

Development of Flax Fibre Reinforced Biocomposites for Potential Application for Automotive Industries

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ABSTRACT

{ Natural fibre-reinforced composite has the potential to replace current materials used for automotive industrial applications. Oilseed flax fibre could be used as reinforcement for composites because it is readily available, environmentally friendly and possesses good mechanical properties. In this research, oilseed flax fibre reinforced-LLDPE and –HDPE biocomposites were developed through extrusion and injection molding. The flax fibre was chemically treated to improve the bond between the fibre and polymer. Flax fibre was mixed with low linear density polyethylene (LLDPE) and high density polyethylene (HDPE) with fibre content varying from 10 to 30% by mass and processed by extrusion and injection molding to biocomposites. The mechanical properties, surface properties, and thermal properties of biocomposites were measured to analyze the treatment and processing effect and to compare the effect of different flax fibre concentrations on the biocomposites. Results showed that developed biocomposites had good properties compared to with pure plastic. Increasing fibre content increased tensile strengths and water absorption; it also decreased molding shrinkage and melting point of biocomposites. The factors in the injection process were also studied to achieve better biocomposite properties.

Keywords: Biocomposite, Flax fibre, Reinforcement, Injection molding, Fibre content

INTRODUCTION

The growth of plastics in automobiles, including use in demanding under hood and body part applications, has been steady over the past decade. Industries are always on the lookout for materials which are enabling the development of safer, lighter and better performing automotive applications and components, which is why biocomposites have gained popularity in recent times.

Today, most automakers are evaluating the environmental impact of a vehicle's entire lifecycle, from raw materials to manufacturing to disposal. In 2006, the European Union legislation has implemented that by 2015, 85% of a vehicle must be from reused or recycled material (Holbery and Houston, 2006). Glass fibre has been in the domain of reinforcement to plastic used in automobile body part materials. However, glass-reinforced plastics exhibit shortcomings such as their relatively high density (approximately 40% higher than natural fibres), difficulty to machine, poor recycling properties, and the potential health hazards posed by glass-fibre particulate. As a result, the utilization of light weight, low cost natural fibres offers the potential to replace a large segment of the glass and mineral fillers in numerous automotive interior and exterior parts. They can be used by suppliers for door panels, seat backs,

headliners, package trays, dashboards, and interior parts. Oilseed flax is one of the oldest commercial crops grown in North America. But only a small percentage of total crop residue produced annually is utilized in paper and pulp industry, still most producers are not able to find a viable market for the flax straw and are burning the straw since it is not easily reincorporated into the soil. The renewed interest in sustained development has reaffirmed the need to better utilize renewable resources.

Natural fibres are gaining importance to make bio-composites for various applications during the last decade due to its desirable properties (Bledski et al. 1999). Flax fibres can provide automobile part reinforcement because they can reduce weight, cost, and CO₂ release from the vehicles. The application of bio-composites also results in less reliance on foreign oil sources, recyclability, and the added benefit that these fibre sources are “green” or eco-friendly.

However, the hydrophilic character of Flax or any other natural fibre leads to low compatibility with hydrophobic polymer matrices and also to a poor dimensional stability as water uptake makes the fibres swell (Panigrahi et al. 2008). This problem can be overcome by treating fibres with suitable chemicals to decrease the hydroxyl group from the fibres (Bledski et al. 1999; Ray et al. 2001; Mohanty et al. 2001; Li et al. 2007).

Many factors including temperature, pressure, type of materials, etc., influence the quality of injection-molded product. There are a number of research publications (Fu et al. 2000; Martins et al. 2001; Weidenfeller et al. 2005) dealing with the processing and properties of polypropylene-glass fibre composites, which are processed by injection molding. But most researchers studied the mechanical or physical properties of composites, not focusing on extrusion and injection molding control processes.

The objective of this research was to develop flax fibre reinforced biocomposites and characterization of biocomposite for the potential utilization of automotive industries. This study further examined the effects of injection temperature, pressure, and flax fibre content on the physical and mechanical properties of the composites.

MATERIALS AND METHODS

The matrices used in the production of the injection-moulded biocomposites were linear low-density polyethylene (LLDPE), which was produced by ExxonMobil Chemical Canada, Toronto, ON, and high-density polyethylene (HDPE), which was obtained from Nova Chemicals, Mooretown, and Ontario.

For use as a reinforcing material in the production of polyethylene composites, oilseed flax fibres (provided by Biolin Research, Saskatoon, Canada) were subjected to different chemical treatments first.

TREATMENT OF FIBRE

Untreated: Fibre was washed with 2% detergent solutions and dried in the oven at 70°C for 24 h.

Silane treatment (S): Fibre was washed with 2% detergent solutions and soaked in 5% NaOH solution for 0.5 h and washed with distilled water. Then it was soaked in 2.5% triethoxysilane coupling agent solution (alcohol water mixture at 60:40) for 0.5h, and the pH was adjusted between 3.5 and 4.0. Finally, it was washed with distilled water and dried in the oven at 70°C for 24 h. The fibre was designated as silane treated (S).

Acrylic acid treatment (A): Fibre was washed with 2% detergent solution and immersed in 10% NaOH solution for 0.5 h, and then soaked in 5% acrylic acid solution at 50°C for 1 h, washed with distilled water and dried at 70°C for 24 h. The fibre was designated as acrylic acid treated (A).

BIOCOMPOSITE PREPARATION

The fibres (treated or untreated) were ground to 2 mm powder and mixed with the matrix carried in a blender (Waring Products Corporation, New York, NY). The mixture of fiber and plastic was then fed into the twin-screw extruder (Werner & Pfleiderer, Ramsey, NJ) located at the Centre for Agri-Industrial Technology (CAIT) of Alberta Agriculture, Food and Rural Development in Edmonton, AB. as shown in Figure 1.

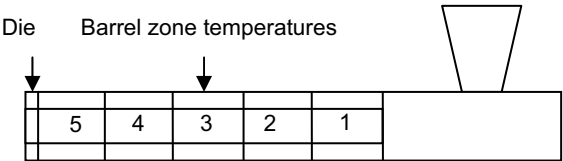


Figure 1 (top left) Twin -screw extruder at CAIT, Edmonton, Alberta, Canada, (top right) Six-hole die with

extrudates coming out, (bottom) Cross-sectional view of the extruder with the five separate heating zones.

Because it is a rotating mixer without heat given on the materials, extrusion process is needed for further mixing. Screw of extruder was 38 mm in diameter and 1440 mm in length. The extrusion barrel zone temperatures from 1 to 5 were kept constant at 90, 110, 120, 130, and 140°C for fiber-LLDPE mixture, and 90, 120, 130, 140, 160°C for fiber-HDPE mixture, respectively. The screw speed was set at 150 rpm. Then the The extrudates were then pelletized using a grinding mill (Retsch GmbH 5657 HAAN, West Germany) at Parkland Plastics in Saskatoon, SK. Then injection molding was used to mold biocomposite to special shaped products

FIBRE CONTENT STUDIES

The fibres after treatment were ground to 2 mm powder and mixed with the matrix (LLDPE or HDPE) at various fibre mass contents from 0 to 30 wt.%.. The mixture was extrusion compounded, pelleted, ground, and injection molded to make biocomposites. The five heating zones of the extruder were set to 90-120-130-140-160°C for fibre-reinforced HDPE biocomposites.

The injection molding experiments were conducted using the injection molding machine (Battenfeld Maschinen, Germany) of NAIT as shown in Figure 2. The barrel to die temperature at injection machine were set to 165°C (335°F), 182°C (360°F), 188°C (370°F), and 188°C (370°F), respectively, and Injection pressure of 5.5MPa (800 psi). The processed biocomposites were subjected to different tests.

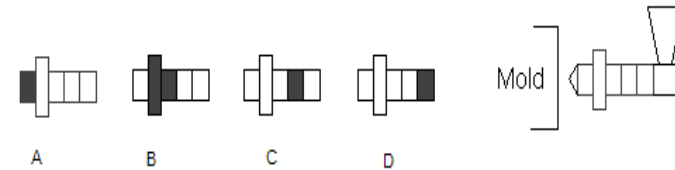


Figure 2 (top left) Injection moulding machine, (top right) Mould used in injection moulding, (bottom) Cross-sectional view of the screw with the four separate heating zones.

INJECTION STUDIES

When considering how injection-molding factors such as temperature and pressure influence the properties of biocomposite, the influence of fibre content was also

considered as one of the factors. The materials were flax fibre-I and HDPE. To process the biocomposites, flax fibre was first acrylic acid treated, ground through 2 mm screen, mixed with HDPE, then extrusion compounded and injection molded to biocomposite specimens. Injection molding was conducted in NAIT, and time was set as: injection - 10s, hold -15s, back - 20s, open - 15 s.

Three factors, namely, fibre content (% mass), injection temperature, and injection pressure were investigated as to study their influence on mechanical properties and water absorption by biocomposites. The experimental design including factors and levels are shown in table 2.

Table 2 Experimental design used in injection trials

Fibre content (% mass)	Injection Temperature (°C)	Injection Pressure (MPa)
10	166-182-188-188	4.8
10	166-182-188-188	6.9
10	177-190-200-200	4.8
10	177-190-200-200	6.9
20	166-182-188-188	4.8
20	166-182-188-188	6.9
20	177-190-200-200	4.8
20	177-190-200-200	6.9
30	166-182-188-188	4.8
30	166-182-188-188	6.9
30	177-190-200-200	4.8
30	177-190-200-200	6.9

The three levels of fibre content were 10%, 20%, and 30% by mass. The two levels of injection temperatures were: 1) D=166°C (330°F), C=182°C (360°F), B=188°C (370°F), A=188°C (370°F); and 2) D=177°C (350°F), C=190°C (375°F), B=200°C (390°F), A=200°C (390°F). During plotting and discussion of results, injection temperature was designated by temperature at zone A, the temperature at which the biocomposites were finally heated. The two levels of the injection pressure were 4.8 MPa (700 psi) and 6.9 MPa (1000 psi).

Tensile properties, water absorption, and density of biocomposite samples were measured to compare the effects of the three factors on biocomposite properties.

TESTING AND CHARACTERIZATION

SEM was used to analyze the morphological structure of fibres and fibre-plastic composites. The materials were first coated with gold using an Edwards S150B sputter coater (BOC Edwards, Wilmington, MA) to make the sample conductive. The coated sample was then taken microscope images using SEM505 (Philips Electron Optics Eindhoven, Netherlands) at 300KV.

Tensile test of biocomposite specimens followed ASTM Standard test method D638 (ASTM D638) as test