Journal of Fiber Bioengineering and Informatics 7:1 (2014) 1–11
doi:10.3993/jfbi03201401

Study on the Influence of Calendaring Process on Thermal Resistance of Polypropylene Nonwoven Fabric Structure

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Abstract

The purpose of this paper is to investigate the influence of calendering process on polypropylene nonwoven structure and thermal resistance. The study was focused on the influence of mass per unit area, thickness, density, porosity, characteristic opening size and additional thermal bonding by calendering. Thermal resistance of polypropylene nonwoven fabric manufactured using the mechanical carding process and bonding using the needling process, where a part of the samples was additionally bonded by the thermal calendering process, were investigated. The nonwoven fabrics were tested for thermal resistance on the guarded hot plate. Statistical analyses were performed to examine the significance between the observed parameters. Correlation matrix analyses were used to reveal relationship behaviour among the variables. A change in structure of the calendered samples caused a considerably lower thermal resistance i.e. better thermal conductivity. A change of the average value of thermal resistance after calendering related to non-calendered fabric mass between 150 and 500 g/m^2 ranged from 53.9 to 41.0%. With increasing nonwoven fabric mass, the difference between thermal resistances of needled and needled as well as additionally bonded by calendering the nonwoven fabric was reduced.

Keywords: Polypropylene; Needled Nonwoven; Calendaring; Characteristic Opening Size; Guarded Hotplate; Thermal Resistance

1 Introduction

Nonwoven textile is a fabric composed of individual fibres mutually bonded by a certain process. For nonwoven productions different types of fibres are used. The choice of fibre depends on the desired properties of the nonwovens and the cost of the chosen fibres [1, 2]. The three most processed synthetic fibres of world consumption for nonwoven production are polypropylene, polyester and viscose [2]. As previously mentioned, nonwoven fabrics produced of polypropylene were chosen for this study. Needled nonwoven fabrics with different functional properties are used

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March 2014

in technical applications such as filters, composites, protective clothing, packaging, geotextiles, home furnishing, heat and noise insulating etc. [3].

Thermal properties are important in many textile applications such as apparel, blankets, and sleeping bags, interlinings, building insulation, automobiles, aircraft and industrial process equipment [4]. One of the major nonwoven applications is thermal insulation materials.

Thermal conductivities in steady state condition was investigated by Mohammadi at al. where they concluded that the thermal conductivity of needled nonwoven structures can be predicted with high accuracy using model with fabric thickness, porosity and structure along with applied temperature [5]. Thermal conductivity decreases with increasing material density were concluded by Jirsak et al. [6]. Morris concluded that when two fabrics have equal thicknesses but different densities, fabric with lower density shows greater thermal insulation [7]. Abdel-Rehim et al. studied heat transfer through different fabrics made by polypropylene and polyester mass in a range from 400 to 800 g/m^2 and they concluded that the investigated fabrics have high thermal performance and thermal response as insulators [8]. Saleh investigated properties of needled lining produced from polyester, cotton and recycled fibre and concluded that fabric thickness, mass and fibre type affect the thermal properties of the fabric [9]. In the same study the compressed linings show lower thermal insulation properties compared with non-compressed which was explained by a possible amount of trapped air of non-compressed nonwoven lining which provides greater thermal insulation.

The calendering process gives a more compact structure of nonwoven fabrics, thus resulting in a controlled and predictable compressibility. With calendering needled polypropylene nonwoven fabrics the range of porosity becomes narrow when the characteristic opening sizes is reduced [10].

The influence of the calendering process of polypropylene nonwoven geotextiles on water permeability under different loads, as well as pore characteristics have been recently investigated and it has been concluded that additional bonding with calendering needled polypropylene nonwoven geotextiles provides a more controlled and predictable performance considering only needled geotextiles [11].

Debnath and Madhusoothanan have studied thermal resistance and air permeability of needle punched nonwoven fabric made from jute and polypropylene blends to observe the effect of fabric weight, needling density and blend proportion on thickness, thermal resistance, specific thermal resistance, air permeability and sectional air permeability [1]. They concluded that thermal resistance and thickness increase but air permeability and sectional air permeability decrease significantly with the increase in fabric weight at all levels of jute contents [12].

The reclaimed fibre based non-woven materials, suitable for automotive application, was studied were authors founded that thermal conductivity of reclaimed fibre-based nonwoven materials varies significantly, depending on the type of reclaimed fibres and the resulting bulk density of the materials [13].

Determination of heat transfer by radiation in woven and nonwoven fabrics was investigated were authors concluded that nonwoven fabrics showed substantially higher increase of thermal conductivity with temperature than woven fabrics due to strong free convection effects caused by high temperature drop between the layers [14].

Nonvowen fabrics produced from polypropylene fibers are used in industry as thermal insulators. By development of its applications there is a need for thermal insulators of lower thickness. After