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Experimental Analysis of Mechanical Properties of Composite Material Reinforced By Aluminum-Fibers

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Abstract - *The present work describes the development and mechanical characterization of new composites consisting of glass fiber reinforcement plastic (GFRP), Nylon and Aluminum. The newly developed composites are characterized for their mechanical properties. In this work, the mechanical properties of GFRP (glass Fiber Reinforcement Plastic), Nylon and their composite with Aluminum were evaluated with reference to ASTM D638-02a. During the tensile load, the maximum strain, and stress are obtained. The maximum strength is found in composite GFRP instead of aluminum and composite Nylon. Composite material has shown an improvement of mechanical properties when compared with individual materials.*

Key Words: GFRP, Nylon, Aluminum, Tensile Strength, Strain

1. INTRODUCTION

The composite materials are used in many engineering applications due to their excellent properties. The sandwich composite materials replace the metals owing to their excellent strength with low weight. Many of the literature deals with the combination of steel or aluminum reinforced with the glass fiber reinforced composites materials (GFRP). The carbon fiber finds application in aerospace and related fields. The cost of fabrication is reduced by using sandwich structures. The aluminum is sandwiched between the carbon layers formed as fiber metal laminates (FML), and it has excellent qualities such as overall reduced weight, corrosion resistance and environment friendly. Along with the host of benefits, the main disadvantage is the fabrication of these composites which is difficult [1]. The aircraft materials are developed based on fiber metal laminates which needs the improved crack growth properties [2]. If layers of different reinforcement materials are combined together to form laminate, they are called hybrid structure. This hybrid structure can be the product combination of layers of different synthetic and natural fabric or it can be prepared by combing layers of different kinds of synthetic and different kinds of natural fabrics. Hybrid structures of natural fibers such as banana-coir [3], and synthetic fibers such as glass and carbon [4] have been used previously for the development of better mechanical properties. Though, there are plenty of methods to build composite structure, hand lay-up is one of the basic and oldest methods to make composite products for study the composite laminate properties during the research stage. This process is cheap, easy to do and no specific machine is required. In this method reinforcement is first placed on the mold surface and the resin is applied to the fabric. As this method is very preliminary, the distribution of resin through laminate is uneven due to which it is difficult to have a uniform part thickness and fiber-resin volume ratio. After lay-up the component needs to be cured at room temperature or at elevated temperature based on resin system used. The part can be cured with compression molding or vacuum bagging to give more compaction during curing. In this paper the authors have used both natural and synthetic fibers for manufacturing composite laminate. Natural fiber, such as Jute, Bamboo and Glass fabric as synthetic fibers have been used for laminate preparation. Hand lay-up followed by vacuum bagging or compression molding to make laminates ensured controlled part thickness. Four different laminates are being manufactured. The details of these laminates are furnished below. The fibre/metal composite technology combines the advantages of metallic materials and fibre reinforced matrix systems. Metals are isotropic because they have a high bearing strength and impact resistance and are easy to repair. Full composites have an excellent fatigue characteristic and have high strength and stiffness. The fatigue and corrosion characteristics of metals and the low bearing strength, impact resistance and reparability of composites have overcome by the combination of metal and fibers [5, 6]. Composite matrix can be classified based on the matrix as metal matrix, ceramic matrix and polymer matrix. Based on reinforcement they can be classified as natural fiber and synthetic fiber reinforced composites. Natural fibers are renewable and biodegradable, which consists low density as well as low machining cost, less irritating to human skin and having efficient thermal and mechanical properties [7-11].

The ultimate tensile strength and hardness of bimetallic weld joint increases by increasing the pre-stress, and ductility was decreases when thermal loading increases. For preventing brittle failure behavior of carbon steel the value of pre-stress and thermal stress should be low as possible [12-16].

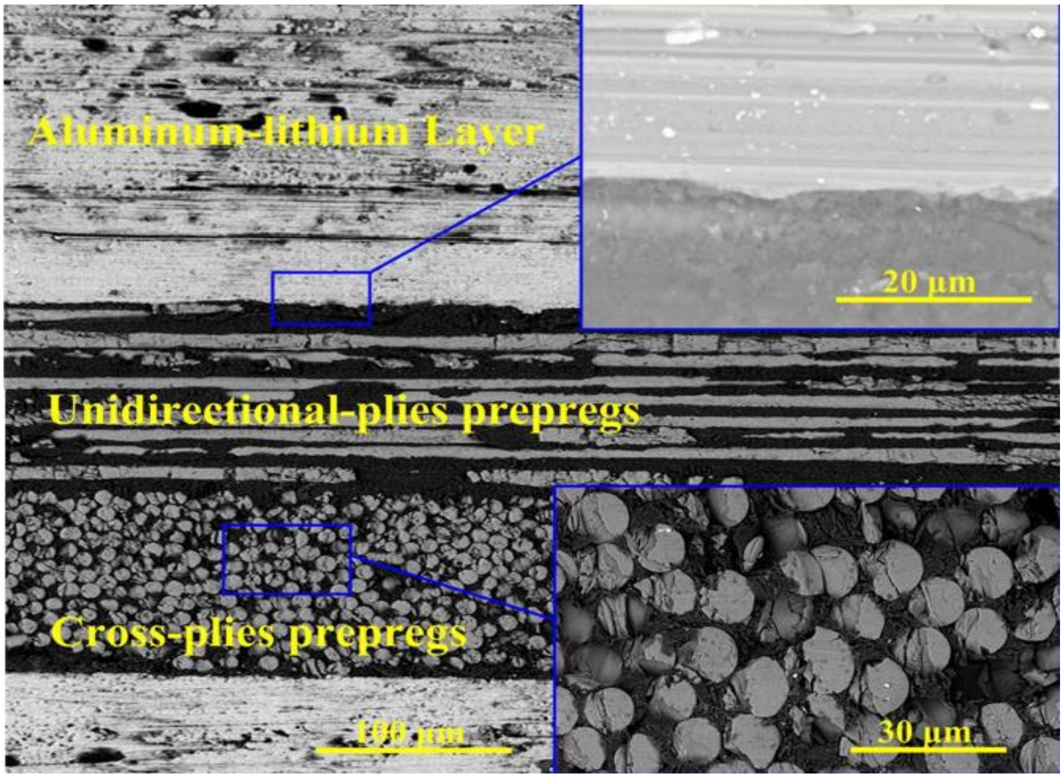
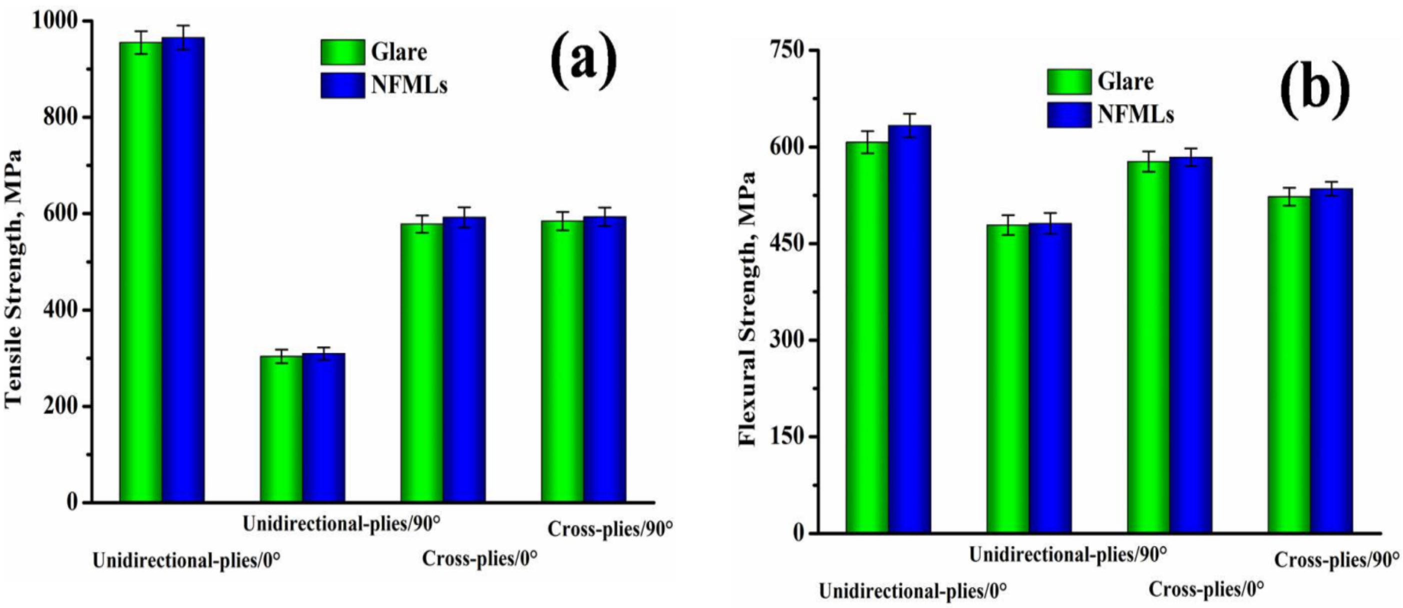
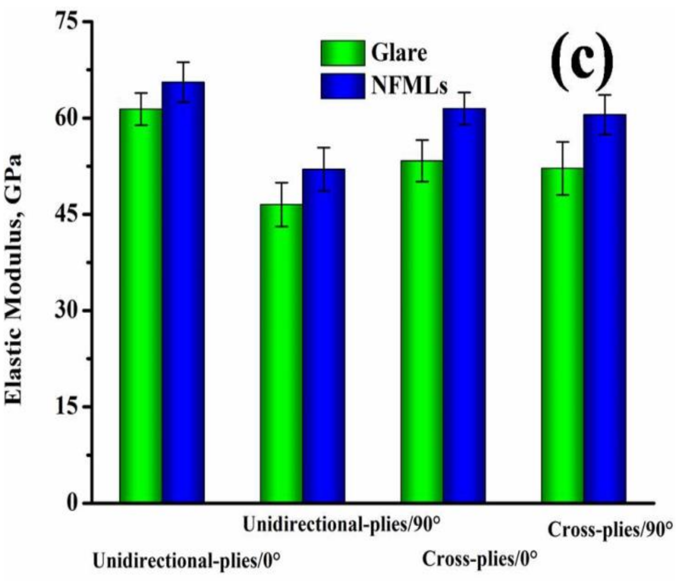


Figure 1: The interface between the aluminum-lithium layer and prepares [17]

The glass fibers uniformly reinforce the epoxy and well spliced, as the section features presented in Figure.1. Meanwhile, aluminum-lithium layers get good combination with the fiber reinforced epoxy through the observation of amplifying interface morphology. The prepared NFMLs and Glare keep the thickness of 1.42 ± 0.02mm, exhibiting almost the same density of 2.45g/m^3 and 2.47 g/m^3





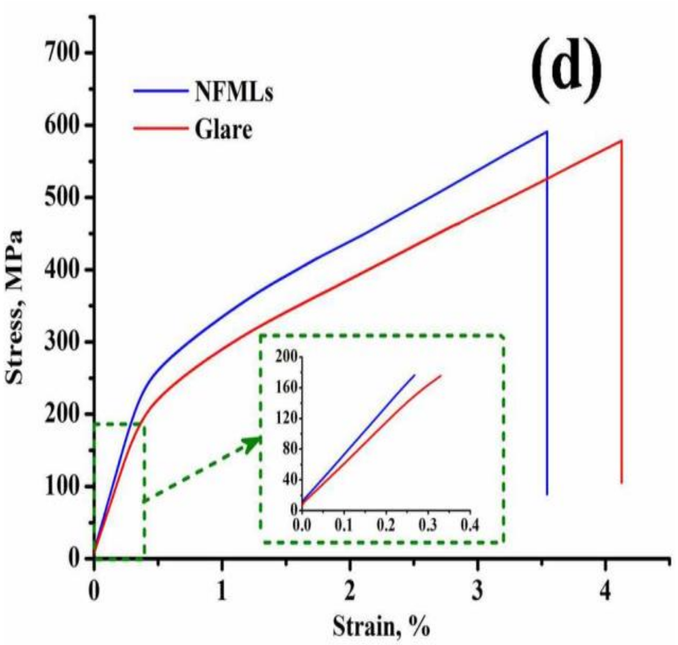


Figure 2: Tensile and flexural properties of NFMLs and Glare: (a) tensile strength; (b) flexural strength, (c) elastic modulus; (d) the tensile stress-strain curves (cross-plies/0^0) [17]

The novel fiber metal laminates (NFMLs) with different plies and sampling directions exhibit quite various strength and elastic modulus, as the tensile and flexural results shown in Fig. 2. However, NFMLs always have better mechanical properties than Glare under the same laminating design. The strength and stiffness of FMLs are mainly influenced by the bonding strength and the performance of each component. The NFMLs and Glare possess the similar bonding strength, which indicates that the performance of individual components determines the properties of the laminates. Hence, the improved strength and elastic modulus of NFMLs keeps in different degrees according to the prediction theory of Metal Volume Fraction (MVF). Only a slight increase of tensile and flexural strength is obtained when using aluminum-lithium alloy, because the fibers, not the metal layers, primarily contribute to the strength in FMLs. But for the elastic modulus, the rule is just opposite. Metal layers usually play a leading role in the elastic modulus of FMLs. The investigated aluminum-lithium alloy behaves a higher elastic modulus of 82GPa, bringing apparent elastic modulus improvement of NFMLs. The introduction of aluminum-lithium alloy increases the stiffness of 8%~12%, which is quite valuable in broadening the application of fiber metal laminated [17].

These material systems are created by bonding composite laminate plies to metal plies 6. The concept is usually applied to aluminum with aramid and glass fibers, also it is applied to other constituents [18]. Several articles have shown that, FMLs possess both the wonderful impact resistance characteristics of metals and the attractive mechanical properties of fiber reinforced composite materials [19-21]. Carbon fiber reinforced plastic (CFRP) is a high strength-to-weight and stiffness-to-weight ratio materials and they have been widely used in many fields such as aircraft, aerospace, ship, etc. Since the CFRP has more advantages than aramid fiber reinforced plastic (AFRP) and glass fiber reinforced plastic (GFRP), it is used as a potential composite layers to fabricate GLARE. GLARE is a material consisting of alternating layers of thin metal sheets and thin composite layers. High stiffness of carbon fiber provides more efficient crack bridging aluminum layers than aramid fiber and glass fiber. The presence of aluminum layer provides good impact resistance. This combination of high stiffness and strength with good impact resistance gives GLARE a great advantage as an application to the structures of aircraft, space, helicopter, robot, laminated pipe, drive shaft and so on [22-25].

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 [26-27]. The fabrication and characterization of the carbon-aluminum thermal management composites [28]. The microstructure and mechanical properties of 1050/ 6061 laminated composite processed by accumulative roll bonding. They have indicated that the 1050 layer shows coarse structure when compared to the 6061 layer [29]. The mechanical response of carbon fiber composite sandwich panels with pyramidal truss cores. They have studied the failure modes and analyzed the structures [30]. The low velocity impact behavior of glass fiber reinforced plastics aluminum sandwich composite materials [31]. The mechanical properties of Steel/Aluminum/GRP Laminates and presented in detail [32]. The mechanical behavior of fiber reinforced metal laminates (FRMLs). They have also studied the fracture behavior of fiber reinforced metal laminates. From the above research studies, it has been asserted that the carbon fiber reinforced aluminum sandwich composite materials are one of the important class of materials and are used in many applications [33].

2. EXPERIMENTAL PROCEDURE

In this work we used GFRP (Glass fiber reinforcement Plastic), Nylon and Aluminum. Mechanical properties are evaluated for GFRP, Nylon and Aluminum individually and their composite with aluminum, using specimens prepared with reference to ASTM D638-02 a. Figure 3 shows typical specimens for composite GFRP-Al- GFRP

Figure 3: Aluminum-GFRP Composite specimen

3. RESULT AND DISCUSSION

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.3 shows the test rig used in the experiments.

The mechanical properties of 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.

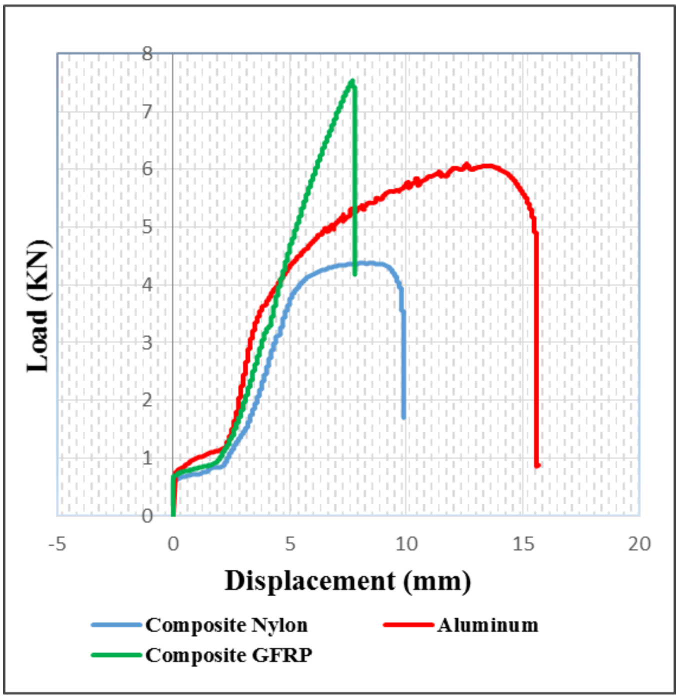
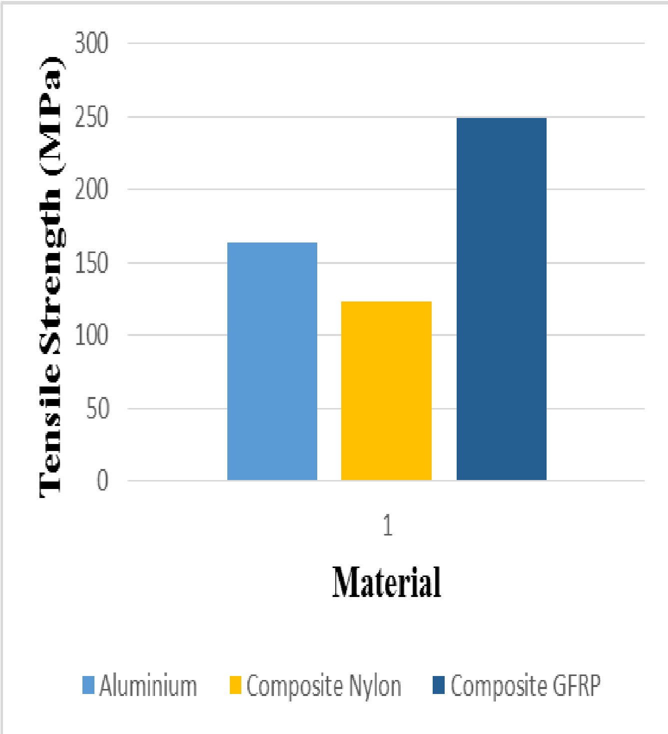
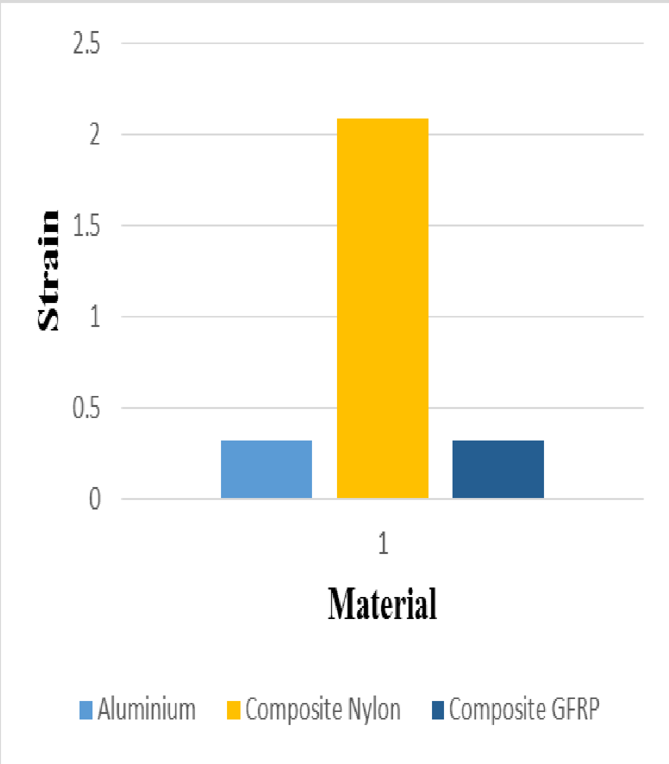


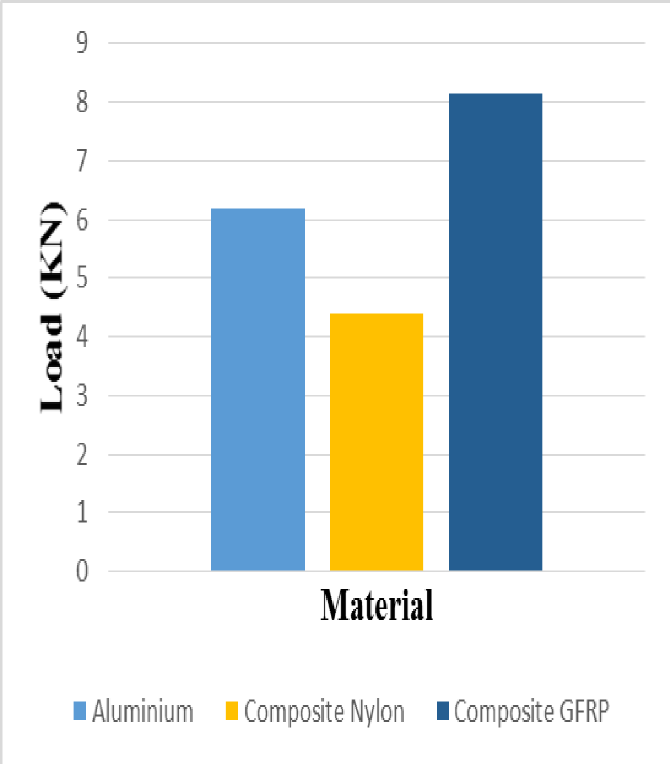
Figure 4: Load Displacement diagram for various composite material



(a)



(b)



(c)

Figure 5: Comparision of Composite material (a) Tensile strength, (b) Strain, (c) bearing load

Table 1: Mechanical Properties of Aluminum fiber

Material	Specimen	Ultimate Strength	Mean Strength	Strain	Mean Strain	Load	Mean Load
Aluminum	1	164.25	163.83	0.324	0.324	6.18	6.19
	2	158.34		0.319		6.29	
	3	168.9		0.329		6.12	
Composite Nylon	1	119.64	122.95	1.95	2.087	4.48	4.403
	2	125.74		2.14		4.31	
	3	123.48		2.17		4.42	
Composite GFRP	1	244.56	249.06	0.239	0.235	8.12	8.157
	2	253.27		0.237		8.34	
	3	249.36		0.231		8.01	

The fibre/metal composite technology combines the advantages of metallic materials and fibre reinforced matrix systems. Metals are isotropic because they have a high bearing strength and impact resistance and are easy to repair. Full composites have an excellent fatigue characteristic and have high strength and stiffness. The fatigue and corrosion characteristics of metals and the low bearing strength, impact resistance and reparability of composites have overcome by the combination of metal and fibers [32-34].

Table 1 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. Aluminum somewhat has properties in between these two materials thus could be considered as an ideal material to form composites with the other two.

4. CONCLUSIONS

The following conclusions are as follow

- The tensile strength of Aluminum-GFRP material is highest with least ductility as it shows minimum elongation in length before failure.
- 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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