Smart firefighters PPE: impact of phase change materials

Gilda Santos[1], Soraia F. Neves[2,3], Margarida Silva[2,3], João M. Miranda[2,3]; João B. L. M. Campos[2,3], J. Ribeiro[4], A. Moreira[4], P. Fernandes[4], F. Miranda[4], Rita Marques[1]*

[1] CITEVE - Technological Center for Textile and Clothing Industries of Portugal, V. N. Famalicão, Portugal
[2] CEFT - Transport Phenomena Research Centre, Faculty of Engineering, University of Porto, Porto, Portugal
[3] ALiCE - Associate Laboratory in Chemical Engineering, Faculty of Engineering, University of Porto, Porto, Portugal
[4] CeNTI – Centre for Nanotechnology and Smart Materials, Vila Nova de Famalicão, Portugal
* Corresponding author gsantos@citeve.pt

Keywords
Phase Change Materials, thermal protection, firefighters, smart PPE, smart protection, advanced materials

Introduction

Considering the level of heat and flame exposure firefighters encounter while performing their working activities, the use of personal protective equipment is of utmost importance to enhance their safety. Therefore, in the past years several studies were performed with the aim of increase firefighters' protection and, consequently, decrease firefighters' heat load and skin burn. (1) Recently the use of phase change materials has been studied, in the scope of thermal protective clothing, considering the capability of these advanced materials to absorb and release energy in the form of latent heat, when phase transition occurs. (2) As a wide spectrum of PCM for textile applications is available, their selection should be done in view of the final purpose and considering properties such as heat storage capacities and melting point. For example, PCM with melting points close to body temperature are commonly used to improve thermal comfort, meanwhile for firefighters' thermal protective clothing, as the main purpose is to improve heat protection, PCMs with higher melting points and heat storage capacities should be used. (3) This study comprises thermal performance evaluation of different PCM (different melting points and heat storage capacities) integrated in an ensemble to simulate a possible thermal protective clothing.

Methods

In this study three different encapsulated phase change materials were analysed, varying intrinsic properties such as melting point and heat storage capacities, Table 2. PCM 1 and PCM 2 possess similar heat storage capacities but different melting points and both are in the powder form. Regarding PCM 3, this material presents lower melting point and heat storage capacity, and it is encapsulated in the form of a granulate.

Table 2. Phase change materials properties and characteristics.

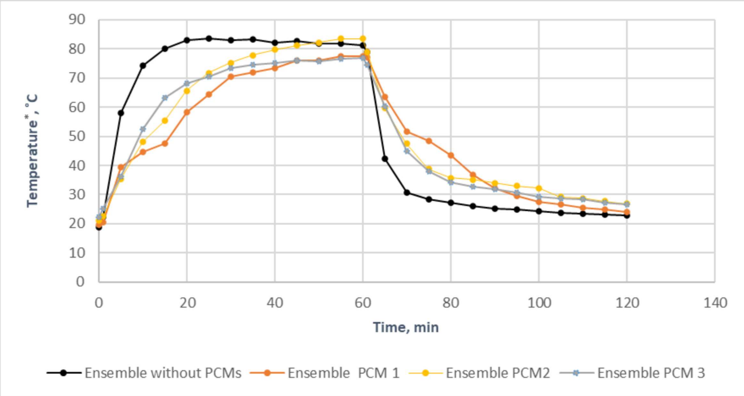
PCM	Melting /Congealing Area, ˚C	Heat Storage Capacity, kJ/kg	Form
PCM 1	77-85 / 85-77	105	Microencapsulated (powder)
PCM 2	49-53 / 52-48	100	Microencapsulated (powder)
PCM 3	38-43 / 43-37	55	Encapsulated (granulate)

To evaluate PCM thermal performance 6 grams of these materials were integrated in a membrane pouch, placed in a multilayer system composed by an outer shell fabric, 3D knit fabric, outer shell/cork matrix (to insert the pouch), and an outer shell layer. Afterwards, these ensembles were tested in an experimental set-up that was built for simulating convective and radiant heat exposure, Figure 3. This set-up consists of a 6x6 cm frame to support the sample, heated using a 1500 W heat-gun. A thermocouple was placed at the centre of the sample, on the opposite side of the exposure, to monitor the temperature over time. The samples are exposed to heat for 60 minutes and afterwards the heat source is turned off and the temperature decrease is also monitored for 60 minutes.

Figure 3. Experimental set-up for preliminary evaluation of PCM pouches: a) global view; b) heat source; c) sample frame; d) sample placed in the frame connected to a thermocouple; e) temperature acquisition device.

Results and discussion

In Figure 4, is possible to observe the increase of temperature over time when the PCM ensembles are exposed to the heat source. To set a term of comparison that allows the analysis of the improvement of thermal performance with the integration of the PCM, samples of the ensemble without PCM were also exposed to heat. The temperature was measured according to the method described previously.



*Temperature measured on the opposite side to heat exposure

Figure 4. Thermal performance evaluation of ensembles with and without PCM.

The figure above allows to observe the positive effect of the integration of PCM in the ensemble regarding thermal protection, since the increase of temperature was delayed in comparison to the results obtained in the ensemble without PCM. Furthermore, was also possible to conclude that within the PCM analysed, PCM 1 obtained better results in terms of thermal protection (major delay in the heating stage), as expected in the literature since this PCM presents higher melting points and higher storage capacities. However, the results presented show that the introduction of PCM delays the decrease of temperature during the cooling stage, while the samples without PCM cool instantly to 42,2 ˚C. The samples with different PCM have presented a similar cooling behaviour.

Conclusions

The results obtained allow to conclude that the integration of PCM contributes to increase the heat protection, delaying the increase of temperature on the heating stage, especially the PCM 1. Further work will approach the effect of PCM through the evaluation of heat transfer resistance (flame and radiation) according to EN 469:2020: Protective clothing for firefighters – Performance requirements for protective clothing for firefighters' activities.

Funding

This work was financially supported by PCIF/SSO/0106/2018 - Project for "Development of an innovative firefighter's jacket", funded by national funds through FCT/MCTES (PIDDAC).

References

1. Santos G, Marques R, Ribeiro J, Moreira A, Fernandes P, Silva M et al. Firefighting: Challenges of Smart PPE. Forests 2022, 13, 1319. doi.org/10.3390/f13081319
2. Fonseca A, Mayor TS, Campos JBLM. Guidelines for the specification of a PCM layer in firefighting protective clothing ensembles. Applied Thermal Engineering, 2018,133, 81-96 doi: 10.1016/j.applthermaleng.2018.01.028
3. Santos G, Marques R, Marques F, Ribeiro J, Fonseca A, Miranda JM et al. An innovative thermal protective clothing system for firefighters. CDAPT 2022, 146-145 doi 10.25367/cdatp.2022.3. p146-155.