Natural Fiber Reinforced Composites in Furniture Industry: A Case Study

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ABSTRACT

The specific properties of the natural fiber reinforced composites have been found comparable to synthetic fiber based composites in numerous engineering applications. Due to their low cost, fairly good mechanical properties, high specific strength, non-abrasive nature, eco-friendly and bio-degradable characteristics, natural fibers are being exploited as a replacement for the conventional fibers. The application spectrum of composites based on natural fibers is still limited. The main objective of the current research endeavour is to analyse the feasibility of these composites in furniture applications. Bagasse fiber reinforced polypropylene granules were used to fabricate back support plate of a chair. The results revealed that these composites possess huge potential in furniture segment towards replacing pure polymeric parts.

KEYWORDS: *Natural fibers; Composites; Furniture*

1 INTRODUCTION

Synthetic fiber (Glass, Carbon and Aramid etc.) reinforced polymer composites are dominating in structural applications as these composite are characterized by high strength and stiffness as compared to other monolithic materials. The energy consumption to produce a flax fiber mat (9.55 MJ/kg), including cultivation, harvesting, and fiber separation amounts only 17% of the energy to produce a glass-fiber mat (54.7 MJ/kg) (Joshi et al., 2004; Wu et al., 2018). Synthetic fibers reinforced composites also cause environmental pollution after end of usable life due to their non-recyclable and non-biodegradable properties. Therefore, government agencies, throughout the world have been developing regulatory laws and general societal awareness on pollution, energy, and raw material waste. This has stimulated a rapid growth of novel uses of natural fibers as reinforcements in plastics to replace traditional monolithic plastic material and synthetic fiber reinforced polymer composites. Plenty of researchers are working and exploring the potential of cellulose based fibers as reinforcement and exploring the possibilities of replacing synthetic fiber reinforced polymer composites, which are currently being used in the various applications.

Mechanical properties of natural fiber reinforced polymer matrix composites, effect of fabrication processes and effect of matrix materials has been reviewed and concluded that the mechanical properties of developed composites depend upon various parameters like percentage of fiber reinforcement, interfacial adhesion, aspect ratio and coupling agents (Faruk et al., 2012). Developing new materials for any application is quite costly, time consuming and potentially risky, therefore, in the beginning, it is advisable to work on the conceptualization, design and development of composites. An integral part of a comfortable chair has been selected to analyse the feasibility of natural fiber reinforced composites in the furniture industry.

2 MATERIALS AND METHOD

In automobile sector, polypropylene based components are used for a variety of parts, including bumper, dash board, panels and door trims due to their low cost, low density, moldability, mechanical properties and recyclability. Thus, polypropylene has been selected as the matrix material for the experimental investigation and a homopolymer of polypropylene (*PROPEL 1350 YG)* has been procured from *Indian Oil Corporation Ltd.* for the experimental work as it has a good MFI (Melt Flow Index), low cost, is easily available and wide uses. Mechanical properties for the matrix material used is shown in table 1.

Table 1: Basic properties of selected polypropylene

Properties	**Standard**	**Value**
Tensile Strength[#]	ASTM D-3039	26.45 MPa
Tensile Modulus[#]	ASTM D-3039	580 MPa
Elongation @yield[#]	ASTM D-3039	21%
Flexural Strength[#]	ASTM D-7264	43.24 MPa
Flexural Modulus[#]	ASTM D-7264	1240 MPa
Melt Flow Index*	ASTM D-1238	35 gm/10 min

The major crop, produced in India is sugarcane (Approx. 360MMT annually), used to produce sugar, but leaving a residue in form of bagasse (Approx. 40MMT, having a low calorific value), containing lot of dust, moisture, pulp, pith and leaves residue. This bagasse is burnt to generate electricity due to its disposal problem thereby, causing environmental pollution. So the by-product of this crop has been selected for the experimental investigation. Raw bagasse has been collected from M/s Uttam Sugar Mills Limited, Libberheri, Uttarakhand, and the fibers have been extracted through the process mentioned in literature (Lila et al., 2018).

Initially, dried bagasse fiber (30% by weight) and polypropylene were weighted and mixed thoroughly in a container. Then these individual mixtures were fed in hopper of injection molding machine (Make: Electronica, Model: Endure-60) and specimens were fabricated as per the ASTM standards by direct injection molding for tensile and flexural testing. Based on the pilot experimentation conducted, the specimens have been fabricated at an injection temperature of 180^0C with an injection pressure of 55 bar, holding pressure of 50 bar at a holding time of 5 secs.

The fabricated specimens were then tested for their tensile and flexural properties as per ASTM-3039 and ASTM D-7264 standards on universal testing machine (Make: Instron, Model: 5982). Based on the results obtained, simulation run was carried using Solidworks and Moldflow softwares.

3 MODELLING AND SIMULATION

After selecting the part, working methodology and steps has been decided for the approach. The major steps involved in the procedure has been decided as:

1. Computer Aided Modelling of component
2. Simulation run for flexible strength under uniform loading
3. Simulation run for mold flow process to identify mold characteristic at experimental process parameters

4. Fabrication of component using Injection molding machine.

The front and rear view of selected chair part has been shown in Fig 1.

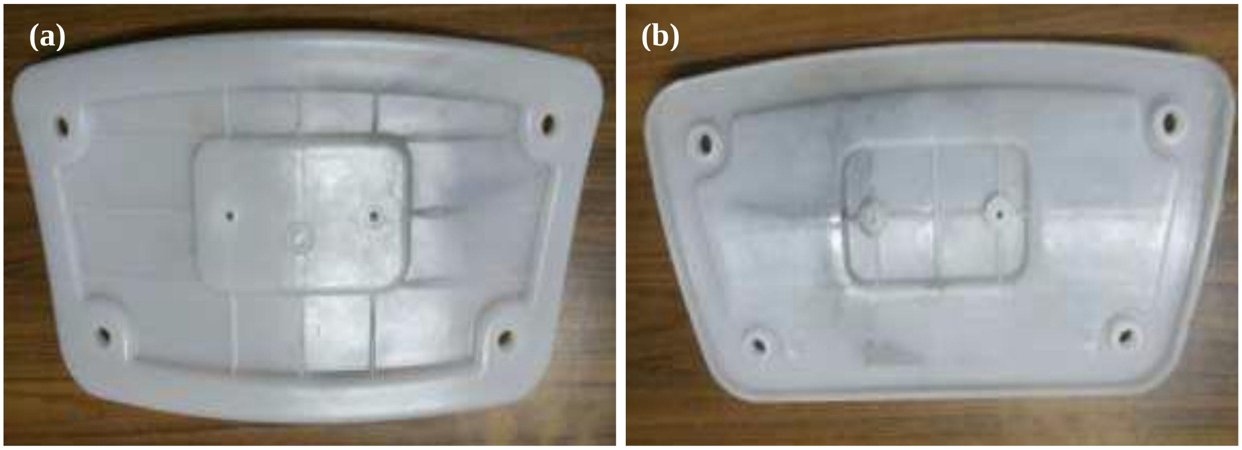

Fig 1: (a) Front view (b) Rear view of inner back plate

The project began with basic modelling of the part using DS SolidWorks. The part was scaled and modelled by using Solidworks as the initial step toward natural fiber reinforcement, shown in Fig 2.

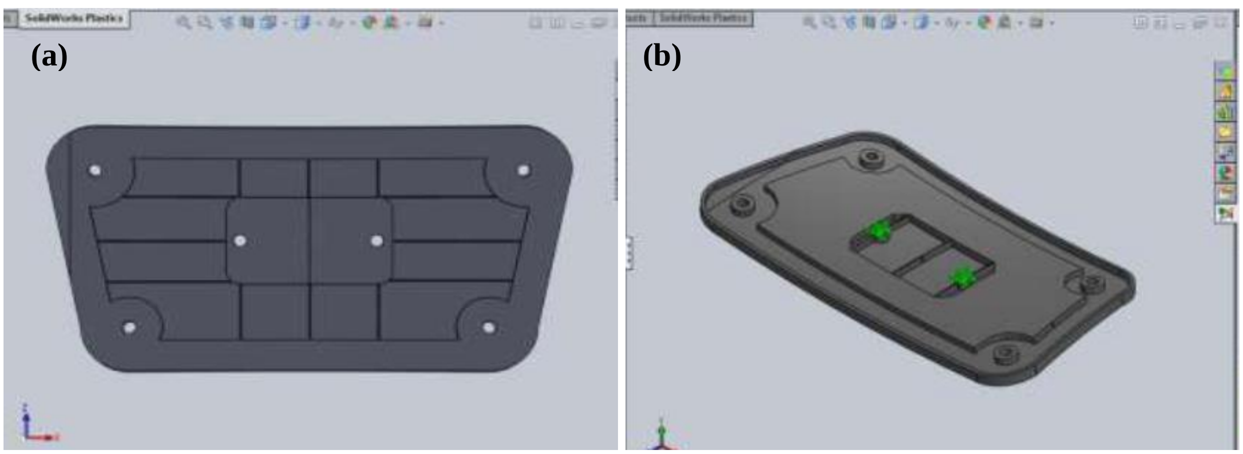

Fig 2: (a) 2-D drawing and (b) Isometric view of part

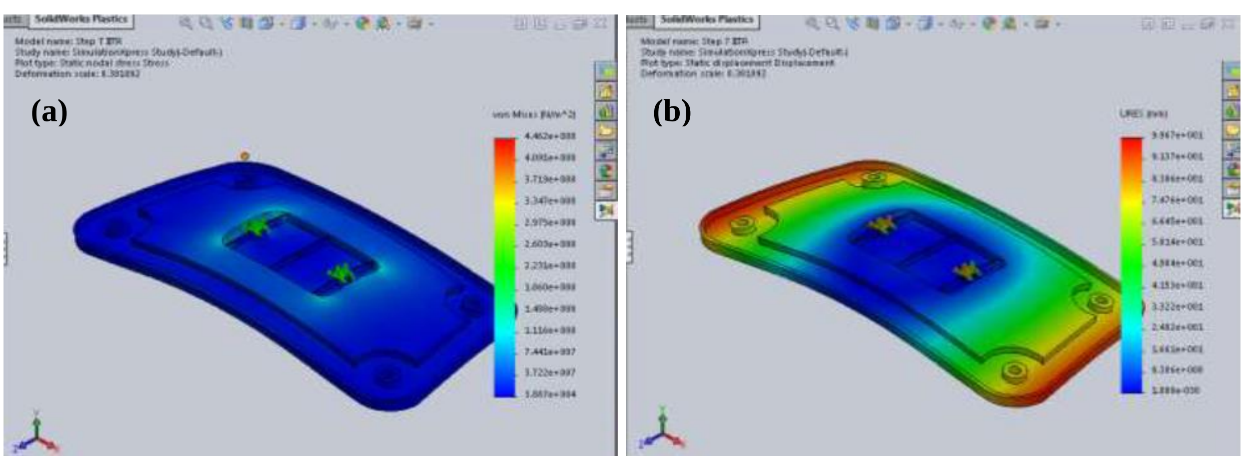

Fig 3: (a) Von-Mises Stress (b) Displacement of fibers in X direction

The part so modelled was then simulated for load testing and then subjected to simulation run to analyse the stress-strain properties of the material. The applied normal load is axial and point loaded with a magnitude of 2800N, as per normal testing standards. It was observed in the simulation run composite material, that the developed stresses are in the acceptable (blue) region, which also reveals that the stress developed are not in critical range, which may be a cause of product failure. The results obtained in the simulation run for Von-Mises stress and fiber displacement along the direction of flow of material are shown in Fig 3.

4 FABRICATION OF PART

A virtual simulation of the molding and flow parameters was then performed again to estimate the desired molding parameters and finally the component was actually fabricated by using Injection molding process. Similar to the pilot experimentation, bagasse fibers (30% by weight) and Polypropylene were weighed and mixed. The mixture was subsequently fed in the hopper of injection molding machine and injection process has been performed at designed process parameters. Several shots were taken until a uniform distribution of fibre took place across the polymer matrix in the whole component. The fabricated part has been shown in Fig 4.

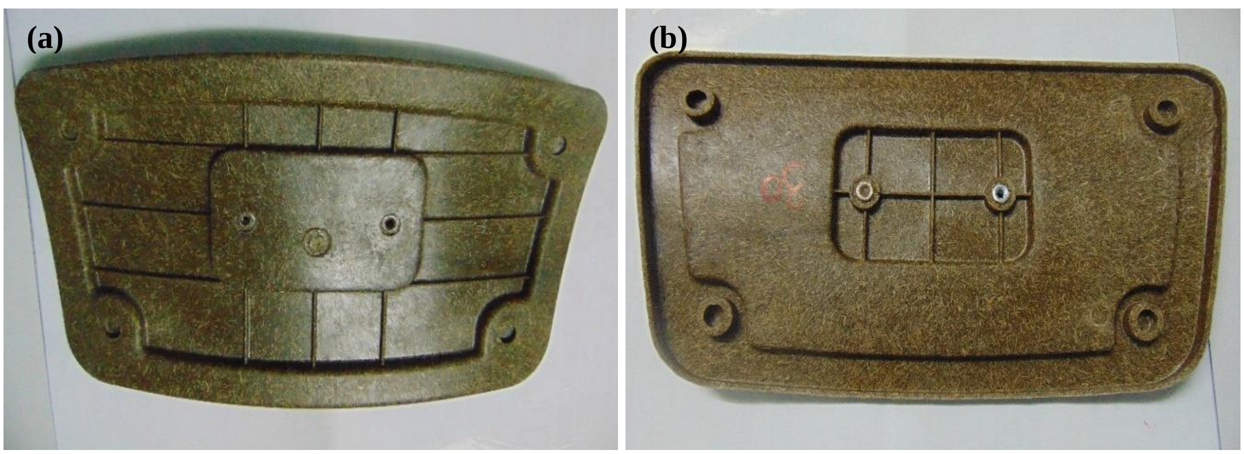

Fig 4: (a) Front view (b) Rear view of chair part fabricated with composites

After successful completion of this work, another part (Back outer cover for the same chair) is fabricated with a reinforcement of 30 % bagasse fiber and with/without 2% coloring agent (Black). The results in the form of reinforced part are shown in Fig 5 and Fig 6, respectively.

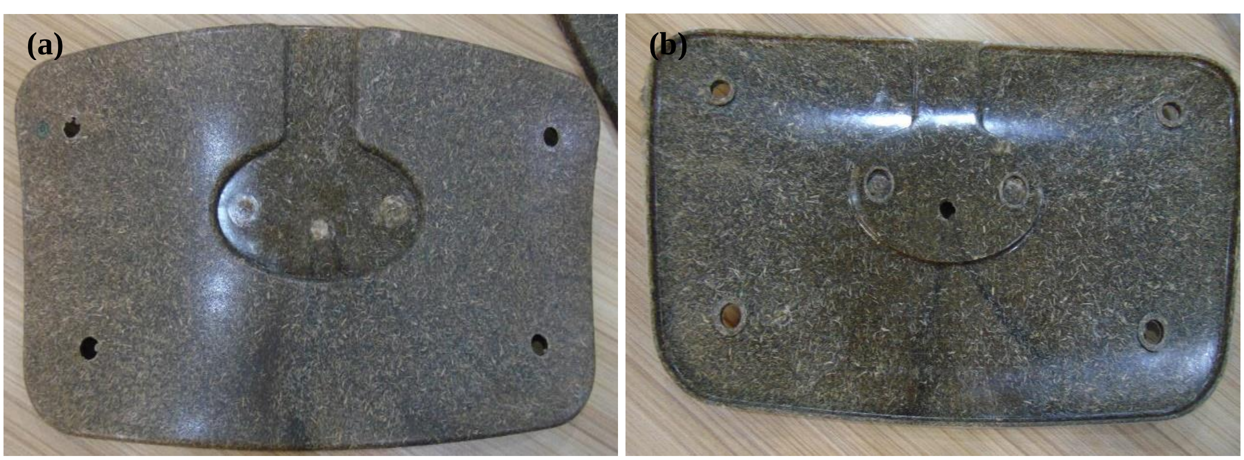

Fig 5: (a) Front view (b) rear view of Outer back plate without coloring agent

Fig 6: (a) Front view (b) rear view of Outer back plate with coloring agent

5 CONCLUSION

The following conclusions has been made after the simulation and experimental work on replacing pure polymeric material with natural fiber reinforced plastic;

- The incorporation of natural fibre improves the mechanical properties of the PP and also serve as a resistance to crack propagation.
- Use of natural fiber reinforced polymer makes the product environment friendly, by reducing content of non-biodegradable polymers.
- Reduces cost of production by replacing 30% of the PP by weight with fibre. The cost of waste natural fiber is significantly less than the matrix material, so this encourage the reduction in cost by increasing the fiber content in the composite.
- “Green” solution can be provided to other parts/ components also by successful utilization of natural fibers.

Certain green fiber composites are preferred as they can offer weight savings and ease of removal from the environment after end use. They also reduce the dependence on petroleum resources. It can be said that the applications of the natural fiber reinforced composite materials in the various segments are bound to multiply manifold in the near future. There is an imminent need to develop high quality manufacturing strategies for fully realizing the potential of these non-conventional fibers based composite materials.

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