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The influence of forming surface on the vacuum pressure in hydroentangling process

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Abstract: Hydroentangling is a process that uses waterjet curtains issued from a series of parallel jet-heads (manifolds) for entangling and interloping fibres in a loose fibre web carried on a belt or perforated surface. The efficient removal of the stagnant water remaining from each waterjet curtain is crucial for the success of fibre entanglement when the web reaches the next jet-head. In this article, we discuss different methodologies that can be used to calculate the minimum vacuum pressure required for extracting the hydroentangling water from non-woven fabrics. A distinction has been made between hydroentangling on tightly and openly woven screens and different modelling strategies are recommended for each. In particular, it is demonstrated that a one-dimensional flow pattern coupled with available analytical permeability expressions can be used to predict the required vacuum pressure in the case of tightly woven screens. In the case of open woven screens where the flow pattern becomes three-dimensional, numerical simulation is needed for calculating the vacuum pressure required for complete removal of hydroentangling water. We also demonstrated that the vacuum pressure increases by decreasing the fibre diameter or increasing the fabrics' solid volume fractions.

1. INTRODUCTION

Non-wovens are assemblies of fibres or filaments bonded together in the form of sheets, webs or bats (Butler, 1999). One of the most popular methods used for bonding fibres in a non-woven fibre web is hydroentangling (Connolly and Parent, 1993; White, 1990). The underlying mechanism in hydroentanglement is the exposure of the fibres to a non-uniform spatial pressure field created by a successive bank of closely packed high-speed waterjets. The impact of the waterjets with the fibres in the fibre web displaces and rotates them with respect to their neighbours. These relative displacements result in a coherent web of entangled fibres. Some of the fibres twist around others and/or interlock with them (Anantharamaiah *et al.*, 2006; Tafreshi and Pourdeyhimi, 2004; Tafreshi *et al.*, 2003). The final outcome is a compressed and strong sheet of entangled fibres.

In hydroentangling, the webs are carried by a moving belt and a rotating perforated drum (also called a forming surface). The interaction of the belt or the drum surface with the fibres will result in the creation of permanent textures in the final result. This particular aspect of hydroentangling will be discussed in a subsequent article.

Hydroentangling waterjets are generated from tiny cone-capillary nozzles with a typical inlet diameter of about 130 μm (Anantharamaiah *et al.*, 2006, 2007; Tafreshi and Pourdeyhimi, 2003, 2004). Hydroentangling nozzles are placed on long stainless steel strips, normally referred to as 'nozzle-strips'. Nozzle-strips span across the width of the machine (often a few metres). The nozzle-to-nozzle distance (spacing between waterjets) is usually about 500 μm–600 μm. Each nozzle-strip is placed in a manifold (jet head) where high-pressure water is supplied to the nozzles. Hydroentangling machines normally have several manifolds. An example of hydroentangling equipment utilising both belt and drum entangling is schematically shown in Figure 1. The first manifold is typically for pre-wetting the fibre web and pre-entangling the web. The configuration shown here is for entangling the web on the face and the back. The face is entangled on a belt, whereas the back is entangled on a perforated metallic drum. Note that there are vacuum boxes underneath manifolds (underneath the belt and inside the drum) to help extract the water from the web for efficient entanglement (see Figure 2a).

It is crucial for the entanglement at each manifold that the stagnant water remaining from the previous manifold is sufficiently extracted from the fabric so that the incoming jets strike the fibres and not a film of water. If the jets hit a film of water formed on the surface of the fabrics, they lose

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