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S1.4.1 - *3D Orientation Distribution Function of Nonwoven Materials*

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Various textile and filtration products in many sectors, such as, hygiene, health care, civil engineering, and automotive are partially or thoroughly made up of nonwoven materials. Understanding and characterization of mechanical behavior of nonwoven materials is comparatively challenging due to their complex microstructure composed of polymer-based randomly orientated fibers bonded together with manufacturing methods such as, thermal, mechanical, or chemical processes. In order to analyze these random complex structures, it is important to implement proper mathematical concepts which represent the random orientation of a fibrous network. During the design process of nonwoven products, strong and reliable numerical tools, such as Finite Element Method can be facilitated to simulate their real-life performance under service conditions [1]. Moreover, sealing and filtration properties of nonwoven materials can be examined numerically using CFD (Computational Fluid Dynamics) based analysis. Consequently, three-dimensional (3D) Computer-Aided Design (CAD) models enable to perform accurate structural, thermal, or flow analyses to analyze the 3D signature of various types of nonwovens. There are limited ways to visualize the microstructure of nonwovens in terms of the orientation distribution which represents the geometrical randomness of a fibrous network. Orientation distribution function (ODF) is a histogram defining the angle of fibres

with respect to a reference direction. Two types of algorithms were developed to represent the two-dimensional (2D) ODF of fibrous structures specially based on image processing techniques using Fast Fourier Transform (FFT) and Hough Transform (HT). Demirci et al. [2] used Hough Transform (HT) to represent the 2D ODF of high and medium density nonwovens using the SEM (Scanning Electron Microscopy) technique and later, Pourdeyhimi et al. [3] used FFT to determine the 2D ODF of nonwovens based on the spatial frequency difference. Subsequently, DVI (Digital Volumetric Imaging) technique is one of the destructive methods which can be used to evaluate the hydroentangled nonwoven models and it was used to visualize and characterize fibrous structures to define the web in terms of 3D ODF as it obtained the thickness direction [4]. This study mainly focuses on the representation of the 3D orientation of randomly orientated nonwoven fabrics using mathematical models by accounting for the fiber curliness as well. Each fiber is represented mathematically to identify the randomness of the fibrous network. Initially, the virtual fiber domain is built up with linear and non-linear fibers which can be modeled based on mathematical expressions. Algorithms are developed to define fiber orientations and their curliness in 3D space. Once the verification of the algorithms is achieved, developed algorithms are extended to measure the parameters of actual nonwoven models. Micro-CT system is used to acquire the 3D volumetric image of nonwoven samples and processed it through various built-in micro-CT software to remove the noise in the image for a certain extent to gain a better visualization. Voxel processing techniques are deployed to enhance the quality of the image and compute the 3D ODF of nonwoven samples. Keywords: Nonwovens, Fibrous materials, Nonwovens, Characterization, 3D Orientation Distribution Function, Fiber Curliness, Voxel Processing, Computed Tomography.AcknowledgementWe gratefully acknowledges the support of The Nonwovens Institute of North Carolina State University, Raleigh, USA. The second author presents his sincere thanks to TUBITAK (The Scientific and Technological Council of Turkey) for the financial support within the project under BIDEB 2219 scholarship program.
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