Effect of Multidirectional and Surface-Treated Abaca Fiber on Mechanical Properties of Polypropylene Composite By Using Compression Mould

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Abstract: Poly-fiber-based composites are the choice that influences to enhance the tensile strength and reduce the weight of components reason attracted to automotive door panel usages. The research motto is synthesis and enriches the mechanical behaviour of the natural abaca fiber (AF) incorporated polypropylene (PP) composite, which interface action enhanced via compression mould route, which is processed by 100 MPa. The developed composites like PP without fiber and PP with 5, 10, and 15 wt% of AF are involved in mechanical performance studies. Actions of multidirectional surface-treated AF on impact toughness, flexural strength, and tensile strength of the composite are studied by ASTM D6110, D790, and D3039 standards. With the combinations of PP/15 wt% surface treated AF spotted as high impact, flexural, & tensile strength are 23, 35, and 38 % better than the monolithic matrix (PP). The optimum PP/15wt% AF composite sample is utilized for automotive roof frame.

# Introduction

Recent research of polymer matrix composite formulation with natural fiber is trending for prospective in broad application because of lightweight, biodegradable, high strength, enhanced fracture toughness, and economic related to synthetic fiber incorporated polymer composites [1]. With the technological growth, natural fiber incorporated polymer composites are identified poor adhesive strength and improved moisture absorption behaviour, leading to limiting the ultimate tensile strength & impact toughness behaviour of nanocomposites [2], which are overcome by way of natural fiber treated with 5 % concentration of sodium hydroxide (NaOH)solutions [3]. Besides, the polymer composites fabricated by using the hand layup method associated with compressive action found better enhancement in mechanical and tribological behaviour [4], which is more economical than another process [5].

The behaviour of coir fiber reinforced epoxy composite. The composite contained a high amount of surface-treated coir fiber and offered maximum tensile and flexural strength properties, which is better than the monolithic polymer matrix without fiber content. The epoxy resin based poly composite is made with the compositions of sisal and kenaf fiber via the conventional route [6]. The fibers are involved in chemical surface treatment, which influences better adhesive behaviour, resulting in improved tensile strength properties and limiting the water absorption behaviour. This is used for automobile components applications [7].

Moreover, the natural fiber surface treated with sodium hydroxide chemical solution with 5 % concentration was found to have better mechanical and thermal stability properties, which is superior to the monolithic polymer phase [8]. The high-density polyethylene composite is developed with different percentages of abaca fiber, which is enhanced by chemical processing. The composite composed of 8 % of abaca natural fiber offered optimum yield and tensile strength, better tensile modulus, and better pinning action [9]. The polypropylene composites are developed from coir fiber and evaluated for their fracture toughness, flexural, impact and tensile strength of the composite. It results show that the composite containinga higher content of coir fiber is offered superior mechanical behaviour of composite. The chemical surface process coir fiber found superior adhesive behaviour, resulting in better tensile and flexural properties [10-11]. The kenaf fiber-made polypropylene composite behaviour with different fiber processing like alkali and alkali with silane. The 5-6% concentrations of alkali solution exposed better adhesive behaviour as well as improved fracture toughness value. The results of microstructure analysis provide better fiber distribution leads to enhance the tensile strength behaviour. However, the hand layup associated with the compression mould technique found batter composite quality with enriched mechanical and tribological properties [12-15].The PP nanocomposites are made by using natural hemp fiber, which is treated with a 5 % sodium hydroxide (NaOH) solution and investigated their thermo-mechanical properties of composites. The composite shows that the tensile and flexural strength was gradually enhanced by the additions of hemp fiber and maximum tensile strength was noted at a higher amount of hemp fiber [16-22]. Moreover, natural fiber incorporated polymer composites are a better choice for high strength to weight ratio applications and expose unique behaviours such as high strength, better stiffness, and biodegradability [23-28].

However, the poly-fibre composite developing methods, reinforcement phases, and their related characteristics are elaborated above. The natural fiber-reinforced composite lacks adhesive behaviour, resulting in reduced tensile, flexural, and impact strength behaviour. This study is to synthesize and enhancing the impact, flexural and tensile strength properties of hand layup associated with compression mould-developed polypropylene/abaca fiber (NaOH treated) composites through the chemical processing of abaca fiber. The 5 % concentration of sodium hydroxide (NaOH) is used to enhance fiber quality and implemented for composite fabrication. The final PP composite contained 0-15 wt% of chemical treated abaca fiber.

## Fabrication

In the current study, polypropylene (PP) and natural abaca fiber are taken as poly matrix and fiber phase reinforcement. The PP poly matrix is lightweight, has better strength, high chemical resistance, is durable, and has good thermal resistance behaviour [10, 29-32]. The abaca fiber is extracted from a natural source and involved in chemical surface processing to enhance the quality of fiber [33]. Initially, the dust particles and other wastes are cleaned from the abaca fiber via running water and by using electrical air-dryer, it is dried. Then, the fiber is immersed in 5 % sodium hydroxide for 60 min and blended every 30 min, which supports to eliminate wastes & fine dust. After, the chemical processing of fiber involves to drying process via electrical type heating furnace with 200 ⁰C for 20 min. It provides better adhesive behaviour and limits water absorption behaviour [13, 34]. Table 1 indicates the behaviour of PP and AF.

Table 1 Properties of polypropylene and abaca fiber

|  |  |  |
| --- | --- | --- |
| Characteristic/Material | PP | Abaca fiber |
| Density in g/cc | 0.94 | 1.5 |
| Elongation in % | 93 to 530 | 4 to 10 |
| Tensile strength in MPa | 47 | 100 to 900 |
| Size | 300 mm X 300 mm | 3 to 5 mm |

Table 2 PP and PP/abaca fiber composite fabrication

|  |  |  |  |
| --- | --- | --- | --- |
| PP composite samples | PP lamina | Epoxy resin: hardener | Treated abaca fiber in wt% |
| 1 | 300 mm X 300 mm | 100:10 | 100 |
| 2 | 92.5 |
| 3 | 85 |
| 4 | 77.5 |

According to Table 2, the PP and its abaca fiber-reinforced composites are synthesized via the hand layup route associated with compression action. Figure 1 indicates the schematic process layout for sample 3 composite preparation.

The PP lamina is placed above the hand layup table, and 10:1 ratios of epoxy resin: hardener are blended via a mechanical stirrer and applied over the PP lamina by hand-operated roller setup. The epoxy resin is lay over the PP lamina, and spitted abaca fiber is stretch over the lamina. The PP lamina is placed over the back of the layer and kept in a compression mould with 100 MPa applied over the lamina for 3 min, providing better interfacial strength [5, 35-38]. Finally, the developed composite cured open atmosphere with an ambient temperature of 24±1 ⁰C at 65 % relative humidity is spotted. The fabricated composite samples are involvedin mechanical testing and follow the ASTM standard [51-52].

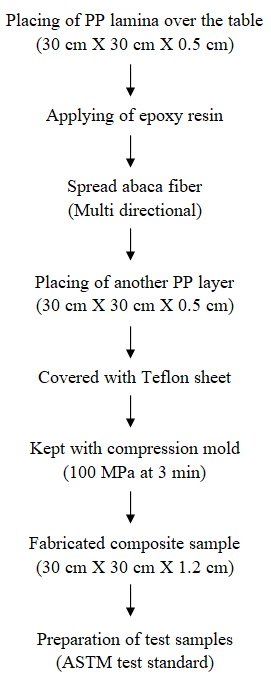
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Figure 1 Schematic process layout for composite preparation

## Characteristics study

The synthesized composite sample is prepared for ASTM D6110 standard and tested its charpy impact strength behaviour via ELMECH made IT300J model impact tester. FIE evaluates the flexural strength of composite make CT30 model is used and followed by ASTM D790 standard. FIE tests the strength properties of PP with its abaca fiber composite samples, making a tensile testing machine with 100KN capacity. It is operated by a 4 mm/min travel speed and follows the ASTM D3039 standard [39-43]. During the composite evaluation, three test samples from each composite sample are trialled, and its mean is considered as the final value of the composite. The tests are conducted atan ambient temperature of 24±1 ⁰C at 65 % relative humidity is noted [44-48].

# Results and Discussion

Based on the investigational results, Table 3 indicates the mechanical properties of PP and PP/abaca fiber-developed composites.

Table 3 Composites behaviour

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| PP composite samples | Impact strength | Flexural strength | Tensile strength | Elongation behaviour |
| kJ/m2 | MPa | MPa | % |
| 1 | 2.4 | 52 | 46 | 104 |
| 2 | 2.9 | 59 | 49 | 132 |
| 3 | 3.7 | 65 | 58 | 141 |
| 4 | 4.4 | 73 | 65 | 158 |

## Impact strength characteristics

Figure 2 indicates the Charpy impact strength behaviour of PP and PP/abaca fiber composite samples. It is noted from Figure 2 that the impact strength of PP/abaca fiber is higher than the PP lamina. The contribution of multidirectional abaca influences to better enhancement in impact strength. The impact strength of PP is noted by 2.4 kJ/m2, and the contribution of abaca fiber (treated) as 5 wt% is offered 2.9 kJ/m2 of impact strength. Effective interfacial action between the AF and PP causes improved energy absorption behaviour [9, 49]. Besides, composite sample 3, prepared with 10 wt% of abaca fiber placed as multi-direction over the PP lamina, is exposed to 3.7 kJ/m2 of its impact strength, which is better than composite samples 1 and 2.

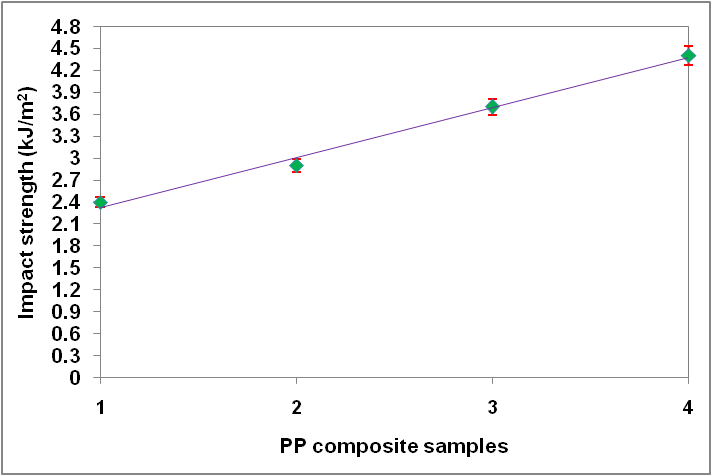


Figure 2 Impact strength characteristics

The impact strength of PP/abaca fiber sample 4 featured with 15 wt% of abaca fiber, was 4.4 kJ/m2, which isdue to better pinning action between the AF and PP. The processing effect and contribution of fiber lead to better mechanical behaviour [10].

## Flexural strength characteristics

The flexural strength of PP and PP/abaca fiber composite samples are illustrated in Figure 3 with a 5 % allowable error bar. With the impact of treated abaca fiber, the PP composite flexural strength was gradually increased, and maximum flexural strength was spotted at higher content of abaca fiber developed composites. The composite sample 1 without abaca fiber is noted by 52 MPa of its flexural strength and hiked by 59 MPa on the additions of 5 wt% abaca fiber. The mechanism for better interfacial bonding with multi-direction abaca fiber influences better improvement in the flexural strength [8-9]. Besides, the flexural strength of composite sample 3 made by 10 wt% of abaca fiber attained 65 MPa due to the action of superior adhesive behaviour [12, 50].

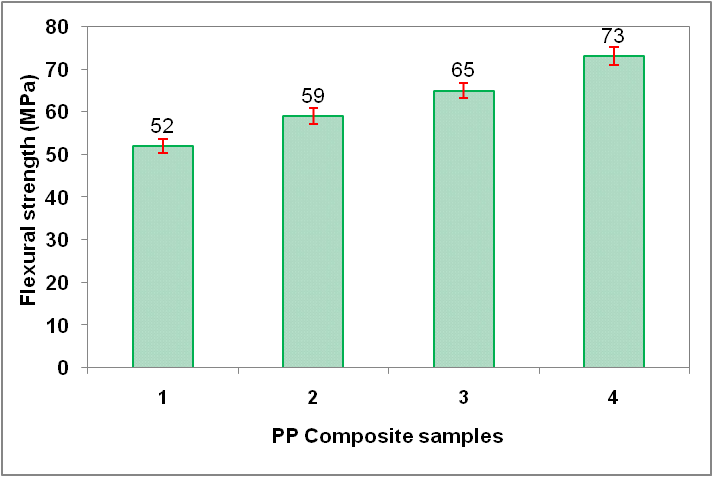


Figure 3 Flexural strength characteristics

Moreover, the composite sample has 15 wt% of abaca fiber leads to better flexural strength, and its value is 73 MPa, which is 40 % better than the monolithic PP lamina without AF. The chemically processed fiber caused better adhesive behaviour, resulting in superior flexural strength of the composite 13].

## The tensile strength value of PP and PP/abaca fiber composites

Figure 4 presents the strength (tensile) of PP and PP/abaca fiber composite samples and the composite sample developed with abaca fiber, which is treated with NaOH chemical solution exposed to superior tensile strength behaviour and higher than the value of monolithic PP matrix (composite sample 1). 46 MPa spots the tensile strength for composite sample 1. The composite sample 2, composed of 5 wt% of abaca fiber, attained improved tensile strength behaviour of 59 MPa, and the composite sample notes 65 MPa has 10 wt% of abaca fiber. The chemical fiber surface treated natural fiber made composite is exposed better adhesive behaviour natural fiber processed with a chemical solution is found to improve adhesive behaviour and make a composite strengthen bonding [10].

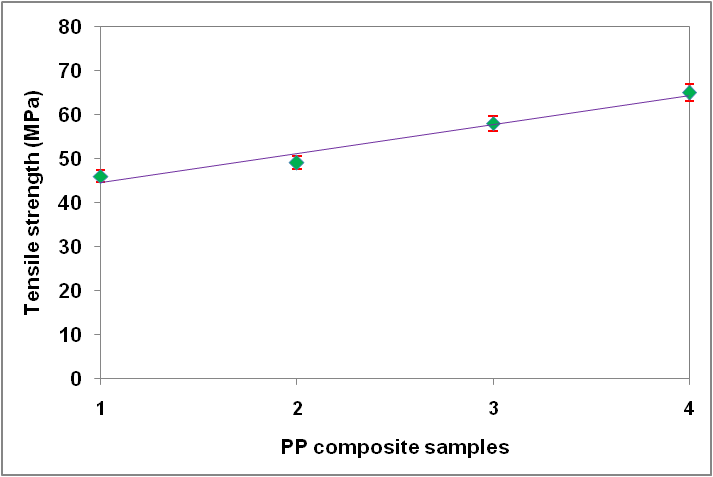


Figure 4 Tensile strength of characteristics

However, the strength (tensile) of composite sample 4 made by natural abaca fiber (15wt%) attained a maximum value of 65 MPa, which is 41 % better than composite sample 1 without abaca fiber. The contribution of multidirectional fiber withstands the maximum tensile load and limits the fiber movement in the PP lamina.

# Conclusion

The polypropylene and polypropylene/abaca fiber (chemically treated) are effectively made via had layup technique associated with compressive action. Influences of multidirectional abaca fiber actions on impact, flexural, and tensile strength of PP and PP/abaca fiber composites are studied, and the important key findings are detailed below points.The actions of multidirectional abaca fiber are recorded as a maximum impact strength value of 15 wt% of its contribution with PP matrix and 83 % better than composite sample 1 (PP without AF).

The multidirectional spread abaca fiber provided better flexural strength, and composite sample 4 of PP/15wt% abaca fiber is 40 % superior to the value of sample 1.The strength (tensile) of sample 4, prepared with 15wt%, showed a 41 % higher value compared to composite sample 1 (PP without AF).The optimum behaviour of composite sample 4 is utilized for automotive roof top frame, and micro-drilling operation & wear performance evaluation is the future investigation.

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