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The study of fibre/matrix bond strength in short hemp polypropylene composites from dynamic mechanical analysis

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ABSTRACT

This paper presents results from an experimental study on the static and dynamic mechanical and visco-elastic properties of short hemp fibre polypropylene composites. Composites containing 10–60 wt.% short noil hemp fibre were injection moulded. The maleic anhydride grafted polypropylene (MAPP) and maleic anhydride grafted Poly(ethylene octane) (MAPOE) were used as coupling agents for modifying the matrices. Dynamic mechanical thermal analysis (DMTA) of the composites were performed over a temperature range of 25–150 °C under frequency of 1 Hz. DMTA revealed no noticeable changes in α-transition temperature when the fibre content was increased or coupling agents were added. The composites revealed better temperature resistance at higher fibre content. However, the increase in storage modulus was negligible in composites reinforced with more than 40 wt.% hemp fibres; due to the agglomeration of the fibres. The results of the damping ratio analysis revealed that higher interfacial bonding was achieved by addition of MAPP coupling agent in comparison with addition of MAPOE coupling agent. This was also confirmed by tensile strength experiments and scanning electron microscope (SEM) observations.

1. Introduction

Natural fibre-reinforced polymer composites are attracting the attention of a number of industrial applications, due to their environmental and economic advantages. As a result of such benefits there has been increasing developments in the production of bio-composites [1,2]. Bio-composites refer to composites that combine natural fibres, such as kenaf, jute, hemp and sisal, with either biodegradable or non-biodegradable polymers [3–5]. Hemp fibre is a sustainable resource which has shown to possess a promising specific tensile strength, which can be utilised as reinforcement in composites for many applications [4,6–11]. Noil hemp fibre is a by-product of the textile hemp fibre industries. In comparison with common hemp fibres, noil hemp fibres are more thermally resistant. They are highly degummed and thus have lower ligno-cellulosic compounds. Although they are too short to be used for fabric or long fibre composite production, they have the potential to be used as the reinforcements in injection moulded thermoplastic composites [12].

Dynamic mechanical analysis, undertaken over a range of temperatures and frequencies, has become a widely used method for determining the viscoelastic behaviour and the interfacial characteristics of heterogeneous polymeric systems [10,13–15]. The DMA analysis is an efficient way to calculate the effectiveness of reinforcements in the composites by investigating the influence of the fibre addition on the storage modulus (E'), loss modulus (E'') and loss factor ($\tan\delta$) of the composites. Moreover, as a result of the molecular motion of the chain segments, DMA can also provide precise information for the evaluation of relaxation/transition processes [16,17].

PP (Polypropylene) has been commonly utilized as the matrix in natural fibre composites for the last decade [18]. Referring to the literature, two relaxation peaks can be observed in the $\tan\delta$ curve of polypropylene at ranges of 5–10 °C (β transition temperature) and 60–100 °C (α transition temperature) [19–22]. The β-transition corresponds to the glass transition temperature and is related to the relaxation of unrestricted amorphous chains of polypropylene. The α-transition is associated with the relaxation of restricted crystalline phase of polypropylene and can be attributed to molecular chain rotation in the crystalline phase [19].

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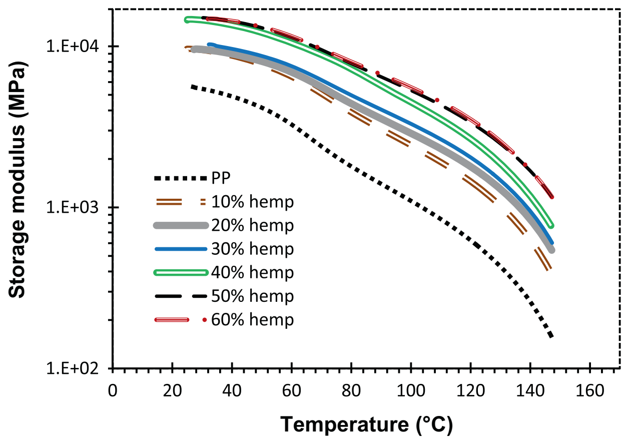

Fig. 1. Storage modulus of uncoupled noil hemp fibre reinforced composites as a function of temperature under DMA loading frequency of 1 Hz.

Table 1
Effectiveness coefficient *C* as a function of noil hemp fibre content.

Fibre content (wt.%)	*C* (90 °C)	*C* (110 °C)	*C* (130 °C)	*C* (150 °C)
10	0.80	0.77	0.73	0.70
20	0.69	0.64	0.60	0.51
30	0.65	0.61	0.55	0.49
40	0.66	0.64	0.62	0.55
50	0.60	0.54	0.48	0.37
60	0.57	0.51	0.45	0.37

Many researchers have studied the influence of the incorporation of fibre into the matrix. An increase in the storage modulus or stiffness of the composite has been reported due to the incorporation of the fibres. Also it has been reported that the storage modulus of the materials decreases at transition temperatures as they transfer from glassy to rubbery regions [16,23,24].

Our previous work [9,25] indicated to the severe fibre breakage during compounding and injection moulding processes. The intense fibre breakage led to fine fibres in the injection moulded composites with final average length of approximately 200 μm. The effects of the fibre content, compatibilizer addition and involved mechanisms on final fibre size were studies in the previous work [9]. The current project's aim is to investigate whether very short noil hemp fibres can be effectively used to reinforce the matrix, the effect it would have on DMA at elevated temperatures, and the influence of coupling agents have on the viscous elastic behaviour of the noil hemp fibre reinforced polypropylene composites. In this study the hemp/matrix bonding strength was not aimed to be measured directly but the hemp/PP interface damping was extracted from composite damping. This could provide a reliable comparison between hemp/matrix bonding strength of the different composite samples.

2. Experimental

2.1. Raw materials

Noil hemp fibres were supplied by China-Hemp Industrial Investments and Holding Co. Ltd. A M800E polypropylene (Sinopec Shanghai Petrochemical Co. Ltd., China) with melt flow index of 8.0 ± 1.5 g/10 min was used as the matrix. Maleic anhydride grafted polypropylene (MAPP) and maleic anhydride grafted poly ethylene octane (MAPOE) were used as the compatibilizer to the resin mix.

2.2. Composite fabrication

The composites were fabricated with noil hemp fibre content (0–60 wt.% with the interval of 10 wt.%). Different contents of 0, 2.5 and

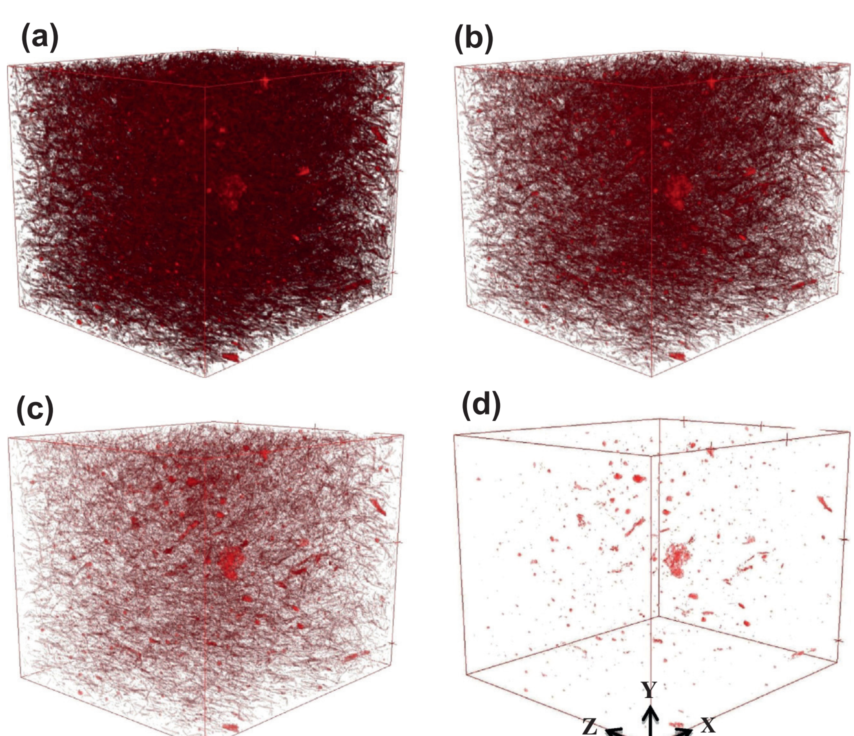

Fig. 2. Extraction of the fibre agglomerations from 3D views of 10H sample using FIJI software package. (a) original 3D view, (b) and (c) evolution of the 3D views by optimizing of the threshold filter and (d) extracted fibre agglomerations.