EXPERIMENTAL INVESTIGATION OF MECHANICAL PROPERTIES OF RICE HUSK ASH, FLY ASH REINFORCED WITH Al 356 - HYBRID COMPOSITES

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Abstract: The composite materials are more demand in industrial and aerospace sectors having very good passive damping in order to mitigate the amplitude of vibrations caused during dynamic service conditions. Hybrid composites are widely used in the structural applications like aircraft, automotive, marine, and machine tool structures owing to their excellent strength to weight ratio, cost effectiveness and nowadays they replace metallic materials predominantly. The recent fabrication of structures in hybrid composites contains reinforcing organic and inorganic nature. The wastage articles such as RHA and fly ash are interlaced in two mutually orthogonal directions to one another which promote excellent integrity and conformability and balanced mechanical properties within the fabric plane. Because of these advantages hybrid composites become popular in all such mentioned structural applications. The investigation mainly focus on fatigue life influenced by organic and inorganic particles with different weight fraction measured at different stress levels over a wide range spectrum of three different materials are evaluated and compared. The mechanical properties such as fatigue strength, hardness and compressive strength were studied for all specimens. The micro/macro cracks and fracture surface are revealed under the scanning electron microscope (SEM) analysis. Optical microscope (OM) analysis is used to find out the difference at different stress level conditions to determine the safe stress level.

Keywords: Hybrid composite materials, mechanical properties, SEM

I. INTRODUCTION

In the last two decades, research has shifted from monolithic materials to composite materials to meet the global demand for light weight, high performance, environmental friendly, wear and corrosion resistant materials. Aluminium metal matrix composites (AMMCs) have considerable applications in aerospace, automotive and military industries due to their high strength to wear ratio, stiffness, light weight, good wear resistance and improved thermal and electrical properties. Ceramic particles such as Al2O3 SiC are the most widely used materials for reinforcement of Aluminium. Rice husk and Fly ash could be an alternative to SiC and Al2O3 due to their availability in large quantity.

Rice husk and Fly ash have attractive properties like high strength, extremely high hardness, good wear resistance, low coefficient of friction, high thermal conductivity and also contains excellent machinability. Rice husk is an agricultural residue which accounts for 20% of the 649.7 million tons of rice produced annually worldwide. This RHA is a great environment threat causing damage to the land and the surrounding area in which it is dumped. This ensures the researcher for effective utilization of this agricultural waste. Burning the husk under controlled temperature below
750 °C can produce ash with silica mainly in amorphous form, which can produce the composites with low density and having high temperature resistance and hardness.

Fly ash is one of the residues generated in the combustion of coal. It is an industrial byproduct recovered from the flue gases of coal burning in electric power plants. Depending upon the source and makeup of the coal being burned, the components of the fly ash produced vary considerably, but all fly ash includes substantial amounts of silica (silicon dioxide, SiO2) (both amorphous and crystalline) and lime (calcium oxide, CaO). The high electrical resistivity, low thermal conductivity and low density of fly-ash may be helpful for making a light weight insulating composites. Stir casting is the most popular commercial method of producing aluminum based composites.

In principle, it allows a conventional metal processing route to be used, and hence minimizes the final cost of the product. In the present work, rice husk ash and fly ash particles of 5% each by weight were added to A356 alloy through Stir casting to produce hybrid composite. The Surface morphology and mechanical properties were studied for the resulted hybrid composite.

II. LITERATURE REVIEW

[1] Prasara and Gheewala (2017) well explained that, Rice husk ash is a potential material, which is amenable for value addition. The usage of rice husk either in its raw form or in ash form is many. Most of the husk from the milling is either burnt or dumped as waste in open fields and a small amount is used as fuel for boilers, electricity generation, bulking agents for composting of animal manure, etc.

[2] Sonsino and Franz (2017) observed that, the use of castings in military aircraft for both primary and secondary structural components is not a new concept. Al-7Si-0.3Mg casting alloys have been in use for at least three to four decades. The early F5 and T38 aircraft made extensive use of structural castings. Other examples include the inlet duct on the F16, the Boeing bifurcation castings and primary structural components of the Pave Tack pod used on the F11 and F4. These are some examples of structural aircraft castings that have been, and are being used.

[3] Singh et al, (2016) observed that, the need for high-performance and lightweight materials for some demanding applications has led to extensive R&D efforts in the development of hybrid metal matrix composites. For instance, the Aluminium matrix hybrid composite unidirectional reinforced with continuous carbon fibre can readily show a bending strength of 1000MPa with a density as low as 1.8g/cm3. The superior mechanical property can be retained at elevated temperatures up to 350-400°C. The availability of a wide variety of reinforcing techniques is attracting interest in hybrid composites. This is especially true for high performance Aluminium materials, since the characteristics of a hybrid composite provide an effective approach to strengthening Aluminium alloys.

[4] Zhuang et al (2016) reported that incorporating fly ash into aluminum castings decreased the energy content, cost and weight of material. Fly ash was incorporated in aluminum alloy matrix using stir casting and pressure infiltration techniques. The sand and permanent mold castings demonstrated adequate castability of aluminum melts containing up to 10 % by volume of fly ash particles. The density and coefficient of thermal expansion of castings decreased with increase in fly ash content. The hardness and wear resistance increased as the fly ash content increased. Tensile strength of heat treated composites (T6) containing less than 8 vol% fly ash was similar to that of the aluminum alloy.
[5] Govindharajan et al (2015), examined the Aluminium is a matrix and the reinforcements are E-glass fiber and fly ash with various weight fraction the E-glass fiber is constant and the fly ash is varied 0,3,6,9 wt. % fabricate by using stir casting method. After the composite sample are subjected to examine the mechanical properties such as tensile, hardness and toughness strength. From the test result the four different wt.% composite samples is increased gradually adding with increasing the fly ash wt.% gradually achieved higher hardness and tensile strength compared to base alloy.

III. 3. EXPERIMENTAL PROCEDURE

3.1 Materials

Aluminium A356 alloy with different weight fractions (0 and 5%) of Rice Husk Ash and Fly ash as reinforced particles are fabricated using stir casting technique. The utilization of waste materials is beneficial not only lower the production cost but also environment-friendly. The fatigue tests are conducted according to Basquin constants on un-notched specimen under different stress levels at constant stress ratio R=0.1 with the frequency of 15Hz.

Table 3.1 Chemical composition of Al A356 alloy

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Si</th>
<th>Mg</th>
<th>Fe</th>
<th>Cu</th>
<th>Mn</th>
<th>Zn</th>
<th>Ti</th>
<th>Others (Total)</th>
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<tbody>
<tr>
<td>Wt. (%)</td>
<td>6.5-7.5</td>
<td>0.25-0.45</td>
<td>0.2</td>
<td>0.2</td>
<td>0.1</td>
<td>0.1</td>
<td>0.2</td>
<td>0.15</td>
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</table>

Table 3.2Chemical composition of Rice husk ash

<table>
<thead>
<tr>
<th>Constituent</th>
<th>SiO₂</th>
<th>Al₂O₃</th>
<th>C</th>
<th>CaO</th>
<th>MgO</th>
<th>KaO</th>
<th>Fe₂O₃</th>
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<tbody>
<tr>
<td>Wt. (%)</td>
<td>90.23</td>
<td>3.54</td>
<td>1.23</td>
<td>1.58</td>
<td>0.53</td>
<td>0.39</td>
<td>0.21</td>
</tr>
</tbody>
</table>

Table 3.3 Chemical composition of Fly ash

<table>
<thead>
<tr>
<th>Constituent</th>
<th>SiO₂</th>
<th>Al₂O₃</th>
<th>MnO₂</th>
<th>Na₂O</th>
<th>K₂O</th>
<th>CaO</th>
<th>Fe₂O₃</th>
<th>TiO₂</th>
<th>CFA</th>
</tr>
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<tbody>
<tr>
<td>Wt. (%)</td>
<td>63.95</td>
<td>26.07</td>
<td>0.02</td>
<td>0.02</td>
<td>0.04</td>
<td>2.43</td>
<td>4.88</td>
<td>0.68</td>
<td>1.91</td>
</tr>
</tbody>
</table>

3.2 Preparation of hybrid composites

For the fabrication of aluminum metal matrix composites, different techniques are used among them stir casting is a commercial technique in the production of Aluminium hybrid composites are extensively utilized in automobile sectors. At present study double stir-casting process was done by using an ultrasonic probe to fabricate hybrid composites. The schematic representation of stir casting set up as shown in Fig.3.4. The Aluminium A356 alloy taken as matrix and Rice husk ash (organic) and Fly ash (inorganic) as reinforcement consist of different weight ratios of (0 and 5wt.%) were utilized in the production of hybrid composite materials. Initially, the agro waste particles are pre-heated at a 250°C temperature to reduce dampness and improve wettability. The matrix alloy is charged by argon gas and heated above liquidus temperature to make sure that alloy melts completely in a crucible furnace. The liquid alloy was cooled at room temperature and pre-heated reinforcement particles are added at same temperature primary stirring performed for 10 min manually [30]. The second stirring process was conducted for 15 minutes at a speed of 400 rpm with the help of mechanical stirrer. After successful preparation of hybrid composite, then the molten metal was transmitted into a mild steel finger die in the form of cylindrical rods with 20mm diameter and 150mm long to solidify.
IV. RESULTS AND DISCUSSION

4.1 Effect of crack orientation by SEM analysis

The fractographic observations have revealed that the alloy and hybrid composite fatigue tested at high stress level was failed by a mixture of quasi-cleavage fracture presence of small density of micro-cracks. The fracture morphology remained similar for all the strain amplitudes of testing except for the density of micro dimples, which was found to be higher at higher strain amplitudes. The facture modes are assessed and measured using un-notched specimens under HCF by means of macroscopic as well as microscopic observations. Initially, the samples were etched using a solution composed 68% of HCl, 31% of HNO$_3$ and 1% of HF to reveal the grain shapes as shown in Figs.15 and 16 [39]. The behaviour of cracks is mentioned detailed in following data. Typical microstructure of A356 alloy before the test and after the crack initiation is observed close to large pores and cracks.

![Fig. 4.1 SEM images of fatigue fracture surfaces of the un-notched specimen A356 alloy](image)

![Fig. 4.2 SEM images of fatigue fracture surfaces of the un-notched specimen A356/5%RHA-5%Fly ash hybrid composite](image)

4.2 Fatigue behaviour influence of mean stress

To perform fatigue tests efficiently long life regime, this study has been developed a high efficiency of testing machine in respective different stress parameters with axial loading. For each stress level four specimens were tested for notched and un-notched factor; average of three results is plotted for Aluminium alloy and hybrid composites. For each sample quantitative measurements of the fatigue crack were tested at different stress levels ranging from 80, 100 and 120 MPa with a frequency of 15Hz and stress ratio of R=0.1. The response of cyclic stress amplitude as a function for different weight fractions of a notched and un-notched factor is investigated for as-cast Al alloy and
hybrid composites are shown in Fig.4.2. The S-N curve of high cycle fatigue is described by using above equation (1). The effect of fatigue-life is determined by comparing S-N curves of Aluminium alloy and hybrid composites. The data for HCF are plotted in terms of different stress level based on a net section of the specimen.

The characteristic of S-N curve for un-notched factor are plotted, the number of cycles (N) and stress amplitude (σf) with respective fracture modes have appeared at different locations. The experimental results of the fatigue tests of A356 Aluminium alloy reveal a clear difference between the stress range and number of cycles is plotted and fatigue limit was observed on Aluminium alloy in the investigated region. The S-N curve is determined with a comparison of experimental results. However the failure started at a higher stress level of 120MPa, this is attributed due to a low number of cycles initiated. At lower stress of 80MPa number of cycles though it is increased still the crack initiated internally. this kind of fatigue crack is known as non-defect failure. Generally, the stress increased above the threshold limits and fatigue life decreased with increasing number of cycles. Addition of a mixture of lightweight particles to matrix alloy at minimum stress (i.e. 80MPa), In A356/5%RHA-5% Fly ash hybrid composite, while increasing the stress up to 120MPa fatigue life-time is defined as sudden 10% drop of maximal stress before the fracture of the specimen due to number of cycles decreases failure initiated internally, same observations are identified by Sonsino. This mainly due to lower porosity and increasing hardness compare to matrix alloy. Therefore, it is noticed that addition of organic and inorganic particles has no deleterious effect and also increases strength of material compare to as-cast Aluminium; it is induced in preparing of turbine blades and rotors for engine parts. The A356/5%RHA-5% Fly ash hybrid composite endues more number of cycles and exhibits 30% higher strength than that of aluminium alloy.

![Fig. 4.3 Comparison of number of cycles Vs estimated stress amplitude for un-notched specimen based on different weight fractions of (a) Al A356 alloy and (b) A356/5%RHA-5% Fly ash hybrid composite.](image.png)

**4.4 Hardness and Compression test**

Vickers microhardness test and compressive strength was conducted on polished specimens of A356 Aluminium alloy and A356/RHA-Fly ash hybrid composite and following trends are evident
from Table 1: (i) Hardness was improved due to an addition of reinforcement particles irrespective of the material and (ii) The maximum hardness is noted when materials are aged \[3\]. Tests are carried at three different positions average five readings are reported to avoid potential the result of indenter resting on hard reinforcement particle. The high hardness is observed in A356/5%RHA-5% Fly ash hybrid composite. Compression value of Aluminium alloy was decreased due to agglomeration. While adding the weight fraction of reinforcement particles it is increased up to 471K/Nmm\(^2\) attributed due to presence of high amount of silica particles. The experimental data reveals that selection of reinforcement is one of the important aspects in production of metal matrix composites especially when the enhanced mechanical properties are desired.

**Table 4.1 Micro hardness and compressive values of investigated materials**

<table>
<thead>
<tr>
<th>Material</th>
<th>Micro hardness (HV)</th>
<th>Compression strength (N/mm(^2))</th>
</tr>
</thead>
<tbody>
<tr>
<td>A356/5%RHA-5%Fly ash</td>
<td>77</td>
<td>462</td>
</tr>
<tr>
<td>A356/5%RHA-5%Fly ash</td>
<td>84</td>
<td>479</td>
</tr>
</tbody>
</table>

**V. CONCLUSION**

The main objectives of research performed in this study was able to better understand and estimate fatigue crack initiation in components subjected to complex service loading histories. Therefore, the fatigue life analysis techniques evaluated for constant amplitude loading conditions involving stress ratio. As a result issues related to transient material deformation behavior, the mean stress at different levels through damage parameter and crack initiation definition were of specific interest in this study. From the experimental results and analysis presented for the un-notched specimen critical life estimations, some key findings can be summarized as follows:

1. The influence of different weight fractions at various stress level for un-notched specimens exhibits higher number of cycles compare and represented by S-N graphs.
2. The A356/5%RHA-5%Fly ash hybrid composite has higher fatigue strength of 15% compared to the matrix alloy.
3. Due to the high stress level experiencing plastic deformation, a result of significant mean stress causing non-reversed yielding in the loading histories investigated, overall improvements in life estimation accuracy gained through the consideration of transient material stress-strain response were found to be negligible in this study.
4. While changing the crack initiation definition from final failure, this due to minimize the stress level fatigue strength increases made the overall improvement in life estimation accuracy relatively small for all loading conditions considered.
5. For all three stress levels, it could be seen that below 100Mpa stress level achieved the superior mechanical properties. This suggests that the fatigue procedures implemented on material in this study are able to capture differences in fatigue damage accumulation relatively well, regardless of the complexity of the loading.
6. The mechanical property of A356 alloy matrix was increased due to the addition of organic and inorganic particles, a formation of more interfaces in the matrix. The higher compressive strength and hardness is always associated with presence of high amount of silica content in RHA. The A356/5%Fly ash&5%RHA hybrid composite offered higher hardness and compressive strength compared to other hybrid composites is due to uniform distribution of reinforcement particles in the melt and having good wettability.
REFERENCES


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