Experimental Analysis of Mechanical Properties of Composite Material Reinforced by Aluminium-Synthetic Fibers

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Abstract: Composite materials are engineering materials made from two or more constituent materials that remain separate and distinct on a macroscopic level while forming a single component. In this work the mechanical properties of GFRP (glass Fiber Reinforcement Plastic), Nylon and their composite with aluminium were evaluated with reference to ASTM D638-02 a. During the tensile load, the maximum strain, and stress are obtained. The maximum strength is found in composite GFRP instead of Aluminium and composite Nylon. Composite material has shown an improvement of mechanical properties when compared with individual materials.

Keywords: *GFRP, Nylon, Aluminium, Tensile Strength, Strain*

1 Introduction

Many of our modern technologies require materials with unusual combination of properties that cannot be met by the conventional materials [1]. Many composite materials are composed of just two phases one is termed the matrix, which is continuously surrounded by the other phase, often called the dispersed phase [2]. Recently an increasing use of composites reinforced with different types of fibers has occurred, owing the following advantages: they are strong enough, light in weight, abundant, non-abrasive and cheap [3].The damage tolerance of polymeric materials can be enhanced by improving the inter laminar properties of the polymer composites [4]. Fiber is known as material which strengthens the composites. For decades, fiber has been used to increase toughness and tensile ductility. Some innovations have been applied such as Fiber Reinforced Concrete (FRC) High Performance Fiber Reinforced Cementitious Composites (HPRFCC) which is known as Engineered Cementitious Composites (ECC). It is important to conduct study to know the performance of fiber in cementitious matrix. The properties of interfaces between fiber and cementitious matrices and their stress transfer takes an important role in determining the whole composites properties, selecting the main ingredients of composites, and predicting the failure of composite. The majority of engineering composites materials in demanding applications consists of continuous fibers of glass or carbon reinforcement in thermosetting epoxy polymer. There has been a tremendous advancement in recent days. Compared to metals, the polymeric composites have many advantages as higher fatigue strength, higher corrosion resistance and lower weight [5,6] polymeric composites are susceptible to mechanical damages when they are subjected to efforts of tension, flexural, compression which can lead to material failure. Therefore it is necessary to use materials with higher damage tolerance & carryout an adequate mechanical evaluation. Damage tolerance of epoxy polymeric composites can be enhanced by improving the inter laminar properties by toughening matrix [7], reinforcement with bidirectional woven fabrics [8]. The basic concepts of composites material along with details of earlier works are explained by author at reference [9]. Harish et al. [11] developed coir composite and mechanical properties were evaluated. Scanning electron micrographs obtained from fracture surfaces were used for a qualitative evaluation of the interfacial properties of coir /epoxy and compared with glass fibers. Wang and Huang [12] had taken a coir fiber stack characters of the fibers were analyzed. Length of the fibers was in the range between 8 and 337 mm. The fibers amount with the length range of 15~145 mm was 81.95% of all measured fibers. Weight of fibers with the length range of 35~225 mm accounted for 88.34% of all measurement. The average fineness of the coir fibers was 27.94 tex. Longer fibers usually had higher diameters. Composite boards were fabricated by using a heat press machine with the coir fiber as the reinforcement and the rubber as matrix.

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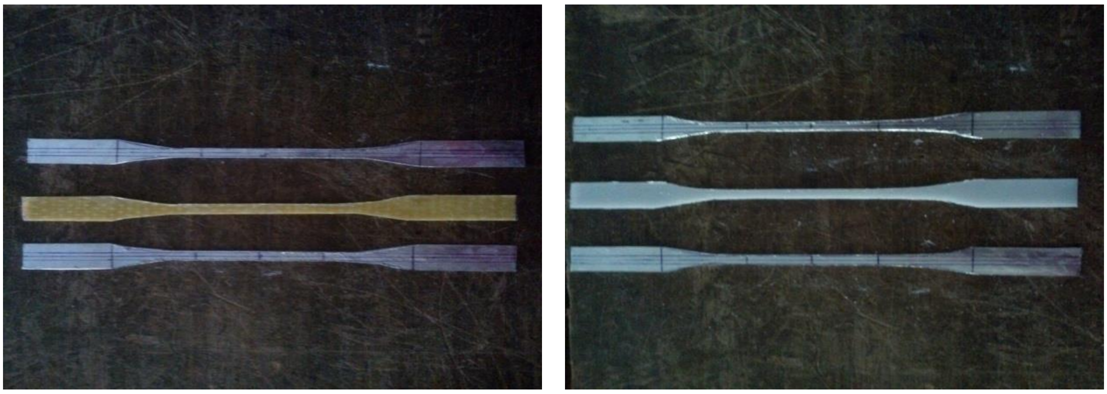
Tensile strength of the composites was investigated Materials and sample preparation**.** Nilza et al. [13] use three Jamaican natural cellulosic fibers for the design and manufacture of composite material. They took bagasse from sugar cane, banana trunk from banana plant and coconut coir from the coconut husk. Samples were subjected to standardized tests such as ash and carbon content, water absorption, moisture content, tensile strength, elemental analysis and chemical analysis.

In this work we used GFRP (Glass fiber reinforcement Plastic), Nylon and Aluminium. Mechanical properties are evaluated for GFRP, Nylon and Aluminium individually and their composite with aluminium, using specimens prepared with reference to ASTM D638-02 a [10]. Fig.1 shows typical specimens for composite Al-GFRP-Al and Al-Nylon-Al.



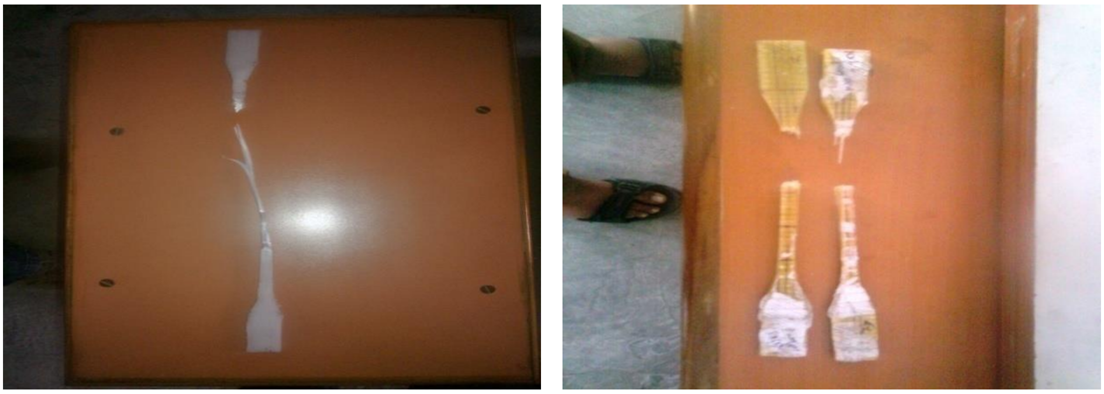
(a) (b)

Figure 1:- Specimen of ASTM code D638-02 a (type II) (a) Composite Al-GFRP-Al, (b) Composite Al-Nylon-Al [10]

2 Experimental Procedure

The composite specimens were subjected to various loads and computer controlled Universal Testing Machine (UTM). The specimens were clamped and tests were performed. The tests were closely monitored and conducted at room temperature. The load at which the completed fracture of the specimen occurred has been accepted as breakage load. Fig.2 shows the test rig used in the experiments. Fig.3 shows the fractured specimens using the test rig of Figure.2.

Figure 2:- Tensile Test of Nylon Fiber on Digital UTM



(a) (b)

Figure 3:- Fractured Specimens (a) Nylon, (b) GFRP [10]

Specification of Specimen:

All the specimens 1, 2 and 3are made with the help of ASTM code D638-02 a [10] and have the characteristics.
For figure 5,6,7,8 and 9
Specimen 1: Aluminum (Type-I)
Specimen 2: Aluminum (Type-II).
Specimen 3: Aluminum (Type-III)
Similarly all the three specimens are made by Type-I, Type-II and Type-III for composite and their individual materials.

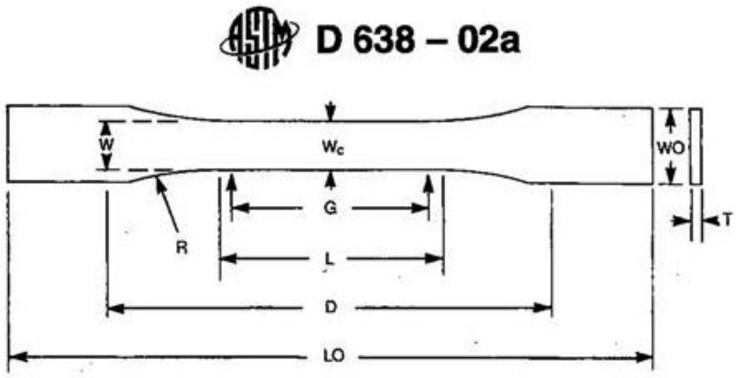


Figure 4: Drawing of Specimen

3 Results and Discussions

Table 1: Tensile properties of Al, GFRP, Nylon and their Composite

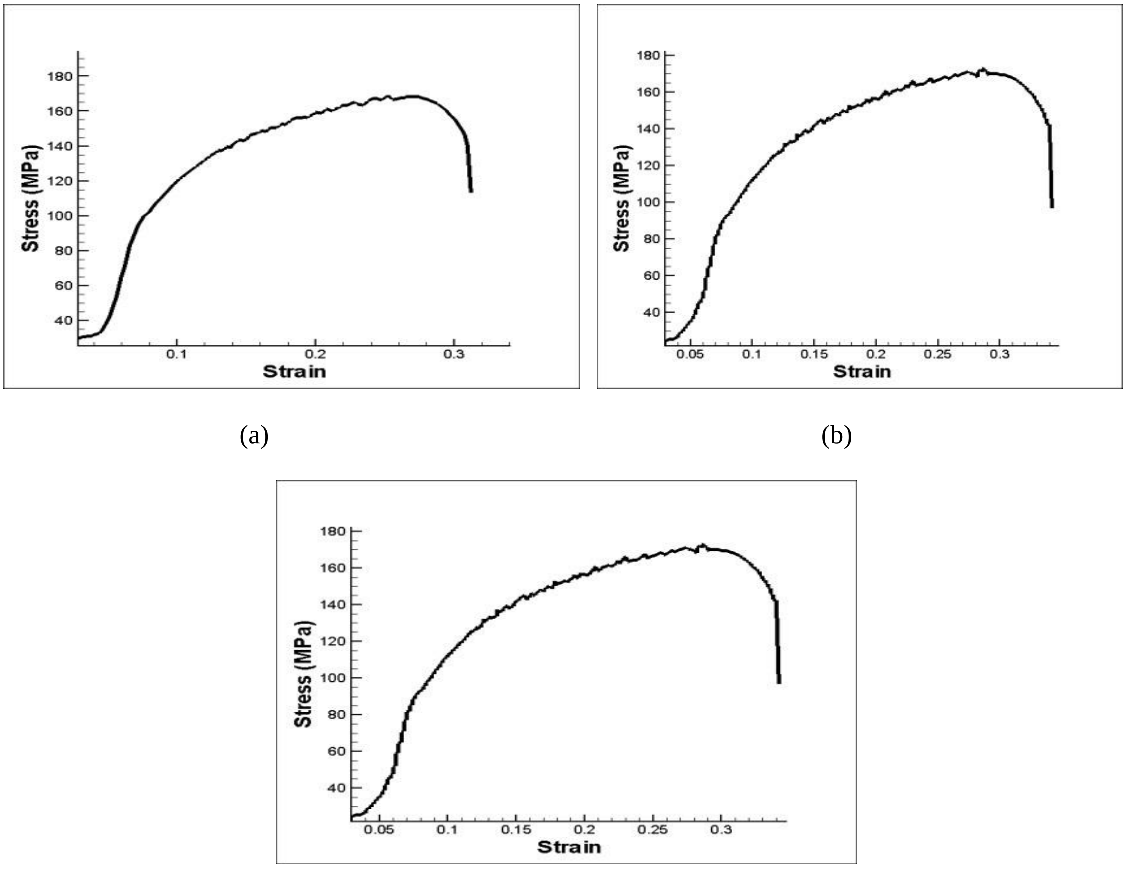
Material	Specimen	Ultimate Strength (N/mm^2)	Mean Ultimate Strength (N/mm^2)	Strain	Mean Strain
Aluminium	1	155	158.33	0.376	0.340
	2	162		0.314	
	3	158		0.33	
Nylon	1	39	42	0.572	0.570
	2	43		0.634	
	3	44		0.506	
GFRP	1	218	217	0.16	0.157
	2	213		0.156	
	3	220		0.156	
Composite Nylon	1	128	122.33	1.8	1.960
	2	121		2.07	
	3	118		2.01	
Composite GFRP	1	242	239.33	0.246	0.229
	2	246		0.222	
	3	230		0.220	

Table 2:- Dimension of Specimen with ASTM code D638-02 a [10]

Dimension (See Drawing)	Specimen Dimensions mm		
	Thickness 7 mm or less		Over 7 to 14 mm
	Type-I (mm)	Type-II(mm)	Type- III (mm)
W- Width of Narrow section	13	6	19
L-Length of narrow section	57	57	57
WO-Width over all	19	19	29
LO Length over all	165	183	246
G-Gage length	50	50	50
D-Distance between grips	115	135	115

R-Radius of fillet	76	76	76

Figure-5 shows the engineering stress-strain curve for Aluminium specimens with an enlarged scale, now showing strains from zero up to specimen fracture. Here it appears that the rate of strain hardening diminishes up to UTS (Ultimate Tensile Strength).Beyond that point, the material appears to strain soften, so that each increment of additional strain requires a smaller stress.



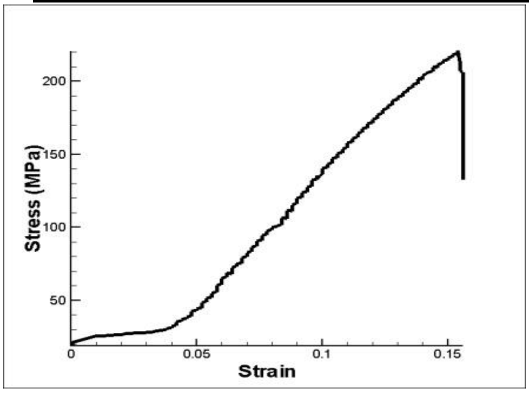
(a) (b)

(c)

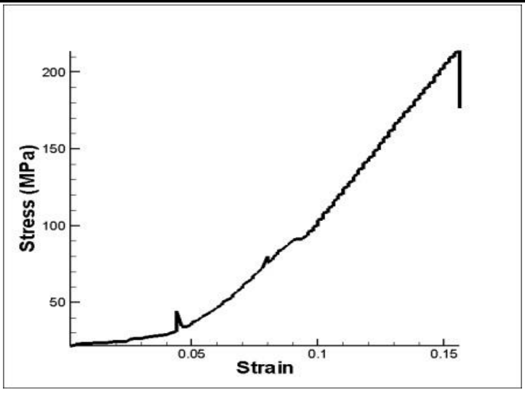
Figure 5:- Stress Strain Diagram for Aluminum (a) Specimen-1, (b) Specimen-2, (c) Specimen-3

The apparent change from strain hardening to strain softening is an artefact of the plotting procedure, however, as is the maximum observed in the curve at the UTS. The load must equal the true stress times the actual area ($P = \sigma_t A$), and as long as strain hardening can increase σ_t enough to compensate for the reduced area A, the load and therefore the engineering stress will continue to rise as the strain increases. Eventually, however, the decrease in area due to flow becomes larger than the increase in true stress due to strain hardening, and the load begins to fall.

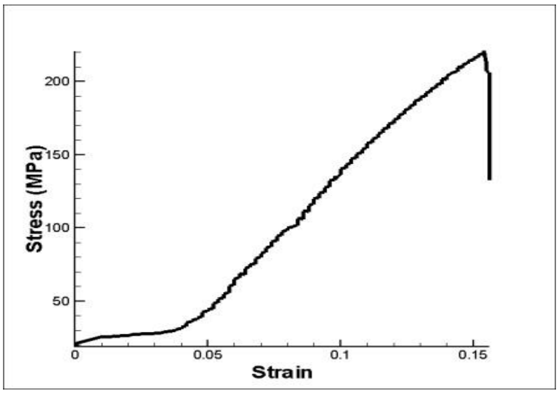
Figure 6 shows the stress strain curve for GFRP specimens, it shows similar behaviour as that of stress-strain curve for aluminium up to UTS i.e. the rate of strain hardening diminishes up to UTS. But after this point as the tensile load is increased the failure of GFRP take place resulting in sudden decrease in stress with no or constant strain. But it is interesting to observe that the ultimate tensile strength of GFRP is higher than that of pure aluminium but its strain is lesser.



(a)



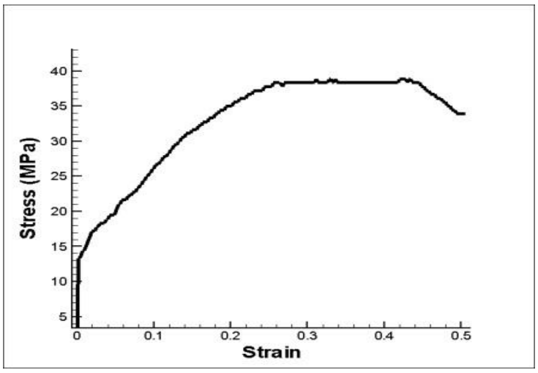
(b)

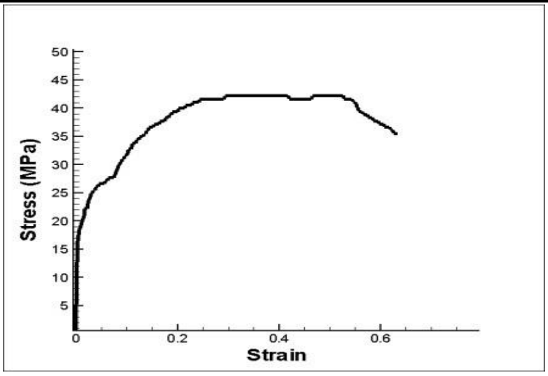


(c)

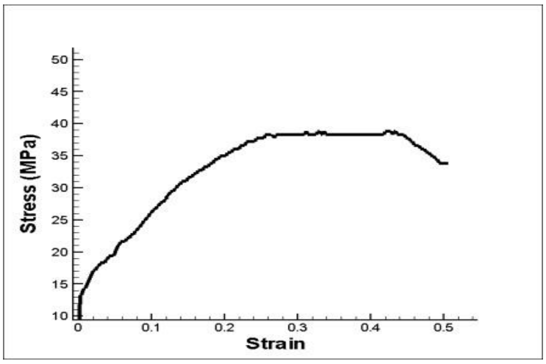
Figure 6:- Stress Strain Diagram for GFRP (a) Specimen-1 (b) Specimen-2, (c) Specimen-3

Figure 7 shows the engineering stress-strain curve for Nylon specimens. There sponge of this material is similar to that of Aluminium seen in Fig. 4, in that it shows a proportional limit followed by a maximum in the curve at which necking takes place. (It is common to term this maximum as the yield stress in plastics, although plastic flow has actually begun at earlier strains).





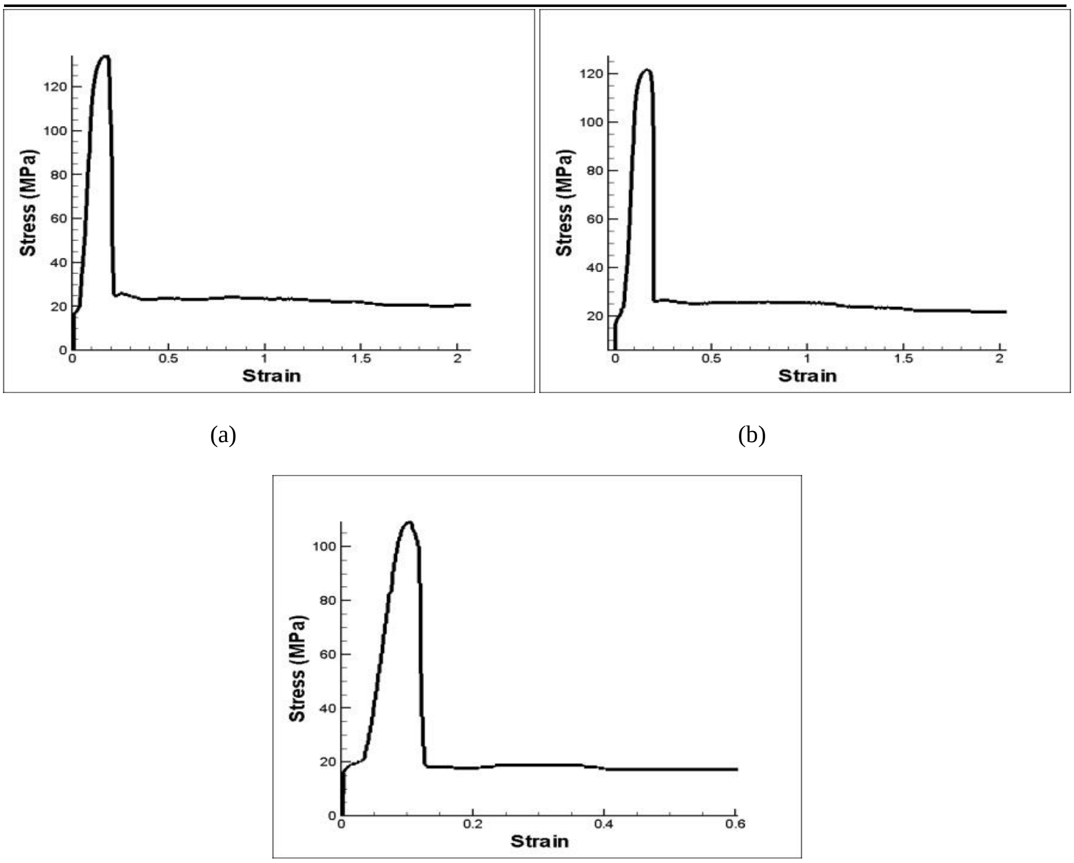
(a) (b)



(c)

Figure 7:- Stress Strain Diagram for Nylon (a) Specimen-1 (b) Specimen-2, (c) Specimen-3

The Nylon, however, differs dramatically from Aluminium in that the neck does not continue shrinking until the specimen fails. Rather, the material in the neck stretches only to a "natural draw ratio" which is a function of temperature and specimen processing, beyond which the material in the neck stops stretching and new material at the neck shoulders necks down. The neck then propagates until it spans the full gage length of the specimen, a process called drawing. Figure 8 shows the stress-strain curve for Nylon composite specimens, it shows that up to UTS (Ultimate Tensile Strength) there is sudden increase in stress with small increase in strain as up to this point there is large strain hardening on the layers of aluminium. After UTS, as the tensile load increases, failure of the aluminium take place due to which there is a sudden decrease in load indicating the failure of aluminium. After the failure of aluminium, tensile load acts on nylon but as nylon is highly elastic material it keep on stretching with constant load. Thus there is a straight line in the figure depicting the drawing of aluminium due to which strain goes on increasing with a small change in stress.

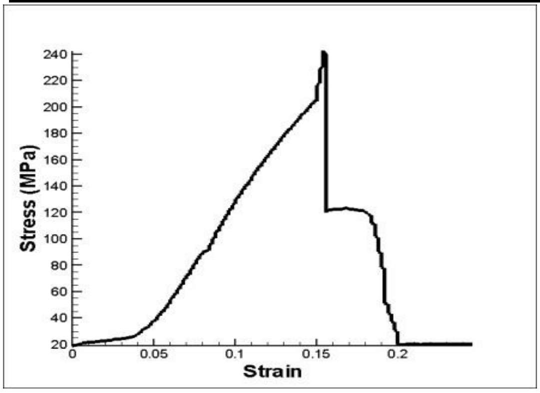


(a) (b)

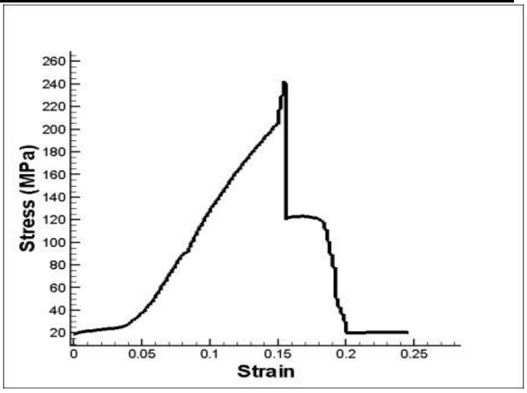
(c)

Figure 8:- Stress Strain Diagram for Composite Nylon (a) Specimen-1 (b) Specimen-2, (c) Specimen-3

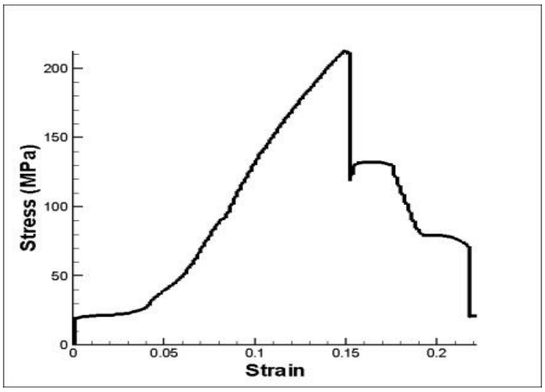
Figure 9 shows the stress strain curve for composite GFRP specimens, in all the graphs shows the similar behaviour as that of aluminium just before the UTS in fig 9(a) & fig 9(b) but fig 9(c) behaves similarly as aluminium up to UTS point. This could be due to variable conditions of testing so as the two curves 9(a) & 9(b) are somewhat similar so we could analyze the mechanical properties of GFRP on the basis of these two curves. Beyond a certain point in these two curves there is a sudden rise in load up to UTS this is due to the fact that both aluminium and GFRP have high tensile strength.



(a)



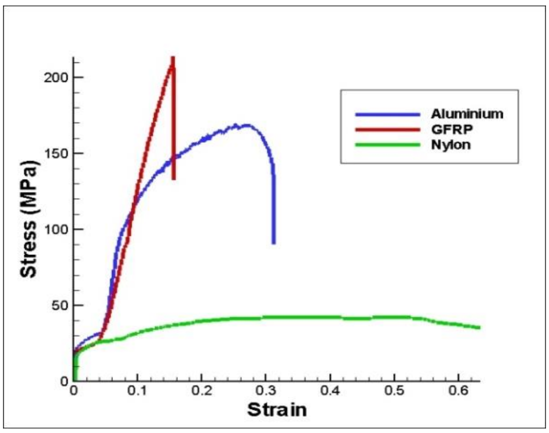
(b)

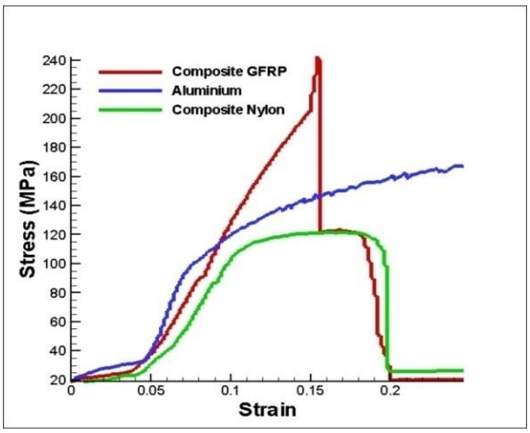


(c)

Figure 9:- Stress Strain Diagram for Composite GFRP (a) Specimen-1 (b) Specimen-2, (c) Specimen-3

After this point as the tensile load increases failure of the aluminium take place first due to which stress reduces suddenly with strain constant as the load is increased further, failure of GFRP takes place after with small increase in strain. However, in Fig 9(c) the failure of composite have taken place differently layer by layer as firstly one layer of Al failed then second layer and lastly GFRP had failed during tensile test. That’s why the stress strain curve is slightly different from the other two curves.

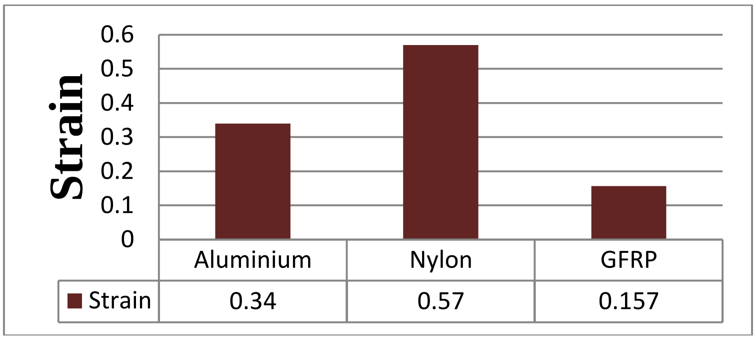




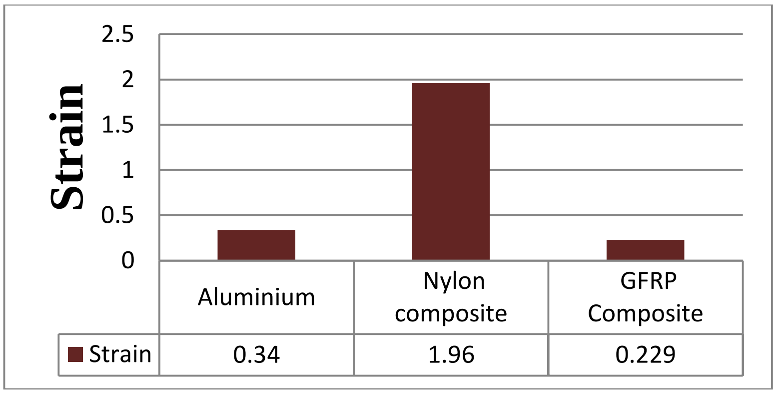
(b)

Figure 10:- Combined Stress Strain Diagram for (a) Individual Material (b) Composite Material

Figure 10 (a) shows the comparison between individual material aluminium, GFRP and Nylon. It shows that GFRP have higher strength than the other material and Nylon shows the lowest strength. But when we use the composite of GFRP and Nylon with aluminium then the strength of composite Nylon is increased, and the strength of composite GFRP remain higher than the other composite as shown in figure 10 (b).



(a)



(b)

Figure 11:- Comparison of Strain for (a) Individual Material, (b) Composite Material

Fig 11 (a & b) it shows GFRP have minimum elongation in length before failure. Nylon shows totally opposite properties as it has least tensile strength with maximum elongation due to which it has highest ductility. Aluminium somewhat has properties in between these two materials thus could be considered as an ideal material to form composites with the other two

Conclusions

The mechanical properties of aluminum, nylon, GFRP, aluminum-GFRP composite & aluminum-nylon composite were found by using experimental method. One layer of GFRP is sandwiched between two layers of aluminum to form GFRP composite. Similarly, nylon composite is formed. Acrylate is used as an adhesive material to form composites. From the above results following conclusions are as follow

- Figure 10 clearly shows the conclusion of this research paper, as it clearly shows the comparison between the mechanical properties like tensile strength and ductility of the three materials separately and when used as composites.
- From Fig 10 (a) and Fig 11 (a & b) it can be concluded that the tensile strength of GFRP material is highest with least ductility as it shows minimum elongation in length before failure. Nylon shows totally opposite properties as it has least tensile strength with maximum elongation due to which it has highest ductility. Aluminum somewhat has properties in between these two materials thus could be considered as an ideal material to form composites with the other two.
- From Fig 10 (b) it can be concluded that when composite of aluminum and GFRP is made then there is a significant change in the properties like the tensile strength becomes maximum of all the composites as well as individual materials and also unlike pure GFRP, the composite GFRP has higher elongation which shows the improvement in ductility. The nylon composite also shows revolutionary changes in the properties as its tensile strength increases as compared to pure nylon and its ductility is also somewhat reduced which can be useful in various applications.

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