Effect of Rice Husk Ash on the tensile strength of Epoxy based bio-composite

Abstract

The present study aims at investigating the effect of incorporating rice husk ash as a filler in the composites developed form Rice Husk and epoxy. Rice husk ash contains 90% Silica, significantly contributes to the mechanical properties of materials. RHA was obtained by incinerating RH at about 600^0C for 6 hours. The ash obtained with this procedure is shiny white in colour and rich in silica. In the present study composition of a previously developed bio composite (RH+epoxy) was altered by incorporating small amounts of RHA. Addition of RHA increased tensile strength significantly. In addition, the RHA also provided stiffness. Scanning electron microscopy was conducted to understand the mechanics involved.

Keywords: Rice Husk, ~~Rice Husk~~ Ash, Epoxy, SEM

1. Introduction

It is estimated that the production of rice husk worldwide is approximately 700 million tons [**1**], of this 22% of this is husk (175 million tonnes) **[2]**. This waste has no practical use and is mostly burned which adds to the environmental woes already plaguing the earth. On the other hand excessive use of artificial materials has also impacted environment inversely. The solution to this lies in developing materials that rely on natural wastes. Rice husk has proved to be a feasible solution both in raw form and grounded form. Plenty of research work has been carried out to utilize rice husk as fibre with polymer matrix. Team of Yang et al. [3] have done an extensive work on utilizing RH with polypropylene as the matrix material. It was reported that the tensile strength slightly decreased with increasing filler loading. Tensile modulus however increased. It was also seen that the impact strength decreased with increasing filler content. In a different study **[4]** the same composition of filler and matrix was used and the same results have been obtained and the tensile strength has reduced by around 50% for 40% RH. Bisht et al. [5] conducted similar study with Epoxy and RH, the tensile strength reduced with increasing RH content and 20% RH wt % was seen to give the hg hest tensiule strength.

This can be attributed to the opposing natures of fibre (hydrophilic) and polymer (hydrophobic) due to which the adhesion is improper. There is also the tendency of rice husk to agglomerate due to which the tensile strength decreases as filler loading is increased as reported by Premalal et al.[6] in which they utilized rice husk with polypropylene. A different number of studies concerning the same compositions **[7-11]** have conclusively proven that the increase in filler loading is detrimental to the tensile strength of the composite obtained.

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In abstract supposed to have;
1. Overview/Intro/problem statement
2. Research objective
3. Methodology
4. Findings
5. Conclusion & future work

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Garcia *et al.*, 1983[12] were the first to suggest hybrid composites for improving the matrix-dominated properties of continuous fibre reinforced composites. In this technique, a supplementary reinforcement such as particulates, whiskers, or micro fibres is added to the matrix prior to resin impregnation.

The chemical composition of RH from different regions was anlysed and found to have an average composition of 80% organic matter and 20% ash **[13]**. RHA is 92% silica and can be beneficial in improving the mechanical properties due to the inherent properties of silica. Sarvana and Kumar Senthil, 2013[14] in their studied have used RHA as reinforcement in Aluminum alloy ($AlSi_{10}Mg$) Matrix Composites. Ahmed Khalil *et al.*, 2013[15] in their study have used Rice husk derived silica to develop natural rubber composites and experiments have been conducted for mechanical properties. In a study by Turmanova*et al.*, [16] 2008 composite materials were obtained by filling polypropene with raw and thermally treated rice husks at filler contents from 1 to 20%. The physicochemical properties were determined. A slight increase was observed in the tensile strength of the composites based on white rice husk ash WRHA] and aerosil AR] at degree of filling up to 3%. Recently Sisal fibre based polymer composites were developed [17]. Their properties were tailored by hybridizing them with natural pine needles and agro waste mustard. A remarkable improvement in mechanical and wear properties was observed.

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Specifically rice husk has been used to develop hybrid bio-composites with Bauhinia-Vahlii-weight and Bauhinia-Vahlii-weight/sisal fibres [18]. The mechanical properties like tensile strength and flexural strength improved significantly (34.42 and 33% respectively) and hardness by 7.1% due to hybridization. RH particulates with glass were also used for epoxy matrix [19]. The hardness, tensile modulus and impact energy improved while there was deterioration in tensile and flexural strength.

Another method of improving mechanical properties of RH based composites is surface modifications. A lot of research has been focused on this area as well. to improve properties the interface between the matrix and the lignocellulosic material has to be improved. There are various methods for promoting interfacial adhesion in systems where lingo-cellulosic, treatment with silicon compounds, graft co-polymerization], use of compatibilizers, plasma treatment, and other chemicals. Some of the above-mentioned methods have also been applied to RH **[20-28]. In all the studies a significant improvement in properties was reported due to improved adhesion between matrix and filler.**

he use of low cost material metal matrix composites is increasing rapidly in various engineering fields because of their better mechanical properties. In this study aluminium alloy (LM6) is used as matrix metal and rice husk ash (RHA) as reinforcement for developing a new

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metal matrix composite material. A rice husk ash 6% by weight are added and artificial aging process is done at temperature 135°C, 175°C and 225°C to develop metal matrix composites using stir casting method. The mechanical properties of composite such as hardness and wear properties were studied for the all test specimens. [29]

AA6061 aluminum matrix composites (AMCs) reinforced rice husk ash (RHA) particles (0–8 wt %) were produced. The sliding wear was assessed using a pin-on-disc wear apparatus with a heating facility, and the temperature was varied from 40 °C to 240 °C. The incorporation of RHA particles was beneficial in improving the wear resistance and reducing the COF values over the entire range of temperatures used. The increase in temperature deteriorated the wear resistance of the composites. AA6061/(0–4 wt %) RHA AMCs showed a clear transition from mild wear to severe wear at a temperature of 200 °C. The increase in RHA particle content increased the transition wear temperature. The wear mode changed from abrasive wear at 40 °C to adhesive material flow at 240 °C.[30]

Rice husk ash (RiHA) was employed as the bio-originated and inexpensive filler prepared from agricultural wastes for reinforcing high-density polyethylene (HDPE) and linear low-density polyethylene (LLDPE). X-ray fluorescence (XRF) spectroscopy showed ~80.82% for the silica content of RiHA as well as the values of other components present in this bio-based filler. The composites were obtained *via* melt mixing followed by the compression molding *by* the hot press forming. Characterization of the composites by FT-IR spectroscopy revealed that the filler has the sheer effects on the vibrational bands of the polymers. The usage of X-ray diffraction (XRD) analysis to investigate the d-spacing values and the crystallinity of the samples, exhibited the increase of d-spacing upon reinforcing the polymers with RiHA. The scanning electron microscopy (SEM) images showed an average size of 32 μm for the irregular RiHA particles which uniformly dispersed in the polymeric matrices. The energy dispersive X-ray (EDX) analysis displayed C, O, and Si as the main constituting elements of the composites and alternatively confirmed the well dispersion of the filler particles into the polymer matrices. The mechanical measurements showed the significant improvements in Young's modulus, yield stress, and hardness results of the polymers after reinforcing with the rice husk ash. For example, Young's modulus of HDPE was increased ~15% after incorporating 7 wt.% of RiHA into this polymer. These mechanical properties of the polymers were increased upon increasing the RiHA content, while the parameter of elongation at break was decreased. [32]

The application spectrum of low-cost material reinforced metal matrix composites is growing rapidly in various engineering fields due to their superior mechanical properties. In the present study an attempt is made to explore the possibilities of reinforcing aluminium alloy (AlSi10Mg) with locally available inexpensive rice husk and fly ash for developing a new composite material. Hybrid Rice husk and Fly ash particles are added in Aluminium Alloy Matrix at 20% by weight with different proportion using Stir casting method. The fabricated cast specimens are characterized with Optical and Scanning Electron Microscopes. SEM study validates the presence of Rice husk and Fly ash in Aluminium matrix. The mechanical properties such as tensile strength, percentage elongation, and hardness are studied for all stir-cast specimens. A significant improvement is observed for 10% Rice husk+10% Fly ash reinforced Aluminium Alloy composite compared to as-cast specimens without reinforcement additions. [33]

Metal matrix composites have been utilized in the field of engineering and technology. In this study, fabrication was done by stir casting techniques and the mechanical properties of AA6061/rice husk ash were assessed. The cast were produced with liquid metallurgy route through the reinforcement of 2–8 weight percentages of particle sizes of 75 µm rice husk ash. The microstructural test like SEM/EDS and mechanical properties were studied. From the results, the mechanical properties were found to increase at 8% rice husk ash reinforcement. SEM images revealed that homogenous dispersal of particulates without voids occur in cast and an increase up to 8% rice husk ash revealed substantial blending of matrix and reinforcement as evidenced in the microstructure examination. [34]

There is a dual perspective regarding agricultural materials. The first one is regarding the removal of certain chemical elements for specific applications, and the second one is regarding the recovery of certain elements to make them more appealing. The most appropriate use of agricultural and industrial waste materials demands the development of knowledge insights as a requirement for setting up of demonstration plants on a pilot basis and large-scale industrial adoption resulting in all associated socio-economic benefits. The Stir casting method is employed to fabricate the Metal Matrix Composites (MMCs) material for the application of various industrial products. In the present paper, Aluminum (Al6061) hybrid composite is fabricated and reinforced with Silicon Carbide (SiC), Alumina (Al_2O_3), Zirconia ($ZrSiO_4$) and agro-waste material, such as Rice Husk Ash (RHA) particles of various configurations. The amount of reinforcement varies SiC (0–2.5 wt%), Al_2O_3 (0–1.1 wt%), $ZrSiO_4$ (0–0.5 wt%) and RHA (0–1.4 wt%). The effect of reinforcement SiC, Al_2O_3, $ZrSiO_4$ and RHA on ultimate tensile strength (σ_{ut}), yield strength (σ_{yt}), elongation, breaking strength (σ_b) and hardness has been studied. Experimental results revealed that hybrid metal matrix composites are improved for σ_{ut} and σ_{yt} by 45.03% and 82.1%. The elongation and hardness of the composite are also enhanced by 19.43% and 12.72% from the base material. [35]

Present work studies the effect of particle reinforcement on fracture toughness of bio-composites. The filler used has been taken as rice husk. Epoxy resin has been taken as matrix material. Composites with varying filler loading of 10, 20, 30 and 40 wt.% were fabricated. The fracture toughness was seen to be increasing with increase in filler loading. However beyond 20% there was a decrease in fracture toughness with increase in filler loading. The effect of fibre treatment on toughness was also observed. Rice husk fibres pre-treated with NaOH were used. It was observed that fracture toughness further improved due to treatment. The increase in fracture toughness was significant. Fracture toughness increased from 1.072 to 2.7465 MPa√mm for 20% reinforcement and after treatment it increased to 2.876 MPa√mm. It was observed that concentration of treatment media also affects the fracture toughness. Further the effect of hybridization was observed by addition of rice husk ash as a secondary reinforcement. The fracture toughness of the resulting composites was remarkably higher than that of pure epoxy. [36]

This paper explores the microstructural, mechanical and the tribological behaviour of rice husk ash (RHA, 5, 10 and 15 wt%) reinforced aluminium based composites fabricated using the powder metallurgy (PM) route. The main advantage of this composite is utilization of RHA (an agricultural waste), with its improved mechanical and wear properties. Powder mixtures are cold pressed uni-axially and later the green compacts are sintered under argon gas atmosphere in electric furnace. For the investigation of microstructural features, Scanning Electron Microscopy

(SEM) and x-ray diffraction (XRD) analysis has been performed. Tribological behaviour was evaluated on pin-on-disc wear tester machine using Taguchi and ANOVA techniques. Addition of RHA increased the composite's hardness by 20%–25% and wear behaviour got improved by 15%–40%. Based on the micrographic images of worn out surfaces and wear debris, wear mechanism is also discussed. In addition to this, artificial neural network model is also proposed and wear behaviour of the composite is also predicted. By comparing the experimental results with predicted results, it can be said that a well-trained ANN model is an efficient tool for predicting tribological behaviour. [37]

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2. Experimental

2.1 Materials

In the present investigation epoxy resin CY-230 purchased from M/s Excellence Resins Limited, India has been used as matrix material. Epoxy resins, also known as polyepoxides are a class of reactive prepolymers and polymers which contain epoxide groups. Araldite CY-230 is a liquid solvent free epoxy resin. Hardener (HY-951) purchased from M/s Excellence Resins India Limited, India has been used as curing agent which is a yellowish-green coloured liquid.

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Rice husk ash is the product of thermal degradation of rice husk. When rice husk is incinerated, it generates between 17-20% ash, made up of about 87-93% opaline silica and other metallic oxide impurities [Turmanova*et al.*, 2012][29] depending on the source of the husk. When rice husk is incinerated, two types of products can result, white rice husk ash (WRHA) and carbonised rice husk (CRH). In either forms, rice husk has some applications.

Sodium hydroxide and Hydrochloric acid were provided by M/s Allied Business Limited, India. NaOH was used for treatment of rice husk fibres while HCl was used for treatment during the processing of rice husk ash. Different processes have been used by different researchers to obtain silica from rice husk. The process which has been utilised here as proposed by Ahmad *et al.*, 2013 [15] can be summarized in following steps:

1. Rice husk was washed with water to remove any foreign material.
2. Hydrochloric acid solution of 0.4 M was prepared than 100 g cleaned husk was mixed in 1 L of prepared acid solution and boiled at 100–105^{0}C for 30–45 min. After the reaction, the acid was completely removed from the husk by washing with tap water.
3. It was then dried in an oven at 110^{0}C for 3–5 h in oven.

4. The treated husk burned in an electric furnace at 600^0C for 6 h; silica was obtained as white ash. The shape of the silica is similar to the shape of the husk but smaller in size.

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2.2 Sample Preparation

For the optimization of rice husk different proportions of rice husk were added to the epoxy resin. The ratios taken were 10, 20, 30, 40 wt%. Depending upon the size of the moulds rice husk, epoxy and hardener were taken in the desired proportion. Hardener and epoxy are taken in the ratio of 10:1 i.e. 10 parts epoxy and 1 parts hardener. Firstly, rice husk and epoxy were mixed and heated at a temperature for 1 hour in an electric oven as per the recommendations of Bisht and Gope 2015 and then allowed to cool down to 45^0C (to avoid bubble formation) after which hardener was added. The particulate matter before casting was treated with NaOH. Here also the process of alkali treatment was optimized by treating the fibres in different amount of alkali solutions viz. 2, 4, 6, 8 and 10%. The rice husk flour was kept in these mixtures for approximately 5 hours and after that was washed with running water so as to remove the alkali and then was dried to remove moisture. To study the effect of RHA addition RHA in different proportions of 0.5, 1 and 2% were added to the already optimized composition of rice husk.

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2.3 Mechanical Testing

The tensile tests were conducted on 100 KN ADMET make servo controlled universal testing machine at 0.5 mm/min crosshead speed under displacement control mode. The specimens are made according to the ASTM British standard.

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2.4Morphology

The scanning electron micrograph study generally performed by scanning electron microscope, which uses electron to form an image with high resolution or magnification. To obtain the scanning electrons micrographs square samples are cut from the cast material and are gold coated to avoid the artefacts associated with sample charging and then placed inside a chamber in which an electron beam fall on the material. The accelerated voltage was 10 kV. Different images are taken at various magnification ranges.

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3. Results and Discussion

3.1 Tensile properties

Fig 1-4 shows the tensile behaviour of rice husk and rice husk ash reinforced bio-composite. In the literature it has been established that addition of second filler can be beneficial in terms of strength. The hybridisation can have a positive or negative hybrid effect. If a property improves it is known as positive hybridisation effect and if it decreases it is known as negative hybridisation effect.

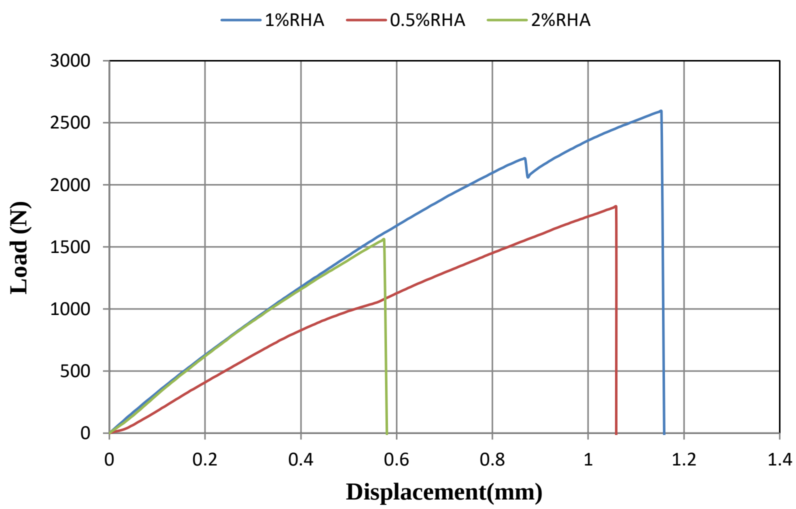

Fig 1: Load-deflection curve for different RHA reinforcement (wt %)

Fig 1 shows the tensile load-deflection curve for RHA reinforced epoxy bio-composite which also contain 20 wt% treated rice husk. From the stress-strain curve it can be seen that there is fibre breakage for 1% RHA which shows that there was maximum adhesion between fibre and matrix and as a result the mode of failure was fibre breakage thus imparting maximum strength to the bio-composite. Also it can be seen that the mode of failure in all the cases is brittle in nature. It can be seen that elongation was maximum for 1% followed by 0.5% and for 2% RHA it was lowest.

In Fig 2 comparative study of tensile strength for various amount of RHA has been done. The tensile strength obtained has been compared with that of 8% NaOH treated 20% RH reinforced bio-composite.

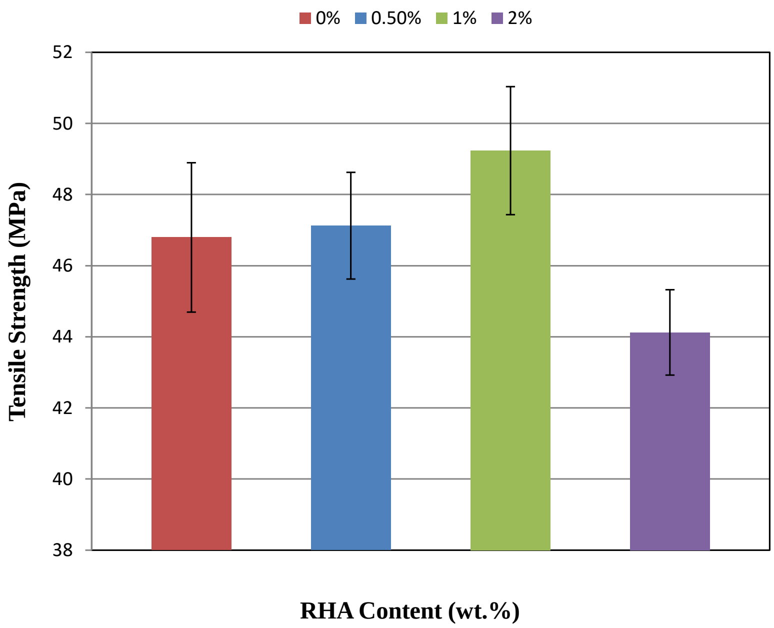

Fig.2. Tensile strength for treated fibres for different level of RHA addition

From the Fig 2 it can be seen that addition of RHA has a positive hybridisation effect on tensile properties. Increase in tensile strength can be observed due to RHA addition initially but addition of 2% RHA results in decrease in strength, the strength becomes even less than composite for composite without RHA. Addition of 0.5% RHA increases the tensile strength only marginally by 0.705%, it can be said that addition of 0.5% RHA has limited hybridisation effect. For 1% RHA the improvement in tensile strength was 5%. However beyond 1% there was a decrease in tensile strength. For addition of 2% RHA the decrease in tensile strength was 5.7% which negates the benefit of hybridisation and even the pre-treatment effect. The increase in tensile strength initially can be attributed to the fact that RHA has high aspect ratio d so therefore there is better stress transfer from matrix to RHA thereby increasing tensile strength. However at higher filler loading the RHA nano particles are not able to disperse well and so therefore there is reduction in tensile strength.

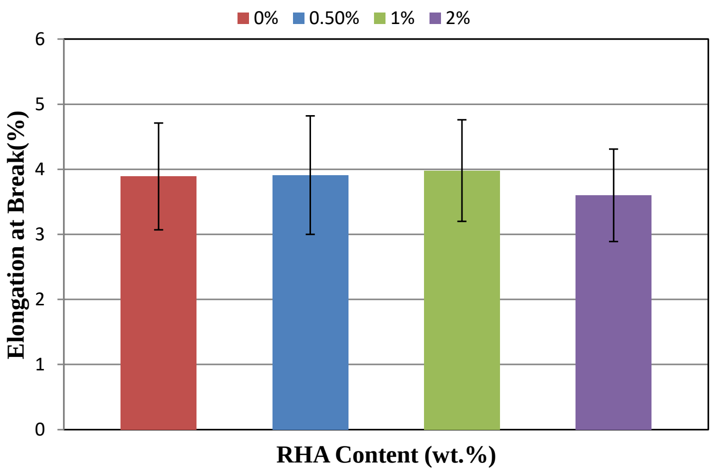

Fig.3. Elongation at break for treated fibres for different level of RHA addition

From Fig 3 it can be said that with addition of RHA the material becomes ductile. Similar to the tensile strength the increase in percentage elongation was not significant. However at 1% RHA the ductility improved significantly. At 2% RHA however the percentage elongation decreased significantly reducing from 4% for 1% RHA to around 3.6% for 2% RHA a decrease of around 10%. Compared to non-RHA composite the percentage elongation decreased by about 6.5%.

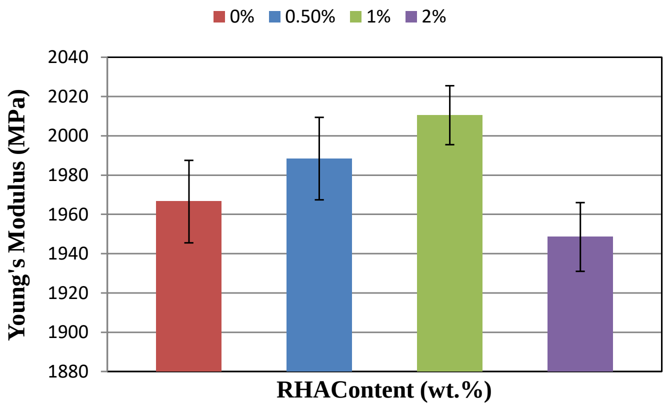

Fig.4. Young's modulus for treated fibres for different level of RHA addition

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Flexural properties

The flexural behaviour for different RHA reinforced composites has been done.

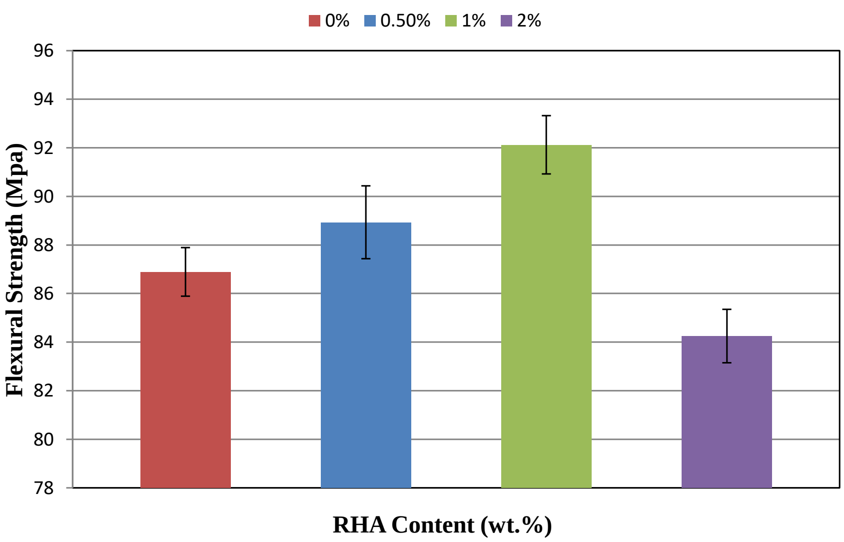

Fig 5: Flexural strength for treated fibres for different level of RHA addition

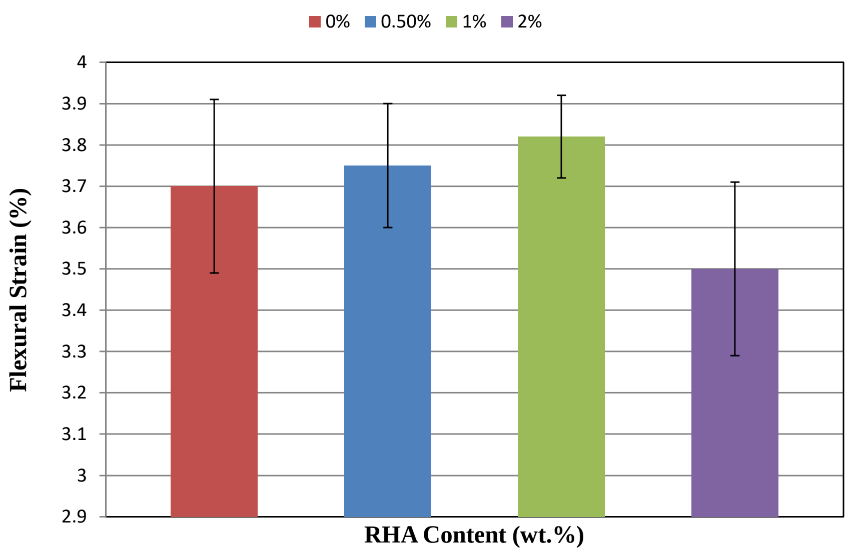

Fig 6: Flexural strain for treated fibres for different level of RHA addition

From Fig 5 which shows the effect of RHA addition on flexural strength shows that with RHA addition there is an increase in strength of 2.35% and 6.02% corresponding to 0.5% and 1% RHA. For further addition of 2% RHA the strength reduced by about 3.04% compared to composite without RHA and reduction of 8.54% compared to 1% RHA reinforcement. The trend is similar to that for tensile strength.

Fig 6 represents the variation of flexural strain with RHA addition. From the Fig it is clear that similar to the elongation at break for tensile test, the flexural strain is also maximum for 1% reinforced RHA. Compared to composite without epoxy there is an increase of 1.35% for 0.5% RHA and an increase of 3.24% for 1% RHA. For 2% RHA however there is a decrease in flexural strain. The decrease in quantitative terms was 5.45%. From Fig 7 it can be seen that there is an increase in modulus for 0.5% and 1% RHA. The modulus increased from 1657.1 MPa to 1660.32 MPa for 0.5% RHA and 1698.312 for 1% RHA corresponding to 0.18% which is insignificant and 1.8% also insignificant respectively. For further RHA addition there is a

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decrease in modulus from 1698.312 to 1650.122 MPa. So it can be said the effect of hybridization on flexural properties is positive to a certain level thereafter it becomes negative.

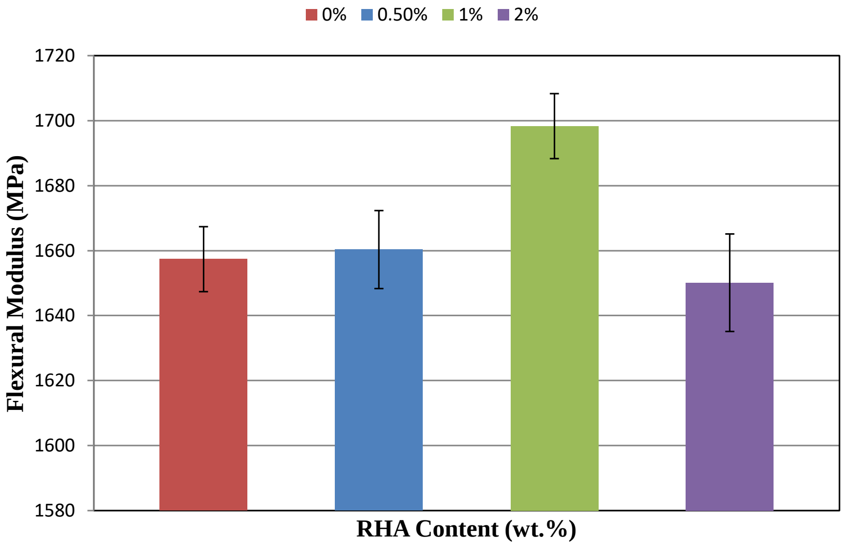

Fig 7: Flexural modulus for treated fibres for different level of RHA addition

4.6.3 Impact Strength

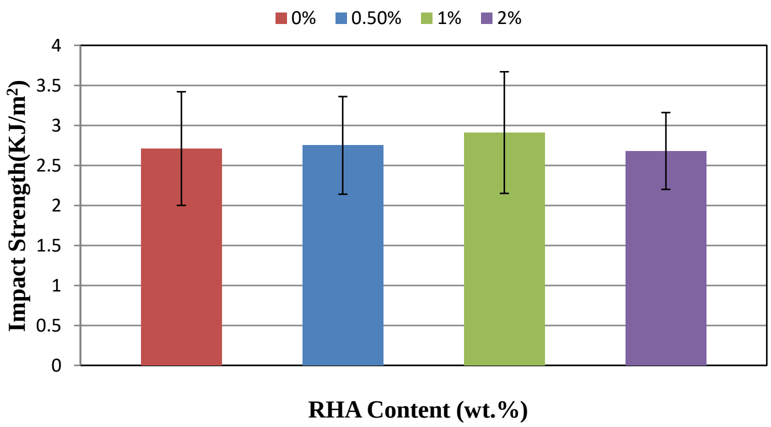

Fig 8: Impact strength for treated fibres for different level of RHA addition

The effect of RHA addition on impact strength was also studied. The proportion of RHA was kept same at 0.5, 1 and 2%. From the Fig 9 corresponding to variation of impact strength with RHA proportion it is observed that initially there is an increase in impact strength from 2.71 for without RHA composites to 2.75 and 2.91 KJ/m for 0.5 and !% RHA reinforced composite. However increase in RHA content further reduced the impact strength by around 8% compared to 1% RHA reinforced composite and it became even smaller than without RHA composite. The difference however was insignificant at a value of 1.1% compared to composite without RHA reinforcement.

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4.6.4 Hardness

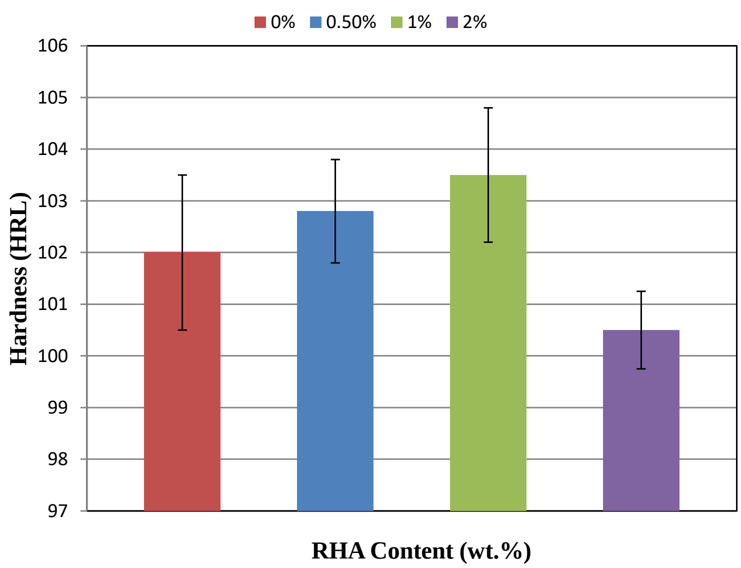

Fig 9: Hardness for treated fibres for different level of RHA addition

Effect of RHA addition on hardness is shown in the Fig 9. Hardness is seen to increase by a marginal amount of 0.5% and 1.4% for 0.5 and 1% RHA reinforced composites respectively so it can be said that RHA addition does not has any profound impact on the hardness. As the RHA content increases to about 2% the hardness drops abruptly from 103.5 to 100.5 a decrease of about 3% which can be attributed to the fact that RHA itself is a soft material and hence its reinforcement in larger amount results in decrease in hardness.

3.5 Morphology

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The images are the scanned fracture surfaces of different proportions of RHA. As is evident from SEM images that at 1% RHA the fractured surface is more even showing that there were no kind of voids present in the casting, however for 0.5% RHA the surface is rougher due to the voids not being filled completely by the RHA. However, at higher filling levels it can be seen that the mixing is improper since the liquid mixture becomes highly viscous and doesn't cure properly.

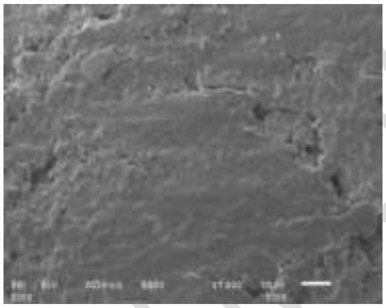

Fig.10 Scanning electron micrograph for (CY-230 + 10 wt% HY-951+ 20 wt% treated Rice Husk (8% NaOH solution) +0.5% RHA)

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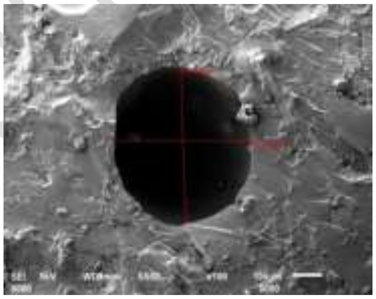

Fig.11 Scanning electron micrograph for (CY-230 + 10 wt%HY-951+ 20 wt% treated Rice Husk (8% NaOH solution) +2% RHA)

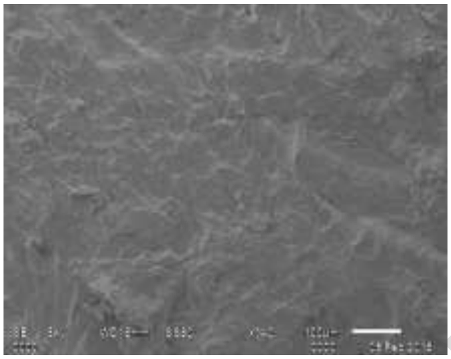

Fig.12 Scanning electron micrograph for (CY-230 + 10 wt% HY-951+ 20 wt% treated Rice Husk (8% NaOH solution) +1% RHA)

4. Conclusions

Although naturally occurring lingo-cellulosic fibres can be advantageous in terms of being environmental friendly and cheaper, the opposing nature of the fibre and the polymer poses a problem with respect to the tensile strength. Modifying the surface by treatment with NaOH can be beneficial in this regard. Further properties can be improved by reinforcing the composite with RHA. The chemical composition of RHA is 92% silica which is known to be hard in nature. Further the small sixed silica particles are embedded in the RH epoxy composite, thereby increasing the tensile strength. The presence of RHA prevents or delays the fibre pull out, the main phenomenon behind the failure of composites. It is also seen that the hardness of the material improves thereby increasing its applicability because of lesser wear and tear. It was also observed that RHA makes the material more ductile and increases the modulus both in flexure and tension terms. The composite developed in this manner has higher strengths and modulus than pure epoxy and as such can be a substitute for epoxy which is otherwise environmentally eroding.

~~5.~~ References

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