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Effect of Aerogel on Thermal Protective Performance of Firefighter Clothing

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Abstract

The aim of this study is to evaluate the effect of aerogel on Thermal Protective Performance (TPP) of fire fighter clothing. Specimens were treated by 5 wt% aerogel dispersed in acetone to obtain various add-on of aerogel and their TPP were evaluated by flame heat transmission test according to ISO 9151. The thermal degradation behavior, flame retardancy and water vapor permeability of aerogel treated specimens were also examined. Finally, the comparison of the burn injuries predicted by instrumented manikin testing of aerogel treated fire fighter clothing and existing fire fighter clothing were performed. The result showed that aerogel treated fire fighter clothing exhibited higher TPP than the existing firefighter clothing. This suggests that there application of aerogel in fire fighter clothing may be possible.

Keywords: Aerogel; Thermal Protective Performance; Firefighter Clothing; Instrumented Manikin Test

1 Introduction

Fire fighters' lives are always under threat due to the hazardous working environments, therefore they need good protection against such environments. Dangerous thermal exposures fire fighters usually confront in hazardous environments include hot environment, high thermal radiation, contact with hot objects and different kinds of flame exposure among which flashover is the most extreme [1]. As an important part of turn out gear of fire fighters, fire fighter clothing must ensure the safety of the fire fighter under such hazardous environments. The main function of fire fighter clothing is to reduce the rate of heat build up inhuman skin so as to provide time for the wearer to react and avoid or minimize skin burn injury [2]. Therefore, to ensure the safety of the fire fighters, the Thermal Protective Performance (TPP) of fire fighter clothing must be regarded as an important factor in the design and development of fire fighter clothing.

Currently, most researches related to TPP of fire fighters' clothing have been studied extensively using some testing equipment such as TPP tester, instrumented manikin system and modelling of fire fighter clothing which simulate the heat and moisture transfer in clothing subjected to intensive heat. These researches concluded that TPP of fire fighter clothing was mainly affected

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by several dominant factors including thermal conductivity, volumetric heat capacity of fabrics, and air gap between clothing and human skin. And the moisture presented in garment can significantly affect thermal physical properties and heat transfer in clothing. Air gap is also an important factor for evaluating TPP of clothing, with larger air gap resulting in higher TPP within a certain range. Assuming that natural convection may occur when the air gap becomes wide enough, for example more than 6 mm, this can lead to increased heat transfer and decreased insulating property. However the air gap is provided by the garment as a result of its design but is not dependent on the characteristic of fabrics themselves. Most of these studies related to TPP of firefighter clothing have mainly focused on assessing or exploring the protection mechanism but did not involve the improvement of TPP, therefore it is our intention to develop a new type of fabric combining aerogel to improve TPP of fire fighter clothing [3-8].

It is known that aerogel has the lowest thermal conductivity among all known solids in terms of unit weight and thickness. In general, aerogel is obtained from wet-gel, which is synthesized by sol-gel process, dried under supercritical or ambient pressure condition to keep the nano-pore structures [9-11]. Due to this property, aerogel is widely used in construction, aerospace and defense, and can also be applied to insulating clothing. However, regardless of the intensive applications of aerogel, application of aerogel in fire fighter clothing has never been explored until recently.

Hence, we came up with this idea that incorporating aerogel into fire fighter clothing to improve the TPP of fire fighter clothing. Furthermore, a series of experiments were conducted to examine how aerogel impacts thermal degradation behaviour, flame retardancy and water vapor permeability of the specimens. Finally we prepared a prototype fire fighter protective clothing using aerogel composite thermal barrier, and compared the TPP of aerogel treated fire fighter clothing and existing fire fighter clothing using the instrumented manikin. In conclusion, our data suggest that application of aerogel in firefighter clothing may be possible.

2 Experimental

2.1 Materials

Usually, firefighter clothing is comprised of 3 layers including outer shell, thermal barrier and inner liner as illustrated in Fig. 1.

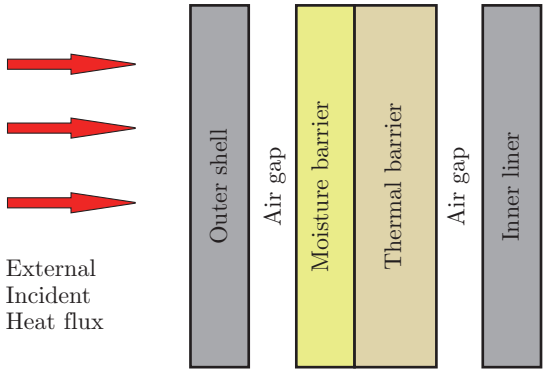

Fig. 1: Configuration of firefighter clothing assemblies