A Comparative Study of Sandwich and Hybrid Sandwich Composites using Jute and Kevlar Fibers

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Abstract. The use of sandwich composites has increased day by day in the structural applications due to high strength to weight ratio, high environmental resistance with good thermal insulation properties. Natural fiber, jute is biodegradable and eco-friendly in nature due to which these fibers are considered as an alternative to conventional materials. In this study jute and Kevlar fibers were used as reinforcement in epoxy matrix. The two different layers of composites using jute and Kevlar fibers with epoxy resin are prepared with a size of 300 X 300 X 1mm using hand layup process. The paper board honeycomb structure with a size of 300 X 300 X 12mm was placed in between layers of composites. In the first case, jute fibers were used to fabricate the two layers above and below the honeycomb structure to make sandwich composite. In the second case, combination of jute and Kevlar fibers were used to fabricate the two layers above and below the honeycomb structure to make the hybrid sandwich composite. The fabricated composites were tested for their mechanical properties like tensile, compressive, flexural, and impact strength. Results reveal that hybrid sandwich composites have superior tensile, impact and flexural strength compared to sandwich composites. The compressive strength remained unaltered in both the cases.

1. Introduction
Carbon-monoxide emissions are rising due to the use of petrol and diesel in automobiles, aircraft, marine, locomotives and thereby accelerating global warming. One way of reducing the emission is by decreasing the weight of the vehicle which leads to fuel consumption. The existing structural materials used in vehicles are very heavy and composite materials are the alternatives to achieve good strength. Sandwich composites are becoming more popular as it can withstand heavy loads similar to the solid structure. These sandwich structures are made up of light weight thick core material in the middle with thin layers on both the sides having high strength and stiffness. Several researches have been carried out with different sandwich core structure like foam, corrugated plate and honeycomb. The core materials like aluminum, paper board, foam can be used according to the requirements. Jauhar Fajrin et al. [1] investigated on natural fiber reinforced plastic (NFRP) laminates incorporated with intermediate layer of hybrid structural insulated panels. The laminates are prepared by jute and hemp natural fibers as the intermediate layer. The results show that there is an improvement in the structural properties of the hybrid composites. Arbaoui et al. [2] investigated on the effect of multilayered sandwich structures. Polypropylene honeycomb is used as cores material and glass/ polyester skins were used as laminates. The effect of multilayer was investigated by three-point bending test and the
result shows that multilayer structure is more rigid. Mamalis et al. [3] developed a new hybrid structure with ten different combinations of face and intermediate laminates with foam as a core material. The stainless steel, aluminum and glass epoxy sheets with different thickness were used as face material and glass epoxy and wood were used as intermediate layer. The new hybrid structure was fabricated by compression molding method under vacuum. The fabricated hybrid structures were tested by three point bending test and FEM simulation. The result shows that there is an improvement in mechanical properties by introducing the intermediate layers and also improves the bonding behavior between laminates. In this study, paper board honeycomb structure is used as a core material and natural fibers jute along with Kevlar were used as face layers which are biodegradable and eco-friendly in nature.

2. Materials and Methods

2.1. Material used

Paperboard honeycomb structure is used as inner core material which provides high stiffness, very low weight and high durability. The dimension of paperboards was 300 X 300 X 12 mm and during stretching of paperboard hexagonal shape of the core is ensured. Jute and Kevlar are used as a face laminates. Biodegradable jute with density of 1.3 to 1.45 g/cc containing cellulose was used as laminates, these kind of jutes don’t generate toxic gases while fabrication. Araldite LY556 is used as epoxy resins this type of epoxy exhibits excellent thermal and mechanical properties and density is 1.15-1.20 g/cc at 25°C. It has good chemical resistance with acids up to 80°C. The HY951 is used as hardener due to its low viscosity and high filler addition possibility.

2.2. Fabrication methodology

The fabrication methodology of sandwich and hybrid sandwich composites is shown in Figure 1 and Figure 2. The Jute, Kevlar fiber and paperboard honeycomb core were cut according to 300 X 300 mm. In the case one, two layers of jute fiber laminate were kept above and below the core material and which is considered as sandwich composite. In the case 2 one layer of jute fiber laminate were kept above and below the core material followed by one layer of Kevlar fiber above the jute fiber on both the sides and which is considered as hybrid sandwich composites. Hand lay-up technique was used to fabricate the sandwich and hybrid sandwich composites. Initially the releasing film is placed on the mold and multiple layers of polymer coating resin were applied on the surface. Then the jute fiber layer is placed above the releasing film and 300 ml of epoxy-hardener was applied on the layer.
epoxy-hardener coated films are allowed to set for 5 minutes as gel time. Then second jute layer is kept above the first layer and same procedure was followed. Now paperboard honeycomb core is placed above the two layers. Similarly, same procedure was followed for two more jute fiber layers above the core material. The prepared composite is then pressed with 1 kg load for removing the air gaps and then allowed to cure for 72 hours. In the case two alternative layers of Kevlar and jute fibers was kept in which jute fibers adjacent to top and bottom surface of the core material and followed by Kevlar fiber on both the sides. Same fabrication procedure was followed to fabricate hybrid sandwich composite.

2.3. Testing of composites
In order to compare the mechanical properties of sandwich and hybrid sandwich composites following tests tensile, compressive, three point bending and impact test was conducted as per the standards. In each test 5 samples were tested. ASTM D3039 standard is used for tensile test in TUE-C-400 UTM machine as shown in Figure 3. (a). The tensile test specimens are in the size of 120 mm length, 34 mm width and 17mm thick as shown in the Figure 3. (b) and (c). The ASTM C365 standard was used to conduct compression test as shown in the Figure 4. (a) and (b) with sizes similar to the tensile test specimens.

![Figure 3. Tensile testing (a) UTM - TUE-C-400 (b) Case 1 sandwich composite (c) case 2 hybrid sandwich composite.](image1)

![Figure 4. Compression testing (a) Case 1 sandwich composite (b) Case 2 hybrid sandwich composite.](image2)
The flexural test (3 point bending) was conducted as per ASTM C-393 standard with sizes similar to the tensile test specimens. TUE-C-400 UTM was equipped with 3 point flexural test set-up as shown in the Figure 5. (a) and (b) two points at the bottom and one point at the top middle. In order to find the impact strength of composites Charpy test was carried out according to ASTM D7766.

![Figure 5. Flexural testing (a) Case 1 sandwich composite (b) Case 2 hybrid sandwich composite.](image)

### 3. Results and discussions

#### 3.1. Variation in Tensile strength of composites

The tensile strength of composites is shown in the Table 1. The hybrid composites results with higher tensile strength as compared with sandwich composite. The result shows that there is an increase in 123% of tensile strength and 120% increase in peak load caring capacity and 32% decrease in elongation. The Figure 6. shows the variation in elongation for sample 1, from the graph it is observed that hybrid composite are posses with higher strength and lower elongation during failure. The sandwich composite are having more elongation and not able to withstand high load. Hence the hybrid composites having high load bearing capacity as compared to that of sandwich composites which is due to the effect of reinforcement and enhanced interlaminar strength.

| Sample No | Load (kN) | Tensile Strength (N/mm²) | Elongation (mm) | Load (kN) | Tensile Strength (N/mm²) | Elongation (mm) |
|-----------|-----------|--------------------------|----------------|-----------|--------------------------|----------------|
| 1         | 2.1       | 3.633                    | 7.10           | 4.7       | 7.932                    | 4.81           |
| 2         | 1.98      | 3.588                    | 6.81           | 4.6       | 7.920                    | 4.76           |
| 3         | 2.3       | 3.755                    | 7.20           | 4.4       | 7.778                    | 4.63           |
| 4         | 2.1       | 3.69                     | 7.05           | 4.61      | 7.895                    | 4.72           |
| 5         | 2         | 3.577                    | 6.95           | 4.77      | 7.971                    | 5.02           |
| Average   | 2.10      | 3.649                    | 7.022          | 4.62      | 7.899                    | 4.79           |
3.2. Variation in compressive strength of composites

The results obtained from compression test for sandwich and hybrid sandwich composite are in Table 2. While comparing the two cases of composites there is 3% increase in compression strength and 3.92% increase in maximum load bearing capacity and 21% increase in elongation with hybrid composites. The elongation behavior of composites during compressive test is shown in Figure 7, which indicates the increase in elongation of hybrid composites. Since the degree of anisotropy is usually high for unidirectional composite the laminate is loaded along the fiber axis. Varying modules of elasticity results in macro instability of the structure and the composite fails by inter laminar shear. Crack propagation takes place in longitudinal direction along the fiber matrix interface due to weak interfacial site. This is the reason due to which jute reinforce composite has reduce load bearing capacity has reduced load bearing capacity when compared with hybrid sandwich composite.

Table 2. The variation in compressive strength of sandwich composite and hybrid sandwich composite.

| Sample No | Load (kN) | Compression Strength (N/mm²) | Elongation (mm) | Load (kN) | Compression Strength (N/mm²) | Elongation (mm) |
|-----------|-----------|------------------------------|-----------------|-----------|------------------------------|-----------------|
| 1         | 6.2       | 10.72                        | 3.00            | 6.38      | 11.03                        | 3.71            |
| 2         | 6.18      | 10.71                        | 3.08            | 6.37      | 11.02                        | 3.68            |
| 3         | 6.22      | 10.73                        | 3.12            | 6.36      | 11.05                        | 3.73            |
| 4         | 6.21      | 10.72                        | 3.10            | 6.38      | 11.04                        | 3.71            |
| 5         | 5.8       | 10.66                        | 2.97            | 6.33      | 11.01                        | 3.69            |
| Average   | 6.12      | 10.710                       | 3.054           | 6.36      | 11.032                       | 3.70            |
Variation in flexural strength of composites

The flexural strength of composites was obtained through three point bending test and the values of the composites are shown in Table 3. The results show that there is an increase in 34% in transverse strength, 25% increase in maximum load and 62% of increase in elongation of hybrid composites as compared to sandwich composites. The elongation behavior of composites during bending test is shown in Figure 8, which indicates that there is an increase in elongation of hybrid composites. During the flexural testing shear crippling was identified as the mechanism of failure. This is due to initiation of kink bands, these bonds originated from the flexural induced damage areas. These area consist of localized and agglomeration distorted fibers this is similar to slip line theory in metals. When the composite is subjected to flexural loading the peripheral walls bulges due to inter laminar transfer load as the radial load increases the peripheral cracking initiates at the center and distortion the composite into two segments. Further increasing in the load there is tendency for the fiber and the matrix to start sliding against each other. Then as the load increased the fracture appears due to fiber breaking and laminates debones.

Table 3. The variation in flexural strength of sandwich composite and hybrid sandwich composites.

| Sample No | Load (kN) | Transverse Strength (N/mm²) | Elongation (mm) | Load (kN) | Transverse Strength (N/mm²) | Elongation (mm) |
|-----------|-----------|----------------------------|----------------|-----------|----------------------------|----------------|
| 1         | 0.66      | 10.075                     | 6.65           | 0.8       | 13.434                     | 10.72          |
| 2         | 0.71      | 10.015                     | 6.51           | 0.78      | 13.411                     | 10.70          |
| 3         | 0.66      | 10.079                     | 6.70           | 0.77      | 13.388                     | 10.68          |
| 4         | 0.63      | 10.068                     | 6.60           | 0.82      | 13.461                     | 10.73          |
| 5         | 0.61      | 10.059                     | 6.58           | 0.89      | 13.485                     | 10.74          |
| Average   | 0.65      | 10.059                     | 6.608          | 0.81      | 13.436                     | 10.71          |
3.4. Variation in impact strength of composites

The impact strength of fabricated composites were obtained as per ASTM D7766 standard through charpy impact test, are shown in Table 4. The impact strength of hybrid composite is 98% higher than that of sandwich composites. The hybrid composites have higher weight due to the reinforcement of Kevlar fibers compared to that of sandwich composites which attributes to good energy absorption and leads to improved impact strength.

| Sample                   | Impact Strength (S) (joule) | Weight (W) gm. | S/W (kJ/gm) |
|--------------------------|-----------------------------|----------------|-------------|
| Case 1 Sandwich composite| 42                          | 20             | 2.1         |
| Case 2 hybrid Sandwich composite | 83                           | 25             | 3.32        |

The figure 9. shows the comparison of mechanical properties of sandwich composite and hybrid composite which clearly shows the hybrid sandwich composite possesses more strength when compared with sandwich composite.

Figure 8. Variation in flexural strength of composites.

Figure 9. Comparison of mechanical properties of sandwich composite and hybrid sandwich composite.
4. Conclusion
In this study, the sandwich and hybrid composites were fabricated by using hand-layup method. The effect of Kevlar fiber in hybrid composite properties were investigated and compared with the sandwich composites. The hybrid composites properties are observed with tensile strength 123%, compressive strength 3%, flexural strength 34% and impact strength of 98% higher than that of sandwich composites. These increased mechanical properties of hybrid composites are mainly due to the presence of Kevlar fibers compared to a sandwich composite. The load carrying capacity of hybrid composites also improved. Hence the hybrid sandwich composites providing better mechanical properties.

5. References
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