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Effect of Thermal Barrier on Thermal Protective Performance of Firefighter Garments

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Abstract

For firefighter protective clothing, thermal protective performance is of primary importance. In this regard, the effects of thermal barrier construction on the level of thermal protection were investigated. In this study, needle punched nonwovens of varying thicknesses for application as thermal barrier were prepared from 100% meta-aramid, 100% wool, and 90% meta-aramid/10% para-aramid fibers. The effect of the number of layers in multilayer thermal barriers prepared from these nonwovens and the effect of spacers on the thermal protective performance were examined. The possibility of incorporation of aerogels into the thermal barrier to enhance the protective performance was examined. The needle punched nonwovens were padded with 5 wt% aerogels dispersion in acetone. The differences in thermal protective performance of nonwovens were evaluated by heat transmission on exposure to flame, heat transmission on exposure to radiant heat and heat transmission on exposure to both flame and radiant heat methods. Multi layer constructions with spacers and nonwovens treated with aerogels exhibited higher thermal protective performance.

Keywords: Aerogels; Thermal Protective Performance; Firefighter Clothing; Flash Fire Mannequin; Multi-thermal Barrier

1 Introduction

Firefighters are exposed to many hazards associated with their work environment. Apart from many toxic substances in the ambient air, high radiant heat intensities and hot flames are common risks in fire extinguishing work. Firefighter's turnout equipment is designed to protect against environmental hazards. Especially for firefighter protective clothing, the thermal protective performance is of great importance to the lives of firefighters. Thermal protective performance is an important factor in the firefighter's protective clothing development. The firefighter's protective clothing must resist heat, flames and hot substances and international standards are available for testing such properties [1-2].

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Generally, firefighter protective clothing was composed of 3 layers such as outer shell, middle layer and inner layer or 2 layers such as outer shell and inner layer with a combination of a moisture barrier and a thermal barrier.

The outer layer prevents body skin from the exposure of heat radiation or flame and middle layer provides both the performance of waterproof and heat insulation. Usually, the aramid fibers are used as the layer of insulation and PTFE membrane is used as the breathable waterproofing layer.

As the thermal insulation is a layer of insulating material to retard heat flow through the garment, it is very important to develop this.

Shin et al. [3] examined heat protective perfor mances of firefighter's protective clothing and heat-resistant clothing circulated in the domestic setting. Song et al. [5] studied the effects of air layers in the firefighter's protective clothing on the heat protective performances under the flash fire.

Zhu et al. [6] investigated into firefighter protective clothing made of different material combinations, based on the demand for radiant protective perfor mance and heat-moisture transfer properties, which are closely associated with comfort performance.

In this study, we aim to apply a new type of thermal layer with increasing thermal protective performance to firefighter's protective clothing.

Aerogel represents what technology experts consider the best insulation material ever invented. Aerogels are synthesized using sol-gel processing followed by supercritical drying or ambient pressure, which leaves the original gel structure virtually intact. Aerogel has an extremely fine and highly porous structure, composed of individual features only a few nanometers in size. By mass, it is 99.8% air, making it the least dense man-made substance. Aerogels with very higher insulation are widely applied in construction, aerospace, defense and clothing [4].

In this paper, we studied the thermal protective performance of nonwovens treated with aerogel and used with spacers. Heat transmission on exposure to flame, heat transmission on exposure to radiant heat, and heat transmission on exposure to both flame and radiant heat methods were used to measure the thermal protective performance of nonwovens treated with aerogels and used with spacers.

Finally we manufactured a firefighter's protective clothing by using aerogel composite material, and the flash fire mannequin test method (ISO 13506) was used to measure the thermal protective performance.

2 Experimental

2.1 Sample

Needle punched nonwovens composed of 100% meta-aramid fibers, 100% wool fibers and 90% meta-aramid/10% para-aramid fibers changing thickness and area mass are compared. We Also prepared the thermal layer at different thicknesses and assemblies.

D50 nanogels with particle size 7∼11um, specific surface area 600∼800 m^2/g and density 30∼45 kg/m^3 were purchased from Cabot Co. (Germ.) The details of the fabrics are illustrated in Table 1.