Cellulose Composite Fibre Spinning Using a Capillary Viscometer

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ABSTRACT

Microfibrillar or nanofibrillar cellulose has in principle good specific mechanical properties which make them interesting as reinforcing agents in composite materials. There are however problems associated with the hydrophobicity of common polymer matrices and the stress transfer between the fibrils, A possible route to avoid problems of this kind is to produce composite fibres to be used in structural components. Such a model procedure is outlined here and some preliminary results on the mechanical properties of the fibres are presented

INTRODUCTION

Microfibrillated or nanofibrillated cellulose (MFC or NFC) has in principle good specific mechanical properties, i.e. a high property-to-density ratio[1]. This is important with regard to the potential reinforcing ability of these fibrils in composite materials, especially in the case of structural components which should be light.

Microfibrillated cellulose is however usually obtained in the form of an aqueous suspension (of low concentration)[2]. Thus they are as such not very compatible with most polymeric materials which often are quite hydrophobic. This leads to separation problems, lack of adhesion between the phases and dispersion difficulties. This calls for modification of the polymer matrix or the microfibrillar cellulose or, alternatively, a selection of a suitable polymer matrix. Water soluble polymers would be an obvious choice in the latter case. In the following some model experiments will be described using poly(ethylene oxide) (PEO) as the matrix.

Here it is focused on manufacturing of composite fibres using MFC as the reinforcement.

MATERIALS

The microfibrillated cellulose was obtained from carboxymethylated pulp[2] and kindly supplied by Innventia AB. The cellulose concentration was kept at 2.2 weight-%. The MFC gel is shown in the photo below.

Figure 1. Photograph of MFC gel with a cellulose concentration of 2.2 weight-%.

The PEO (or poly(ethylene glycol), PEG) was dissolved in the MFC-suspensions. The molecular mass of the polymer was 35000 g/mol. In this study, the nominal MFC-content in the dry fibres was kept at about 30 weight-%.

METHOD

The aqueous MFC-suspensions contained about 2.2 weight-% of cellulose. The high water content presents in many cases a problem, since the final fibre should be dry. It is also a problem when the MFC should be combined with a thermoplastic since many of those are hydrophobic. Many of the processing techniques for thermoplastic polymer composites are not adapted to water-containing systems.

Flakes of PEO were added to the MFC suspension and the polymer was dissolved in the aqueous phase. By adding different amounts of PEO to the MFC suspension, the MFC content in the dry composite fibre can be controlled. The material was then dried in order to evaporate the water. The dried material can then be reshaped by melting the polymer matrix as is done in conventional polymer processing, in this case fibre spinning.

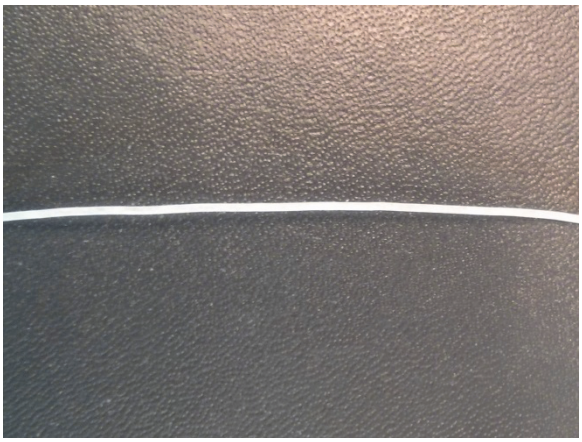

Figure 2. The Extruded fibre containing 30 weight-% MFC (nominal value).

RHEOLOGICAL PROPERTIES

Composite fibres were formed by forcing the now dried material through a thin capillary using a conventional capillary viscometer, see Fig. 2. In addition to manufacturing the composite fibres, the capillary viscometer also provides information on the viscosity of the melt at different applied shear rates. This is exemplified in Table 1 for both unfilled PEO and PEO with 30 weight-% MFC at a shear rate of 115 s^{-1}.

Table 1. Viscosity of unfilled PEO and PEO with 30 weight-% MFC.

	Viscosity [Pa s]	Shear rate [s^{-1}]
Unfilled PEO	4900	115
PEO with MFC	17700	115

The viscosity of the material containing 30 weight-% added MFC was more than three times higher than that of the unfilled material.

MECHANICAL PROPERTIES

The mechanical properties of the extruded fibres, Fig. 2, were measured in tension using dynamic mechanical analysis (DMTA). Such measurements provide information on the storage and loss moduli of the material. Figure 3 gives an example of the storage modulus (E') as a function of the applied strain for a fibre containing 30 weight-% MFC. The applied frequency was in this case 1 Hz. Preliminary results indicate a significant increase in E' when adding MFC to the polymer.

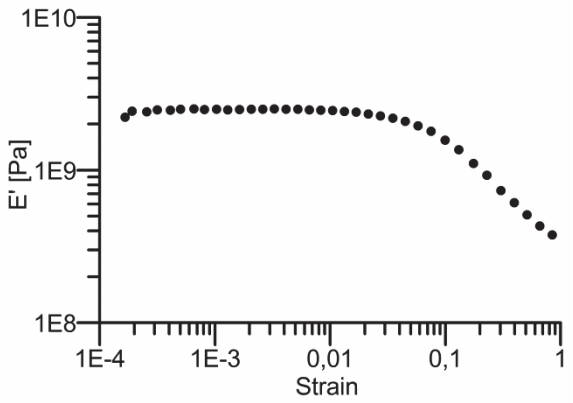

Figure 3. The tensile storage modulus at 1 Hz for a PEO fibre containing 30 weight-% MFC as a function of the applied strain.

The mechanical properties discussed above refer to composite fibres that have not been drawn after the exit of the dye. Further studies are aimed at increasing the orientation of the fibres by optimising the spinning/drying process increasing the MFC-content or choosing another polymer matrix.

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