TECHNICAL NOTE: A METHOD TO DETERMINE THE WETTING OF WOOD FIBERS WITH THERMOPLASTIC[1]

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Abstract. This article presents a method which allows to assess the wettability of thermomechanical pulp (TMP) in contact with thermoplastic. The method is based on the usage of laboratory hand-sheets made of TMP and plastic granules which form drops under heat. The contact angle of the drops after resolidification on the surface of the hand-sheets characterizes the wetting. This method enables a direct and evaluable testing of wood fiber thermoplastic combinations. The exemplary results indicate that wood species, pulping temperature, and mercerization influence the wettability of TMPs with thermoplastic.

Keywords: Thermomechanical pulp, thermoplastic, wettability.

INTRODUCTION

Generally, thermomechanical pulp (TMP) is used in paper and wood-based panel production, primarily medium density fiber board. Here, thermosetting binders are predominant. The wetting of TMP with thermoplastic, preferably polypropylene, is of interest in the development and production of flexible wood fiber insulation mats, wood fiber nonwoven and injection-molded lightweight components with wood fiber reinforcement, etc. In these composite applications, adhesive bonding depends on multiple properties specifically physical and chemical conditions of the lignocellulosic fiber surface. The interaction of wood fibers and thermoplastic codetermines the wettability, which is of relevance to the formation of strength.

Some publications have discussed the wettability of lignocellulosic fibers in contact with thermoplastic. For example, Liu et al (1994) and Fuentes et al (2013) used a dynamic contact angle (DCA) analysis technique to evaluate the wettability of individual fibers. DCA is a standard test method for evaluating the dynamic contact angle and surface free energy of a single fiber in liquids at room temperature. In addition, Liu et al (1994) studied the formation of a microdroplet of polystyrene on a single fiber and measured the contact angle optically.

TMP comprises morphological and surface chemistry variations within a particle size distribution (Sundberg et al 2000). It could be advantageous to consider these properties along with the wetting of

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plasticized thermoplastic at elevated temperatures and the resulting low moisture content (MC) of the materials.

In this context, the application of laboratory hand-sheets (TMP sheets) seems to be promising for a simple and direct determination of the wettability of TMP with thermoplastic. According to Roffael et al (2002), it is possible to measure the wettability of TMP with a colored water drop placed on a TMP sheet. After a series of preliminary tests, a procedure could be worked out which allows to assess effects of process parameters during pulping and additional fiber treatments on the wetting of TMP with thermoplastic. In addition, this method reflects temperature and moisture conditions during bonding, respectively, compounding and therefore provides indications with regard to product and process optimization.

MATERIALS AND METHODS

The raw wood materials used for TMP production in this study were approx. 40-yr-old spruce (*Picea abies* Karst.) and approx. 30-yr-old beech (*Fagus sylvatica* L.). The manually debarked logs were chipped by using a drum chipper. After screening, the wood chips were processed batchwise in a 12" laboratory refiner plant at steaming temperatures of 160°C and 180°C for 3 min and 10 min, respectively. Mercerization was carried out by placing fibers in a 2% sodium hydroxide (NaOH) solution (pH = 14) at room temperature for 1 h. Then, the wet fibers were dried in a drying oven at 103°C for approx. 18 h to form TMP sheets with a sheet machine (Frank-PTI GmbH) according to the standard ISO 5269-2 (2004). A total of six (6) types of laboratory TMP sheets were produced.

The procedure for determining the wettability is briefly described in the following: The thermoplastic and the TMP sheets were pre-dried approximately for 2 h at 80°C. Ten polypropylene granules (HJ120UB, Borealis AG), with a weight of 0.024 g ± 0.002 g and a melting point/range of 130 to 170°C, were placed on a TMP sheet and subsequently heated in an oven for 5 min at 200°C. The granules were plasticized, formed liquid droplets, and reached a static equilibrium. Temperature, MC, and degasification of TMP and polypropylene were comparable to process conditions within a thermobonding oven, respectively, a compounder. After recrystallization of the thermoplastic, the contact angle θ was determined under a digital light microscope (Zeiss Smartzoom 5) with an integrated optical measuring system (free software like Image J is also suitable to measure the contact angle). From 40 individually measured values for 1 TMP sheet (90° incremental rotation), the arithmetic mean was calculated.

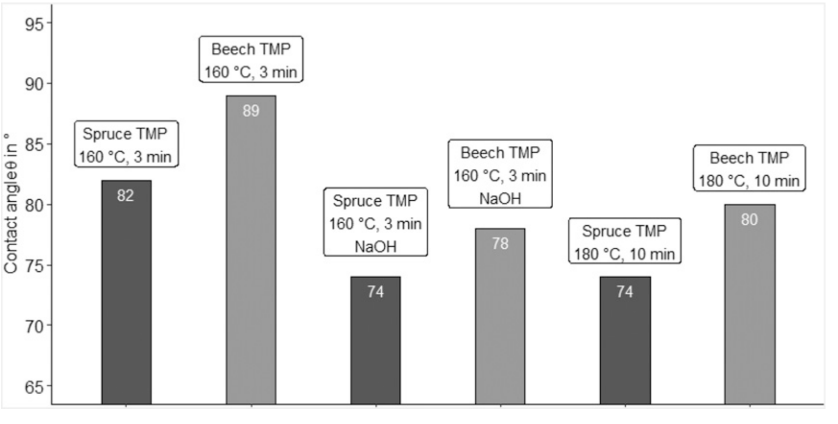

Figure 1. Contact angle θ of polypropylene drops on laboratory hand-sheets made of spruce and beech thermomechanical pulp (TMP) at different pulping temperatures, respectively, mercerized in sodium hydroxide solution.

RESULTS AND DISCUSSION

The contact angles of six types of TMP sheets in contact with polypropylene droplets according to the method proposed earlier are plotted in Fig 1. Depending on the wood species, pulping temperature, and mercerization, the polypropylene drops on the laboratory sheets have different contact angles. At the chosen pulping temperatures, and with mercerization, the contact angle is larger for beech than for spruce. Apparently, the studied polypropylene does not wet beech TMP as well as spruce TMP. Mercerization leads to lower contact angles for either type of wood. Increasing the pulping temperature has the same effect comparatively to mercerization with spruce. A higher pulping temperature for beech results in a similar contact angle as a lower pulping temperature for spruce.

CONCLUSIONS

The experimental results show that the wettability of TMP with thermoplastic is measurable by means of contact angle. The results indicate that wood species, steaming temperature, and mercerization influence the contact angle. Furthermore, the findings provide useful information about the improvement of adhesion between TMP and thermoplastics, which would increase the mechanical properties of wood fiber thermoplastic composites. Future work should be extended to other combinations of wood species and thermoplastics, including further fiber modifications along with coupling agents.

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