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A novel nozzle design for producing hydroentangled nonwoven materials with minimum jet-mark defects

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Abstract The presence of jet-marks, or jet-streaks, on the surface of hydroentangled nonwoven fabrics, is usually regarded as an undesirable outcome of the hydroentangling process. Jet-streaks degrade aesthetic features and physical properties of the resulting fabrics. Jet-streaks are associated with low tear strength along the machine direction and non-uniform appearance. Reducing or eliminating the occurrence of jet-streaks will lead to increased use of this class of fabrics in many applications. Hydroentangling employs closely-packed single or multiple rows of high-speed waterjets to entangle and consolidate fibers or filaments in a loose (un-bonded) web. In this work, we demonstrated that a waterjet curtain made of two rows of staggered jets where the jets in the 2nd row are smaller in diameter than those in the 1st row can help minimize these jet-marks in a cost-effective manner. The optimal ratio between the diameter of the jets in the 1st and 2nd row depends on the hydroentangling pressure, as well as the web characteristics. In this study, different nozzle diameters ranging from 100 μm to 130 μm for the 2nd row were examined in combination with a fixed diameter of 130 μm for the nozzles in the 1st row. For the type of fiber-web used and the operating pressures considered, a combination of nozzles with 130 μm diameter in the 1st row, and nozzles with 110 μm diameter in the 2nd row, was found to provide the optimum setting for eliminating/minimizing the jet-marks.

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Introduction

Nonwoven materials, by definition, are assemblies of fibers bonded together in the form of sheets, webs, or mats [1]. Nonwovens are used in the areas of filtration, composites, geotextiles, hygiene and medical products, as well as clothing and protective garments, amongst many others. Nonwovens are bonded mechanically, thermally or chemically. Hydroentangling is a mechanical bonding process and most popular because the resulting fabric is strong, flexible and most fabric-like [2, 3]. The underlying mechanism in hydroentanglement is the exposure of the fibers 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 fibers in a somewhat random web displaces and rotates them with respect to their neighbors. During these relative displacements, some of the fibers twist around others and/or interlock with them [4–8]. The final outcome is a compressed and strong sheet of entangled fibers.

Hydroentangling waterjets are generated from tiny cone-capillary nozzles with a typical inlet diameter of about 130 μm (see Fig. 1). Hydroentangling nozzles are normally placed on long stainless steel strips, normally referred to as ''nozzle-strips''. Nozzle-strips span across the width of the machine (often a few meters). The nozzle-to-nozzle distance (spacing between waterjets) is usually about 500–600 μm. Each nozzle-strip is normally placed in a manifold (jet head) where high-pressure water is supplied to the nozzles. The generated waterjets are collimated streams with glassy appearance and impact the web. Hydroentangling machines normally have several manifolds. Often, entanglement is accomplished by pre-bonding the web at lower pressures and then entangling the web at higher pressures using the manifolds further downstream. A schematic illustration of the hydroentangling machine used in this study is shown in