

Impact of Fiber Loading on Injection Molding Processing Parameter and Properties of Biocomposite

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ABSTRACT

The research on using natural fibres as the reinforcement in plastic composites has increased dramatically in the last few years. Flax fibres are renewable resources with low specific mass, reduced energy consumption, and relatively low in cost. These advantages make flax fibres recognized as a potential replacement for glass fibres in composites. Among plastic, polyethylene was concluded to be a suitable material used as matrix in natural fibre reinforced biocomposites. However there are few studies on this area so far. In this paper, the processing method of flax fibre-reinforced polyethylene biocomposites is introduced. Flax fibre polyethylene biocomposite consists of flax fibre as the reinforcing component and high density polyethylene as the matrix. Acrylic acid pre-treatment was applied to flax fibre to improve the bonding between fibre and polyethylene. Extruding was used to mix materials and injection molding technique was carried out to process materials to certain shape biocomposites. The injection temperature and pressure were studied during injection molding to determine appropriate processing parameters for the biocomposites at different fibre content.

Keywords

Flax fibre, reinforced plastic composites, biocomposite, injection molding

INTRODUCTION

Flax is an annual crop used both for fibre and its edible seed. Two general types of flax are grown - fibre flax and seed flax. Fibre flax is grown for the use of its fibre and primarily grown in Europe and Asia [1]. Seed flax is grown for its oil

content. Canada is the largest producer of seed flax in the world.

With the huge amount of oilseed flax production in Canada each year, more flax straw is left in the fields without suitable utilization. Because flax stalk requires a much longer time to degrade than many other agricultural residues, it is burned by farmers presenting an environmental problem. Therefore, development of products from flax fibre will benefit Canadian and world seed flax growers and will achieve a degree of a sustainable development for Canada Agriculture.

The stalk from seed flax consists of fibre bundles located between the epidermis (bark surface) and an inner woody core (shive) [2]. Fibre can be obtained from seed flax plants. Flax fibres exhibit many advantageous properties such as low density, low cost, reduced energy consumption and it is a renewable resource. Flax fibre has higher mechanical strength than polyethylene and most of other plastics. Therefore, adding flax fibre into polyethylene increases the strength of the biocomposite, making the composite materials more competitive to market. Plastic matrix composites using natural fibres as reinforcement has attracted a lot of interest in recent years. Some of potential applications of natural fibre-reinforced composites are door and instrument panels, package trays, glove boxes, arm rests, and seat backs [3].

This research mainly focuses on the development of flax fibre-reinforced polyethylene biocomposites via injection molding. Being an important plastic processing method, injection molding is characterized by rapid production rates. It has been showed that injection molding operational conditions and the amount of fibre could affect the properties of composite materials [4, 5]. However, studies on how injection molding parameters influence the properties of biocomposites are very limited.



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To understand the processing and optimize injected biocomposite properties, this research, first of its kind, studied the injection molding process and optimized the operation for manufacturing flax fibre-high density polyethylene (HDPE) biocomposites.

HDPE is easily molded in mass-production quantities by injection molding. HDPE has very low glass transition temperature ($T_g = -110^\circ\text{C}$) associated with a good retention of mechanical properties including flexibility and impact resistance at low temperatures [6]. It is suitable to be matrix in composites especially in country as cold in winter as Canada. High density polyethylene (HDPE) is a suitable matrix candidate for its low cost, low processing temperature, low glass transition temperature associated with a good retention of mechanical properties. But existent research has been mostly conducted on using polypropylene as matrix. This research will promote and accelerate the application development of using HDPE as matrix in fibre reinforced composites.

MATERIALS AND METHODS

Materials

Oilseed flax fibre grown in Saskatchewan was provided by Biofibre Industries (Canora, SK, Canada). HDPE (injection moulding grade) with melt flow index of 12.5 g/10 min was purchased from Nova Chemicals (Mooretown, ON, Canada). Technical grade chemicals including sodium hydroxide (EM Industries, Inc., Gibbstown, NJ) and acrylic acid (Lancaster Synthesis, Inc., Pelham, NH) were used for fibre surface modifications.

Chemical Modifications

Because the hydrophilic nature of natural fibres often causes low interfacial properties between fibre and hydrophobic plastic matrix, chemical modifications are conducted to improve the fibre-matrix bonding. Flax fibre was washed with 2% detergent solution and immersed in sodium hydroxide solution for 0.5 h. It was then soaked in 5% acrylic acid solution at 50°C for 1 h. The fibre was then washed thoroughly with distilled water and dried in an air oven at 70°C for 24 h.

Biocomposite Preparation

The dried fibre was ground through 2 mm screen and mixed with HDPE at 10, 20 and 30% fibre content by mass of composite. The mixture of fibre and HDPE was fed into the twin-screw extruder (Ramsey, NJ, USA) at screw speed of 150 rpm and barrel to die temperatures of 90, 120, 130, 140, 160°C from first to fifth zone. The extrudates after extrusion were pelletized using a grinding mill (Retsch GmbH 5657 HAAN, West Germany) and then processed through the

injection molding machine (Battenfeld, Meinerzhagen, Germany) to biocomposite samples.

During injection molding, three factors (fibre mass content, injection temperature, and injection pressure) were investigated in their influence on injection molding operation on their effect on product mechanical properties and water absorption. The factor levels and experiment design is shown as TABLE I. The particular injection temperature was set based on Fig. 1.

TABLE I. Three-factor experimental design in injection molding of flax fibre-HDPE biocomposites

Trial	Fibre Content (% wt.)	Injection Temperature ($^\circ\text{C}$)	Injection Pressure (MPa)
1	10	168-188*	4.8
2	10	168-188	6.9
3	10	177-200**	4.8
4	10	177-200	6.9
5	20	168-188	4.8
6	20	168-188	6.9
7	20	177-200	4.8
8	20	177-200	6.9
9	30	168-188	4.8
10	30	168-188	6.9
11	30	177-200	4.8
12	30	177-200	6.9

*Injection temperatures are $D=166^\circ\text{C}$, $C=182^\circ\text{C}$, $B=188^\circ\text{C}$ and $A=188^\circ\text{C}$ (refer to Fig.1).

**Injection temperatures are $D=177^\circ\text{C}$, $C=190^\circ\text{C}$, $B=200^\circ\text{C}$ and $A=200^\circ\text{C}$ (refer to Fig.1).

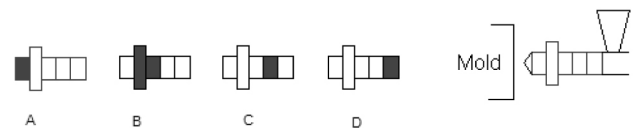


Fig. 1. Temperatures setting at injection molding machine (Battenfeld, Maschinen, Germany).

Property Testing

Morphological property on the surface of chemical treated fibre and matrix was analyzed using scanning electron microscope. The biocomposite samples were coated using an Edwards S150B sputter coater (BOC Edwards, Wilmington, MA) and then analyzed using a scanning electron microscope (SEM505 Philips Electron Optics, Eindhoven, Netherlands) at the accelerating voltage of 300 kV.

Tensile tests were conducted using ASTM standard test method D638 [7]. The tests were conducted using an Instron model 1122 testing machine (Instron, Canton, MA, USA) at a crosshead speed of 5 mm/min. Each test was repeated five