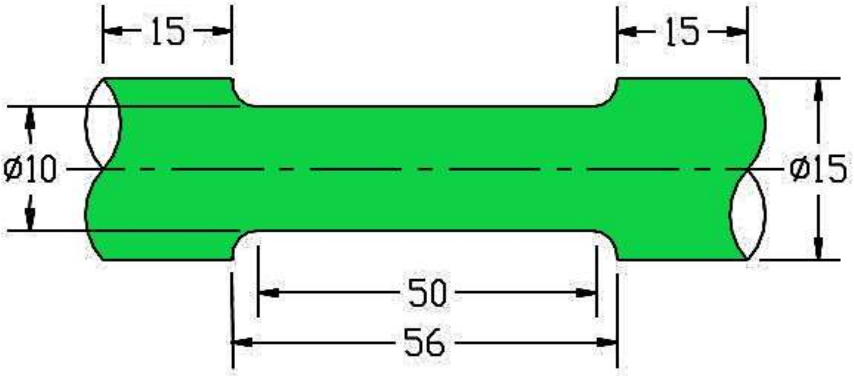
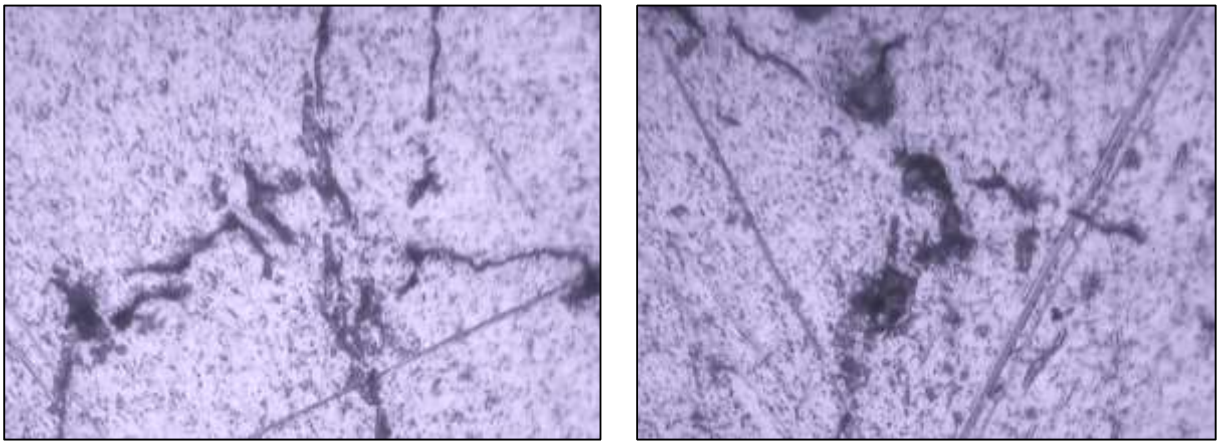


Fig.3 Schematic diagram of tensile specimen

3. Results and Discussion

3.1 Microstructure

Fig.4a-d presents the optical micrographs of AA7075 based hybrid composites before and after heat treatment. It is visible from the images that the dispersion of primary and secondary phases is fairly uniform with exceptional merallurgical bond between AA7075 alloy and reinforcements**.**



(a)AA7075 alloy

(b) AA7075+6%Cenopshere+5%E-glass fiber

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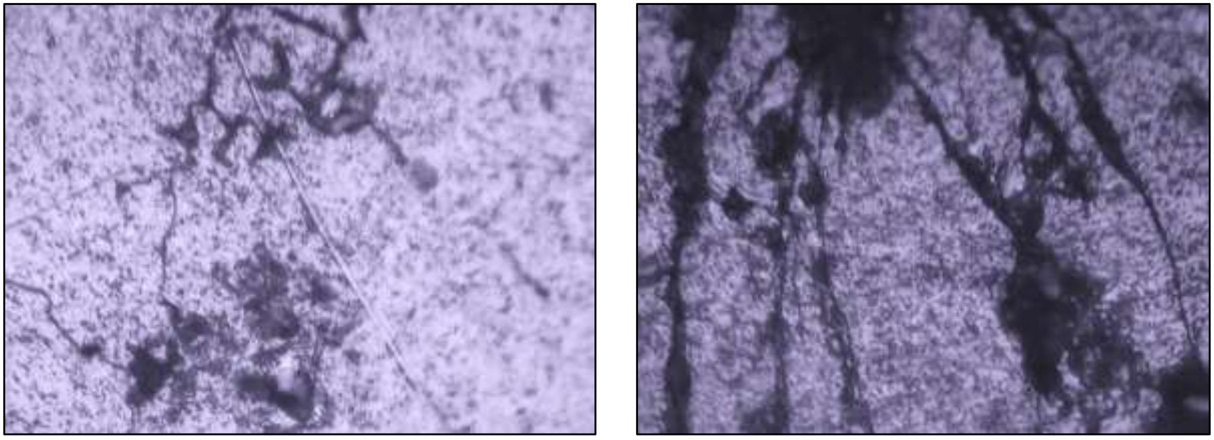


(c)AA7075 alloy (Heat Treated -8 hours aged)

(d)AA7075+6%Cenopshere+5%E-glass fiber (Heat Treated -8 hours aged)

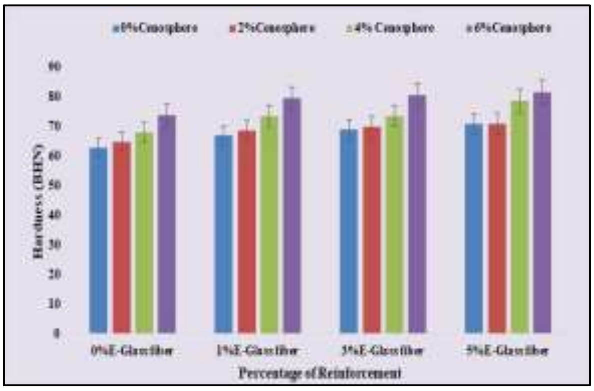
Fig.4(a-d) Optical micrographs of AA7075 alloy and AA7075+6%Cenopshere+5%E-glass fiber hybrid composites before and after heat treatment

When the AA7075 alloy and AA7075+cenosphere+E-Glass fibre hybrid composites are subjected to heat treatment, the optical micrographs of the alloy and the hybrid composites are shown in Fig.4c and d. (Solutionzed and aged at various ageing periods). The optical imaging results show that there are no visible casting flaws can be detected. This implies that the synthesised castings are of good quality, which may be attributed to the employment of the optimum manufacturing conditions possible during the manufacturing process. Following solutionization of both the AA7075 matrix alloy and the AA7075+E-glass fiber+cenosphere hybrid composites, the optical micrograph clearly demonstrates the production of intermetallic precipitates in both the AA7075 matrix alloy and the hybrid composites. The micrographs show that the bulk of intermetallic precipitates are related to grain boundaries, which is consistent with the findings. Aluminum solid solution granules have been ringed by bright intermetallic precipitates that have formed around them. As shown in the micrographs, the intermetallic precipitates Al2Cu, Al2Cu/Al eutectic (lamellar morphology), and $MgZn_2$ phase are the most commonly visible intermetallic precipitates in the alpha–aluminum grains of AA7075 alloy. However, there are a few with block shaped and lamellar morphology that have been identified in the alpha–aluminum grains of AA7075 alloy. [28-31].

3.2 Hardness

After solutionising, quenching, and ageing for a total of ten hours in two-hour increments, the difference in hardness between the AA7075 alloy and its hybrid composites is displayed in Fig.5. (a-e). Hardness of alloy and hybrid composites increases after 8 hours as the ageing duration increases; however, hardness of both alloy and hybrid composites reduces after 8 hours, as the ageing duration decreases. As a result of the figure, it is experienced. It was discovered in Figures 5(a-e) that, as a result of solutionising and quenching, both unreinforced alloy and hybrid composites displayed significantly higher hardness in all circumstances examined as compared to unheated alloy It has been shown that for AA7075+6% Cenopshere+5% E-glass fibre, an ageing time of 8 hours results in a maximum enhancement of 49.2 percent. The increased hardness of the composite as a result of an increased ageing time may be attributed to a technique in which an increased ageing length accelerates the kinetics of precipitation hardening throughout the ageing process.

The intermetallic precipitate particles works as obstruction provides protection from the motion of dislocation as well as hereafter enhances the hardness of the alloy and hybrid composites. For a dislocation to circulate it ought to be possibly cut from the intermetallic precipitates or perhaps even move between them. In both cases an improved stress value is essential when equated with alloy that does not have some precipitates. Nevertheless, long ageing period will leads to coarser intermetallic precipitation.



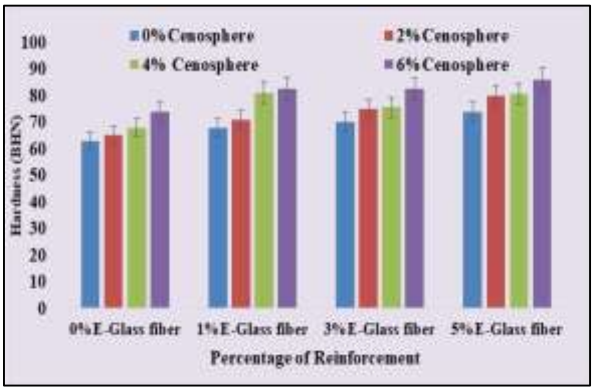


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Fig.5a. Difference in hardness with hybrid reinforcements (2Hour aged)

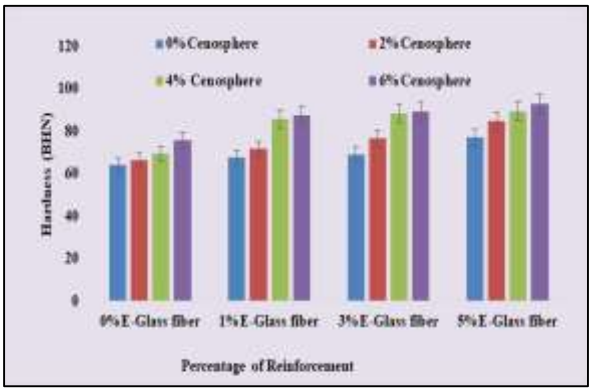

Fig.5b. Difference in hardness with hybrid reinforcements (4Hour aged)

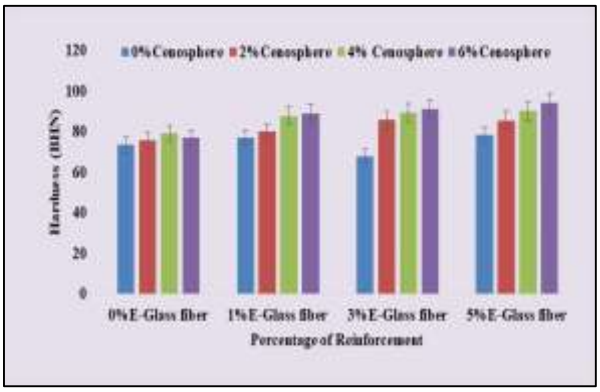

Fig.5c. Difference in hardness with dual reinforcements (6Hour aged)

Fig.5d. Difference in hardness with dual reinforcements (8Hour aged)

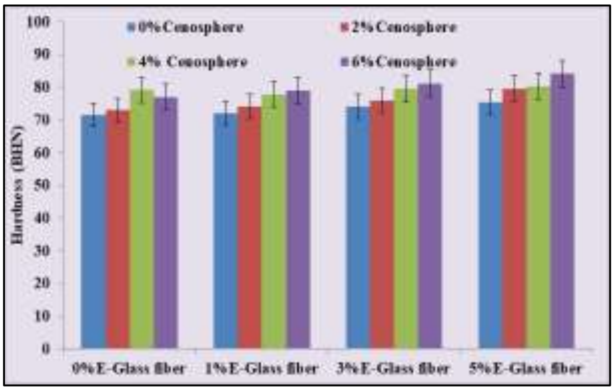

Fig.5e. Difference in hardness with dual reinforcements (10-Hour aged)

The reason behind the abatement within the hardness after reaching the peak valuation at the top ageing period could be due to the point that the intermetallic precipitates begin to cultivate and also turnout being a lot less in number. For the small particles to liquefy and larger particles to get up there has to be diffusion of the solute. As the precipitates can become huge and not many the distance between precipitates enlarges making it easier for dislocation to pass through causing a decreased shear stress and thus hardness. From the graphs it's found that for a certain content of E glass fiber and also Cenosphere particles, there is a regular enhancement in the hardness with expansion in the ageing duration around eight hours, with rise in the ageing duration, it is observed that there is a little drop in the hardness. Under each among the aged period studied, there is a constant increase in the hardness with increased both reinforcements. Nevertheless, both alloy and its hybrid composites under eight hours ageing conditions, exhibited greatest hardness then ageing duration used in the present study [32-34]**.**

3.3 Ultimate Tensile strength

Figure 6 (a-e) depicts the effect of heat treatment on the ultimate tensile strength of AA7075 alloy and hybrid composites of it. After heat treatment, the strength of the composites is seen to increase in a reasonable manner. There is a continuous increase in UTS with ageing period. Peak strength was recorded with 8 hours ageing similar to hardness trend. With for AA7075 alloy, the increment in strength after heat treatment is 21% while in case of hybrid composite with AA7075 6%Cenosphere-5%E glass fiber it is 28%. The increment in ultimate tensile strength values is after heat treatment is associated to development of precipitates. Based on micrographs discussed in earlier section, it may be found the bright coloured precipitates are noticed. These precipitates match to Al_2Cu phase (block shaped), Al_2Cu/Al eutectic and $MgZn_2$. The development of $MgZn_2$ mostly is determined by the Mg: Zn ratio in AA7075 alloy. Hence, influenced by the ratio along with the precipitate morphology it is possible to find out the microstructure that consists of coherent $MgZn_2$ precipitates. Highest increment in strength of approximately ~28 % was shown by AA7075+6 %Cenosphere+5%E-glass fibre hybrid composite in heat treatment conditions that of composite with no heat treatment. The probable cause could be uniform dispersion of precipitates which resulted in highest increment in strength unlike other composites. Similar trend was observed in case of hardness in which the AA7075 cenosphere three % E glass fiber hybrid composite displayed highest hardness before and after heat treatment. Consequently, it is possible to conclude that the hardness and ultimate tensile strength have pattern distribution that is similar with respect to the trend. The probable reason could be uniform dispersion of precipitates which resulted in highest increment in strength unlike other composites. Similar trend was observed in case of hardness where the AA7075+4%Cenosphere+3% E-glass fiber hybrid composite displayed highest hardness before and after heat treatment [32-36].

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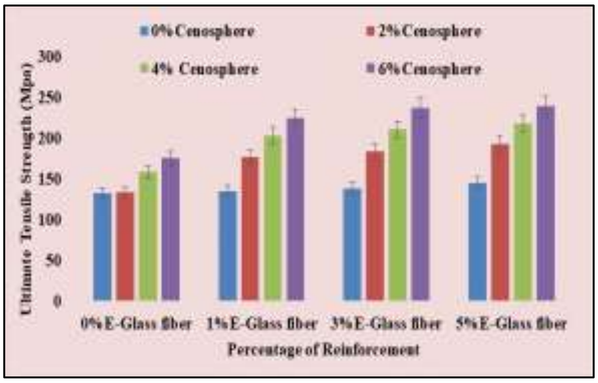


Fig.6a Variation of Ultimate Tensile Strength with dual reinforcements (Heat treated-2Hour aged)

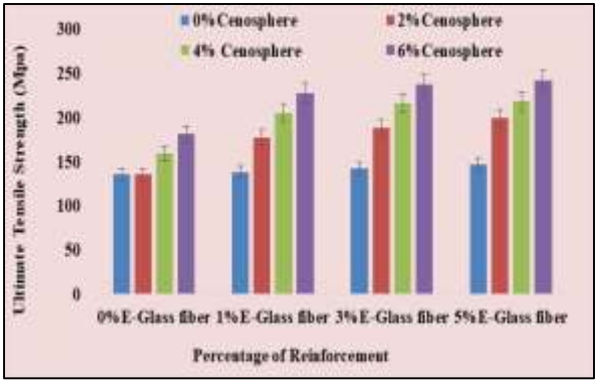


Fig.6b Variation of Ultimate Tensile Strength with dual reinforcements (Heat treated-4 Hour aged)

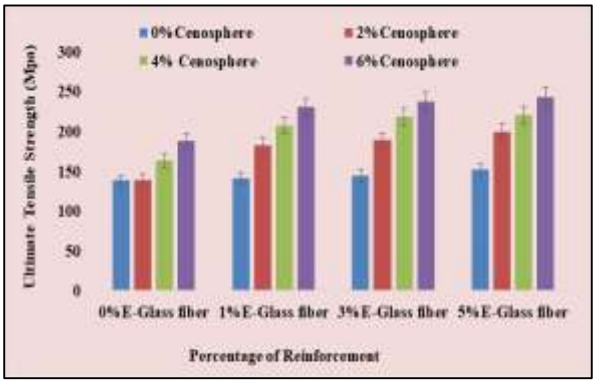


Fig.6c Variation of Ultimate Tensile Strength with dual reinforcements (Heat treated-6 Hour aged)

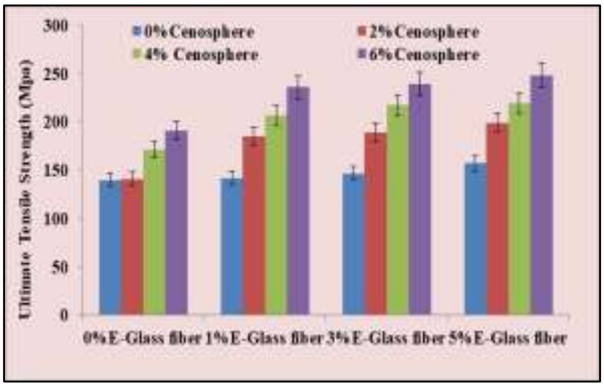


Fig.6d Variation of Ultimate Tensile Strength with dual reinforcements (Heat treated-8 Hour aged)

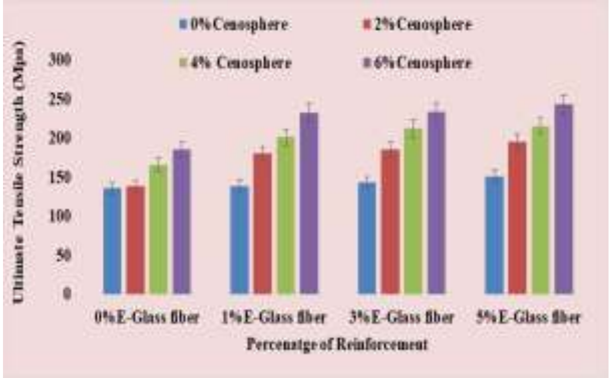


Fig.6d Variation of Ultimate Tensile Strength with dual reinforcements (Heat treated-10 Hour aged)

3.4 Ductility

The ductility of AA7075 alloy as well as hybrid composites of are shown after heat treatment which is displayed in figure.7 (a d). It was observed that after heat treatment the ductility of AA7075 alloy was reduced to 8.4 % from 4.7 % for alloy with no heat treatment.

Fig.7a Variation of ductility with dual reinforcements (Heat treated-2 Hour aged)

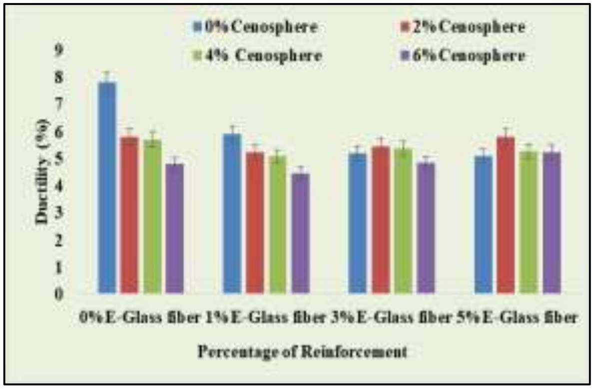


Fig.7b Variation of ductility with dual reinforcements (Heat treated-4 Hour aged)

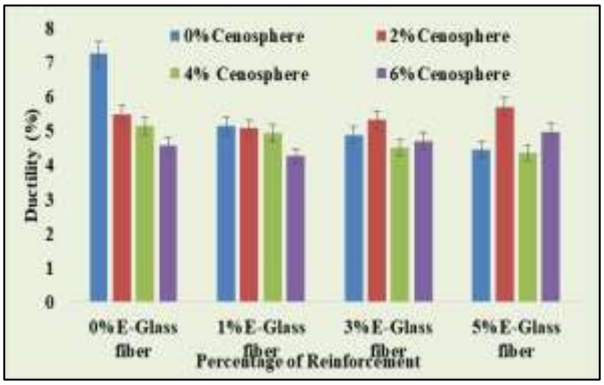


Fig.7c Variation of ductility with dual reinforcements (Heat treated-6 Hour aged)

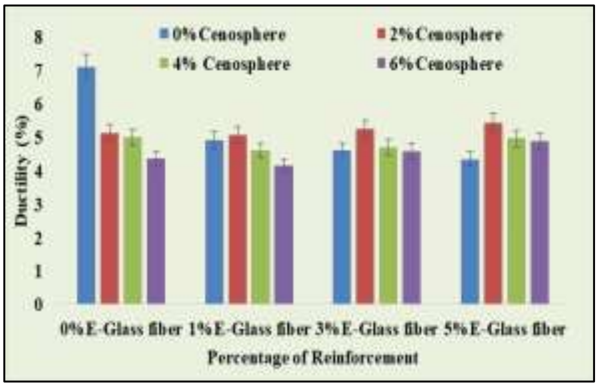


Fig.7c Variation of ductility with dual reinforcements (Heat treated-8 Hour aged)

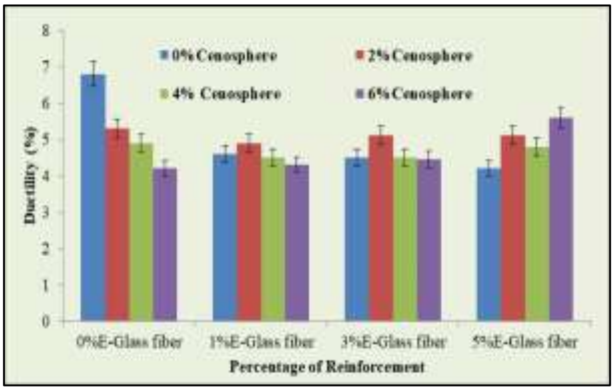
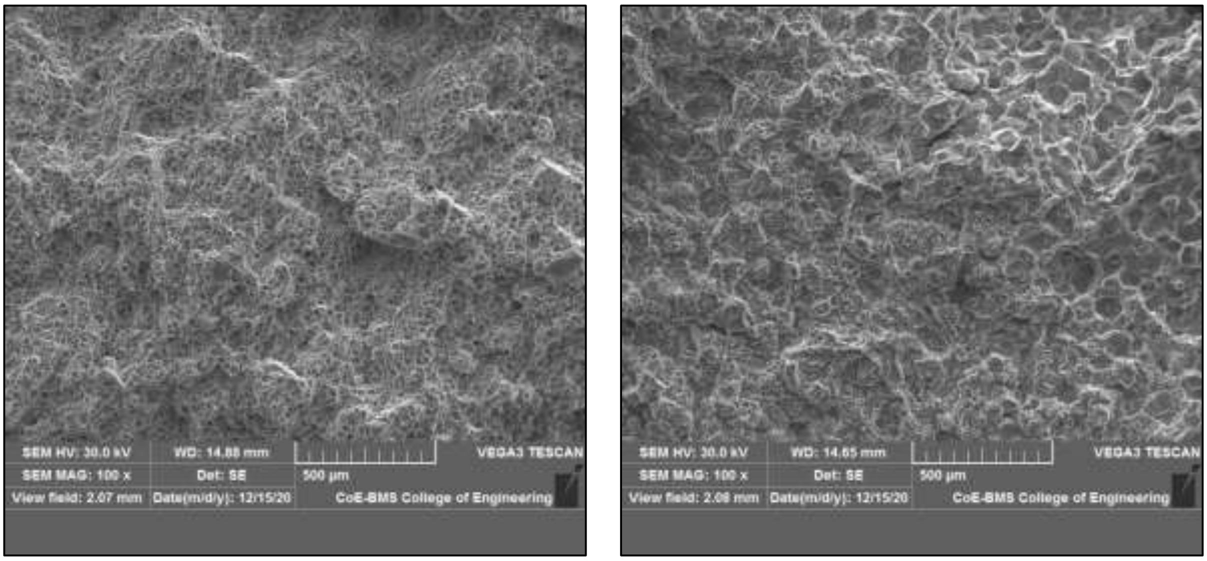


Fig.7c Variation of ductility with dual reinforcements (Heat treated-10 Hour aged)

The hybrid composites have shown further decrease in ductility in comparison with that with no heat treated ones. Out of all, AA7075-6% cenosphere -5 % E glass fiber hybrid composite showed maximum drop in ductility of approximately ~7.5 % after heat treatment in comparison with that of before heat treatment. The reason behind decreased ductility is presence of inherently brittle phases serves as probable sites for crack nucleation resulting in reduction in ductility of composites. But the main stage in case heat treated alloy and composites is that, voids are created near precipitates due to stress concentration during the tensile test. These voids will be uniformly distributed if the precipitated are dispersed uniformly in the AA7075 matrix. In such a scenario the composite will have the tendency to fail earlier than that of those with no heat treated.

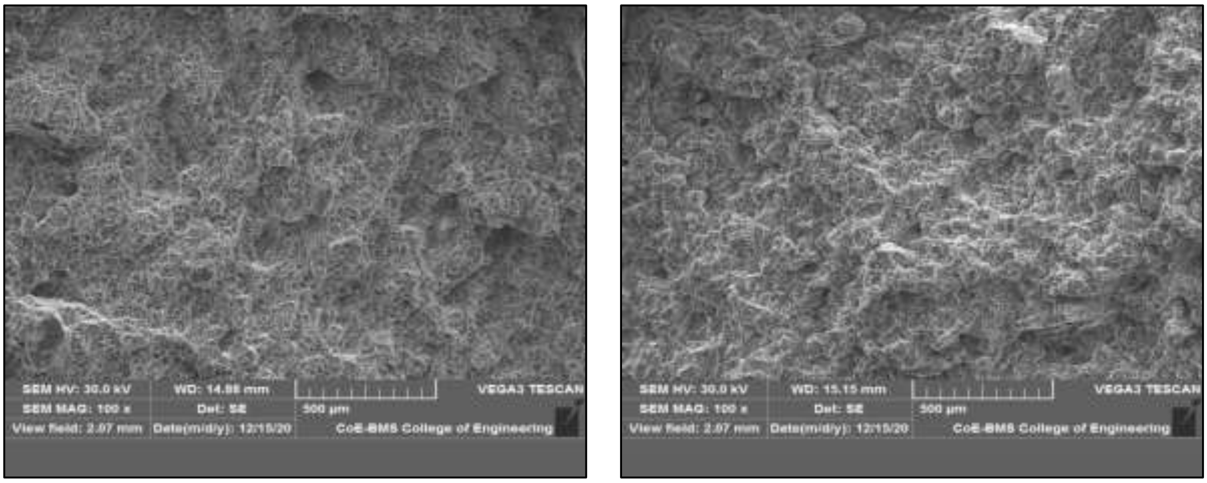
3.5 Fractography

In order to connect the microstructure and tensile behaviour of hybrid metal matrix composites, it's really essential to recognize the fracture mechanism of the AA7075 alloy as well as hybrid composites of its. Failure of AA7075 alloy as shown in Fig.8 a & b, is quite ductile in nature. The occurrence of cavities and their growth indicates that the alloy has encountered considerable quantity of plastic deformation prior to ultimate breakage. Close inspection shows the occurrence of scratch ridges and dimples which designates the typical ductile failure in case of AA7075 alloy. Further, when compared to the hybrid composites the dimples which are deeper as well as bigger is noticed in alloy and that obviously illustrates why alloy seems to have a lot more ductility. Failure in composites occurs predominantly as a result of cracks generated at the reinforcement contact and matrix, resulting to cracking or debonding of reinforcements. SEM micrograph Fig.8 of hybrid composite with dual reinforcements showed brittle failure macroscopically but ductile breakdown on close inspection. Microscopically, smaller size cavities and their development imply ductile fracture. In the case of hybrid composites with the highest dual content of reinforcement, SEM micrographs show that the failure is primarily brittle in nature. The absence of plastic deformation features such as indentations indicates that this hybrid composite failed due to brittle rupture. In addition, particle debonding has been seen in a few locations. Particle debonding is caused primarily by high localised stresses surrounding the particles caused by an increase in flow stress.



(a)Unheat treated AA7075 alloy

(b)Unheat treated AA7075+Cenosphere+E-Glass fiber



(c)Heat Treatment AA7075 alloy

(d) Heat Treatment AA7075+Cenosphere+E-Glass fiber

Fig.8(a-d) SEM of fractured surfaces before and after heat treatment

Furthermore, prior to pre-crack, such high stresses allow voids to form in between the damaged particles, resulting in brittleness failure. Brittle failure of hybrid composites with the greatest dual reinforcement concentration is thus caused by a lack of plastic deformation and particle debonding. Many studies have found brittle breakdown of composites as a result of similar processes. Furthermore, compared to matrix alloys, the matrix cavitation in hybrid composites is substantially higher owing to the large number of shattered reinforcements, as shown in figure.8. During deformation, the segments of shattered reinforcements separate, resulting in a void. Additionally, microcracks in the hybrid composites' fracture surface were discovered at the reinforcement-matrix interface and are propagating through the reinforcements. A mismatch between the reinforcement and matrix thermal coefficients results in the start of cracks in the matrix near the contact.

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4.0 Conclusions

1. By stir-casting route, AA7075/Cenosphere/E-Glass fiber composites were successfully fabricated and heat treated.
2. Microstructure analysis confirms the Cenosphere and E-Glass fibers are homogeneously dispersed all over aluminum alloy.
3. Ageing studies were performed between 2 to 10 hours in steps of two hours; extreme hardness and tensile strength was recorded for 8 hours of ageing.
4. As aluminum alloys and hybrid composites are heat treated, they display increased tensile strength, increased hardness, and decreased ductility when compared to unheated alloys and composites.
5. Fractography investigations reveal that the failure mechanisms of the tensile samples are a mix of brittle (macroscopically) and ductile (microscopically).

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