Making High Temperature Phase Change Materials Functionable in FPCs

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Introduction

High-temperature phase change materials have been vastly applied in high temperature thermal energy storage systems, but never used in the textile field. Firefighting garments exhibit large temperature fluctuations when exposed to fires, rendering the possibility of the incorporation of these materials. Recently it was shown that PCMs with low to medium melting temperatures may be considered adequate candidates for usage[1]. However, vast amounts of PCMs with higher melting temperatures are reported in the literature, but fail to melt due to high melting temperature. Hence, in this work it is shown that a small increase in the inner thermal resistance of the suit, originates a significant increase in the amount of high temperature PCMs which fully melt, and can be considered for incorporation.

Experimental

A firefighter jacket (with an outer shell, PCM layer, and thermal inner) was used and a set of possible modifications were numerically studied. An air gap is utilized to increase the fabric inner resistance. One-dimensional Fourier heat transport is assumed in all garment layers. Radiative and conductive heat transport are assumed in the air gap. For the PCM layer an apparent heat capacity model was employed to take the latent heat associated to the phase change into account in the heat transport calculations. The Pennes' Bioheat model is used to compute temperature and heat fluxes inside the three skin layers. Independent parametric studies were performed where PCM mass and melting temperatures were varied for each air gap width and fabric backside emissivity. Such was done for high- , medium-, and low- intensity exposures. The code was validated against experimental data.

Results

Depending on the exposure intensity considered, an inclusion of a small resistance (e.g. airgap[2]) between the PCM and the skin can allow for the incorporation of PCMs with much higher melting temperatures, whilst still providing adequate time to second degree burn. Air gap width was shown to widen PCM selection the most. For high- and medium intensity exposures, inserting an air gap of up to 3 mm can give PCMs with high melting temperatures (above 200 °C), the potential to be used in this application. Changing the backside emissivity of the garment only has significant effects when it is low (i.e. below 0.5). For higher PCM masses however, thermal resistance addition influences PCM choice less. Lastly, it is also important to note that for high PCM masses, even though time to second degree burn is delayed, large heat accumulation in the skin layers is possible rendering the firefighter to other kinds of heat hazards[3]. In such cases, a more sophisticated bio-heat model should be used.

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