On-line Measurement and Characterization of Nano-web Qualities Using a Stochastic Sensor Fusion System

Design and Implementation of NAFIS (NAno-Fiber Information System)

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Abstract

A process control system has been developed for measurement and characterization of the nano-fiber web qualities. The nano-fiber information system (NAFIS) developed consists of a measurement device and an analysis algorithm, which are a microscope-laser sensor fusion system and a process information system, respectively. It has been found that NAFIS is so successful in detecting irregularities of pore and diameter that the resulting product has been quitely under control even at the high production rate. Pore distribution, fiber diameter and mass uniformity have been readily measured and analyzed by integrating the non-contact measurement technology and the random function-based time domain signal/image processing algorithm. Qualities of the nano-fiber webs have been revealed in a way that the statistical parameters for the characteristics above are calculated and stored in a certain interval along with the time-specific information. Quality matrix, scale of homogeneity is easily obtained through the easy-to-use GUI information. Finally, ANFIS has been evaluated both for the real-time measurement and analysis, and for the process monitoring.

Introduction

Electrospun fibers have long been known as a promising candidate for filtration and membrane application mainly due to their large specific surface areas and micro-porous structure [1]. While the process of electro-spinning at small lab-scales has been relatively well understood, the process and quality relationship of the nano-fibers on mass-production system has yet to be examined [2,3]. The research examines the feasibility of designing a holistic system of measurement and data analysis for electro-spinning processes that can assume an active and prominent role in the maximization of product quality and profits. By combining a microscope-laser sensor fusion system and a multi-layer stochastic model, the system to be developed will extract the essential information required for characterizing the salient qualities of nano-fiber webs, without having to process and store vast amounts of data acquired on-line. The laser micrometer and video microscope have been combined in order to detect the micro pores in the almost nontransparent nano-fiber webs. While structural changes in the webs' surface pore have been detected by the sensor fusion system, multi layer stochastic model automatically generates the pore parameters of the whole web. The results show that a proper combination of the fusion system and the stochastic model are capable of characterizing the non-homogeneity and the microstructure of the nano-fiber webs. Furthermore, the system is capable of monitoring and controlling by detecting the variations in diameter and orientation by employing a morphological image processing algorithm. The nano-fiber information system (NAFIS) developed has been successful in stabilizing the process so that the web qualities maintain their uniformity within a certain tolerance. The system provides the fiber industry with a more meaningful and cost-effective measurement and monitoring system than those presently available.

Experimentals

Poly acrylonitrile (PAN) was employed in order to form nano-fiber webs under "electro-flash hybrid spinning" machine which produces very fine fibers by sequentially applied high pressure and electricity. It produces a bundle of fine filaments at a higher speed than the conventional electro-spinning machines (e-spinning machine).Qualities of the fiber webs spun then

have been measured and characterized by the "monitoring" system placed prior to the winding device. Pore size, orientation and diameter, web thickness have been simultaneously measured and analyzed by the microscope-laser sensor fusion system. Figures 1 -4 shows the equipment and analysis algorithm employed in the research.

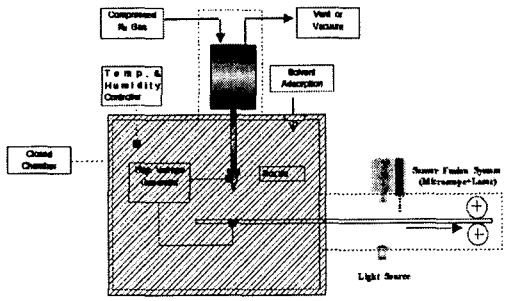

Figure 1. Flash-electro hybrid system equipped with NAFIS

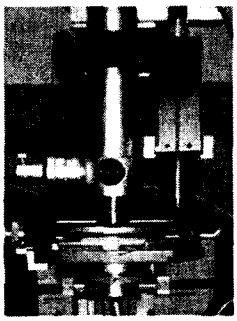

Figure 2. A microscope-laser sensor fusion system

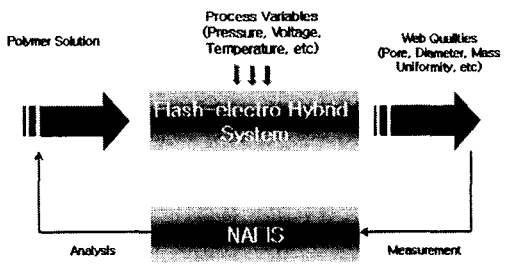

Figure 3. Schematics of the system

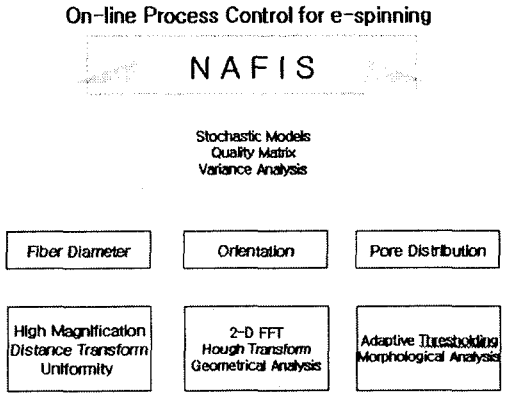

Figure 4. NAFIS

Results

The nano-fiber webs produced in the flash- electro hybrid spinning system have been continuously monitored and analyzed in pore size, diameter and mass uniformity. The resulting parameters have been further utilized in order to detect process defect or improve process capability.

Conclusions

An on-line process control system for nano-fiber webs made by electro spinning has been developed by combining a microscope-laser sensor fusion system and a stochastic image processing algorithm. It has been found that the system has been quite successful in controlling the web qualities in such a way that pore, diameter and mass density have been measured and analyzed on-line.

References

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