

Characteristics of Hybrid Fibre-Composites Boards for Potential Structural Application

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ABSTRACT

This work is based on comparative study of oilseed flax fibre and glass fibre reinforced composite boards for potential application in automotive industries. The material characterizations of flax and glass fibre-composites using unsaturated polyester as matrix were evaluated. Vacuum infusion was used for fabrication of composites. Flexural, tensile, water absorption and color tests were conducted on the composite boards. The density and the moisture content of flax/glass fibre mats were also measured. Three types of composite boards, including flax, glass and flax-glass sandwich were developed and characterized.

Key words: vacuum infusion, flax fibre, glass fibre, mechanical properties, water absorption

INTRODUCTION

Importance of natural fibre-reinforced polymers has been identified in different technical applications such as in the automotive and construction industry due to their mechanical properties associated with low weight [1-3]. In addition, natural fibre reinforced products possess low cost, high specific properties, non abrasive processing characteristics, and biodegradability [4]. However, moisture absorption leading to fibre swelling, low thermal resistance, and local or seasonal variations in quality are some of the negatives [5]. There are different techniques associated with making fibre reinforced composite. The major manufacturing methods of natural fibre thermoset composites include lay-up, press moulding, pultrusion, resin transfer moulding (RTM), and vacuum infusion (VI) [5].

Vacuum infusion has been attracted recent interest in the marine industry as a low-cost, closed mould processing [6]. The patent history of this technology goes back 45 years. The basic principle is the encapsulation of dry reinforcement layers between a rigid, airtight mould and sealing of a flexible membrane peripherally to it. The cavity is compressed and

compacted by evacuating the cavity space by the vacuum system and resin is introduced encouraging the flow across the reinforcement. After curing, the laminate is released by removing the membrane [6]. Moreover, this technique excludes the detrimental effect of being exposed to uncured liquid resin system and volatile compounds in the work atmosphere of vacuum bag and hand lay-up methods [7].

The benefits of vacuum infusion include high fibre-to-resin ratio, less wasted resin, consistent resin usage, unlimited set-up time, and the cleanliness. The popularity of this technique is due to relatively short cycle time, low equipment cost and low labor requirements. Furthermore, for large and complex structures, it offers a high potential of integration in addition to the complete elimination of volatile organic compound emissions [8].

The recent interest of incorporating natural fibre in composite products becomes a challenging task. However, the relative high strength, stiffness and low density of flax fibre enhance the suitability of its usage in composites [9,10]. This paper is based on a comparative study of flax and glass fibre reinforced boards. Flax was chosen as the natural fibre source because it is one of the important bast fibre vastly available in North America which has low density and good mechanical properties for reinforcing various polymers to develop Industrial biocomposite.

Considerable attention has been given to fibre-reinforced polymers (FRP) by vacuum infusion and some of the past research works are discussed in below.

Vacuum infusion

The current trend of increased use of vacuum infusion moulding for large surface-area parts has increased the interest in an advanced modeling of the process. Anderson and co-workers reported possible ways to accelerate the impregnation by using layers of higher

permeability within the reinforcing stack, i.e. flow-enhancing [11].

Inherent heterogeneity of fibrous preforms leads to unforeseen, unpredictable and potentially, problematic flow patterns through infusion experiments. Modi *et. al.*, proposed a new active control system which is capable of monitoring the resin flow, identifying flow disturbances and taking an appropriate corrective action in real-time, through computer-controlled injection ports [12].

The properties were evaluated for powdered fibre in thermosetting matrix and thermoplastic matrix. Rodriguez and co-authors reported the feasibility study on recycling of thermosetting composite material [14]. The study on moisture absorption effect on the mechanical properties of a hybrid sandwich composite formed by orthophthalic polyester resin, reinforced by bi-directional woven fabrics of jute and glass fibres has been done by Aquino *et.al.* [4].

Mechanical properties of natural and glass fibre composites obtained from vacuum infusion has been studied by Rodriguez *et.al.*, [5]. Composites were characterized into two types of matrices viz. unsaturated polyester and acrylic and flax and jute sisal and glass fibre reinforcements. According to the study, flax composites show higher impact energy than other natural fiber composites, due to the existence of the effective energy dissipation mechanisms, like pull-out and axial splitting of the fibers.

Effect of the flow enhancement layer on the compaction response of vacuum infusion has been studied by Hammami [8]. The study investigated the effect of the reinforcement structure on the overall compaction behavior.

Vacuum Infusion Process

Low viscosity resins and dry reinforcements are used in this process. Materials are laid dry into the mould and the vacuum is applied before resin is infused. Well mixed with the catalyst and accelerator, the resin is drawn into the reinforcement and allowed to cure at room temperature and curing usually starts from 20 minutes to 4 hours. The set-up is given in fig. 1.

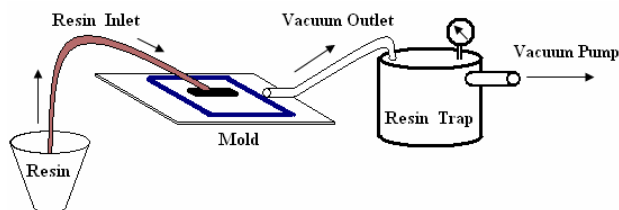


Figure 1. General sequence of equipment set up for vacuum infusion

Flax Fiber

Table 1 shows the chemical composition of flax fibre. Flax fibre can withstand processing temperatures as high as 250°C [13]. The strength characteristics of fibre depend on the properties of the individual constituents, the fibril structure and the lamellae matrix. Flax fibres possess moderately high specific strength and stiffness and can be used as reinforcement in polymeric resin matrix to make useful composite materials. As the flax fibre contain high amount of cellulose it is highly hygroscopic and can become a limitation of using in processing industry.

Table 1 Composition of flax fibre [14]	
Component	Amount
Cellulose (%)	78
Hemicellulose (%)	18.6-20.6
Pectin (%)	2.2
Lignin (%)	2.3

Glass Fibre

Glass fibre is the most frequently used reinforcement in vacuum infusion. Most fiberglass fabrics offer high permeability, allowing resin to easily flow through. When using a non-woven mat, continuous strand mat will offer superior infusion over a chopped-strand. While both offer high permeability, the binder in chopped strand mat somewhat hinders resin flow. This material not only boosts resin flow, but also adds strength and bulk very quickly. Some of the properties of glass fibre are given in table 2.

Table 2 Mechanical properties of glass fibre [13]			
Properties	E-glass	D-glass	R-glass
Density (g/cm ³)	2.6	2.14	2.53
Tensile strength			
Virgin filament (MPa)	3 400	2 500	4 400
Impregnated strand in a composite (MPa)	2 400	1 650	3 600
Tensile modulus (MPa)	73 000	55 000	86 000
Elongation at break (%)	4.5	4.5	5.2
Moisture content (%)	< 0.1	< 0.1	< 0.1
Thermal conductivity (W/mK)	1.0		

Polymer Matrix

Polymer matrix (Resin) choice is a key aspect of vacuum infusion process. Any resin can be used for infusion. Typically, lower viscosity will aid infusion, as it allows easier permeation of the reinforcement. If high viscosity resin is used, more careful planning, more resin lines, and more flow media should be given. Vinyl Ester is the most frequently used resin for vacuum infusion at a viscosity of 275 centipoise. Polyester resins viscosity of about 475 centipoise and will also infuse quite readily. System 2000 Epoxy offers a viscosity of 900-975

centepoise (depending on hardener choices), and therefore will tend to infuse a bit slower.

Unsaturated polyester resins (UPR) are often used to make thermoset FRP. The largest quantities of UPR are made from either ethylene or propylene glycol with a mixture of phthalic and maleic acids. The cross-linking process is usually referred to as curing. Polyester resins can be induced to cure by means of heat, catalysts and accelerators. MEKP (methylethylketoneperoxide) is the most common catalyst used with cobalt accelerator for curing at room temperature [15]. Most polyester resins are viscous, pale coloured liquids.

EXPERIMENTAL METHODOLOGY

Materials

The basic ingredients for the composite particleboards were polyester resin, flax fibre and glass fibre. Flax fibre containing 90% fibre was obtained from Biolin Research Inc., Saskatoon. Buhler Industries Ltd., Saskatoon supplied chopped strand mat cloths of glass fibre having randomly oriented long fibres. The 25 cm x 25 cm pieces of fibre mats were used for the experiment. Medium set time, low viscosity polyester resins were bought from Progress Plastics Inc.

Long flax fibre mats were made using the 'widow maker' (fig.3.a). First, a known weight (44 g) of flax fibres were fluffed and put in to the wooden frame (fig.3.b) where it was compressed in to a 25 cm x 25 cm mat. The fibre mats were laid on the pre treated mould (fig.4).



Figure 3 (a) Widow maker (b) Wooden frame for compression



Figure 4 Flax fibre mat on the mould

Preparation of the Mould

Having a good quality mould is required for vacuum infusion process. The mould should be rigid and has a high-gloss finish. Ideally, this mould has flange of at least 6 inches, to be used for the placement of sealant tape and spiral tubing. After the mould was properly cleaned, 1-2 coat sealant and mould release agent were applied.

For the purpose of infusing, experiment was set-up with the notion that resin could be infused into the center point in the fibre mats. From there, resin was pulled outward via vacuum pressure. The experiment set up is shown in fig 5.



Figure 5 Experimental set up

Water absorption of composites

Water absorption of different composites was measured according to ASTM D570-81. Three specimens of 25 mm x 20 mm from each composite were cut and weights were recorded. Then, they were immersed in distilled water for 24 hours at room temperature. The specimens were wiped with filter paper and the weights were recorded. The water absorption was calculated as:

$$\text{Water absorption (\%)} = \frac{(w(t) - w_o)}{w_o} \quad [2]$$

Where, $w(t)$ = Final weight, [kg]
 w_o = Initial weight, [kg]

Density measurement

The samples were weighed by Ohaus balance (Galaxy 160D, Ohaus Scale Corp., Florham Park, NJ. USA). The volume of the samples was determined by the gas pycnometer (MVP-2, Quanta Chrome Corp., Boynton Beach, Florida, USA) by using nitrogen gas.