Firefighter Hood for Cooling by Exploring Phase Change Materials

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Introduction

Phase Change Materials (PCMs) use chemical bonds to store and release heat and therefore have been suggested as latent energy storage materials. The thermal energy transfer occurs when a material changes from a solid to a liquid, or from a liquid to a solid (Bendkowska, Tysiak, Grabowski, & Blejzyk, 2005). Due to their thermal regulating characteristics, PCMs may be highly suitable for applications in clothing materials in conditions that require workers to face extreme temperatures, such as firefighting.

Firefighters must wear specific protective garments when working on structural fires. Their protective clothing includes a Nomex® hood which covers the head and neck with an opening for the face. It provides protection in those areas and helps create a bond to the face mask to keep the firefighter protected in unsafe conditions. The traditional hood, while protective, could be improved through the use of PCMs embedded in fabric. To accomplish this, researchers have developed a way to encapsulate PCMs into clothing fibers to reduce heat loss or prevent overheating in protective clothing (Mondal, 2008).

When a PCMs temperature increases above its melting point, the PCM absorbs and stores heat as thermal energy as it melts. When the PCM's temperature increases beyond the specified temperature range, the PCM is *powered off* and the PCM cools to below the melting point, releasing its stored energy and returning back to a solid state. As PCMs absorb heat, it provides thermal regulation to wearers, as well as enhances comfort by reducing perspiration. In this way, heat stress is prevented. As heat stress is one of the top reasons for death among firefighters, regulating body temperature is extremely important.

The goal of PCM textiles is to create reusable energy to maintain body temperature, as well as to optimize the performance of protective wear such as gloves. Maintaining a stable body temperature can improve working conditions and comfort. The study also has practical applications for the inner linings of protective clothing in conditions of high heat or extreme temperature (Zeng, Sun, Xu, Tan, Zhang, Zhang, & Zhang, 2007; Mondal, 2008). Laboratory research design was used in this study to explore the application of PCM in the design of a protective hood.

Method

The PCMs were developed in the laboratory through three difference processes: emulsion non-solvent addition method, in-situ polymerization and interfacial polycondensation. Characteristics of the PCMs, such as chemical composition and microstructure of the

microcapsules were evaluated and thermal qualities were tested. The results revealed that good microencapsulation were achieved.

An interlock material made of a 35% cotton/65% polyester blend was identified and used to develop prototype hoods. The interlock material had two layers and between these layers was a coated PCM fabric. All the layers were surrounded by PANEX, a woven carbon fabric, which formed an outer shell. This combination of layers would provide protection and cooling to the neck area exposed between the jacket and helmet.

The design of the firefighter hood was undertaken using feedback from research conducted by Park, Park, Lin and Boorady (2014) which discussed issues of poor fit in firefighter gear, including the hood design. Three prototypes were created and tested on male subjects to evaluate fit, mobility, body movements, and protective functions.

Prototype 1 was developed to give maximum back neck coverage and mobility, prototype 2 gave full neck and shoulder coverage and prototype 3 gave full neck coverage (no shoulder). Qualitative research design was used in this study. A questionnaire was used to interview subjects after they tried out each hood style containing PCM. The questionnaire was revised after the pilot study. The questionnaire covered information about demographics with six questions, and explored the needs of PCMs users in seven closed and two open-ended questions. The seven closed questions reflect consumer values, the effectiveness of PCM, and its availability in the market, while the open questions collected deeper insight into consumer interests and the need for future product development.

Discussion & Conclusion

The results of this study suggest that firefighters may be interested in adopting PCM products as they provide temperature control for the body. More research in the proper design of this hood needs to be conducted with this new material to determine optimal coverage and maximum mobility range.

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