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Preparation of Firefighting Hood for Cooling For Phase Change Materials

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ABSTRACT

There are two types of Phase Change Materials (PCMs) which have been developed and adopted in textiles: heat (energy released) and cool (energy absorbed). This paper discusses current PCM applications and explores future applications in firefighting gear. Phase change materials are considered latent heat storage units because as they change phase from solid to liquid, liquid to gas and vice versa, energy in the form of heat is absorbed or released. 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 hoods. When the wearer's body temperature increases or decreases, the PCMs applied to the fabric will change state helping to regulate the wearer's body temperature by providing warmth or cooling. Maintaining a stable body temperature can improve working conditions and comfort.

Keywords: firefighter, personal protective equipment (PPE), phase change materials (PCM)

I. INTRODUCTION

Each year tens of thousands of firefighters are injured on the job and heat stress is the common factor in the majority of these injuries [1]. PCM applications can help regulate body temperature and offset the critical thermal exposure firefighter's endure [2].

1.1 There are two types of Phase Change Materials (PCMs) which have been developed and adopted in textiles: heat (energy released) and cool (energy absorbed). This paper discusses current PCM applications and explores future applications in firefighting gear. The contents of each section provide information to understand about the opportunities and challenges of this application.

Phase Change Materials (PCMs) have been suggested as latent energy storage materials. This theory derives from the use of chemical bonds to store and release heat. The thermal energy transfer occurs when a material changes from a solid to a liquid, or from a liquid to a solid [3]. This is called a change in state, or "phase." PCM, proven to possess thermal-regulating characteristics, is proposed for applications in clothing materials in conditions that require workers to face extreme temperatures. PCM also is believed to conserve energy and maintain certain temperatures, so PCMs have been chosen for latent energy storage materials.

1.2 In some work environments, jobs require the use of heavy garments or specially designed clothing with specific functions to protect the wearer from injury, heat stress, or contamination. These special-function garments could prevent transfer of hazardous materials onto the skin, as well as prevent the transfer of heat and moisture out of the garment [3]. To accomplish this, researchers have developed a way to encapsulate PCMs into clothing fibers to reduce heat loss or prevent overheating in protective clothing [4]. PCMs react instantly to temperature changes. Because of the energy they release and absorb during these changes, PCMs can be used for thermal storage and thermal control [5, 6].

II. BACKGROUND

Theoretically, PCMs ability to preserve energy is relatively simple. When a PCMs temperature increases above its melting point, the PCM absorbs and stores heat as thermal energy as it melts. When the PCMs 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 [7]. As PCM absorbs heat, it provides thermal regulation to wearers, as well as enhances comfort by reducing perspiration. In this way, heat stress is prevented.

Another characteristic of PCM is that it acts as a mediator between the body and the environment's temperatures. PCM products will help people who need to protect their body during outdoor activities in severe conditions like extreme hot or cold [8]. In agriculture, industry, and recreation, many subjects may encounter severe sun exposure, which poses a risk to their health without proper protection against ultra-violet light. Taking such cases into consideration, another purpose of this project is to explore and enhance PCM product effectiveness relative to consumer needs.

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 hoods. Maintaining a stable hand temperature can improve working conditions and comfort. Hand function is compromised when the hand becomes too cold, as dexterity and ability to manipulate materials is decreased. This project is intended to explore issues for the product development of PCMs to create hoods with improved thermal regulation properties. The study has practical applications for the inner linings of protective clothing in conditions of extreme temperature [8]. Laboratory research design was used in this study to explore the application of PCM in the design of a protective hood.

III. PROCEDURES

3.1 Preparing PCM

The first step involved dissolving 3g of three-isocyanate in 6g of ethyl acetate in the homogenizer. Then 3g of n-eicosane was added and the solution was stirred until the n-eicosane was completely dissolved. Next, 10g of PVA aqueous solution (5% weight) was added to the solution. Once all chemicals were added, the solution was mixed in the homogenizer for ten minutes at a temperature of 40°C to create a completely homogeneous solution. Stirring was continued until polymerization occurred and the ethyl acetate was completely volatile.

In this study, a field emission scanning electron microscope was used to explore the high-tenacity polyester fabric after the irradiation of argon and oxygen plasma treatment. Images were used to determine change in fiber surface according to the different variables: gas treatment, plasma power, and irradiation time. The operating current was 12 mA and the voltage was 10kV. -3-5 contact angle and surface free energy.

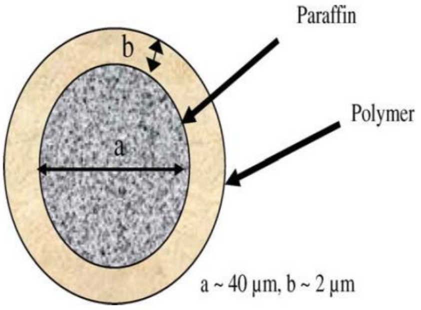

Fig. 1 Microencapsulation: Paraffinic PCM core material individually with a hard polymeric shell

Microencapsulated phase change materials (PCMs) were successfully prepared by three different process: emulsion non-solvent addition method, in-situ polymerization and interfacial polycondensation. The process parameters- such as polymerization temperature, additive, rotational speed and mass ration of phase change materials to monomer etc. –which control the size, shell/core ration and yield the microcapsule were studied. Chemical composition and microstructure of the microcapsules were characterized by FTIR and microscopy, and thermal characteristics were tested by differential scanning calorimetry. The results reveal that good microencapsulation can be achieved.

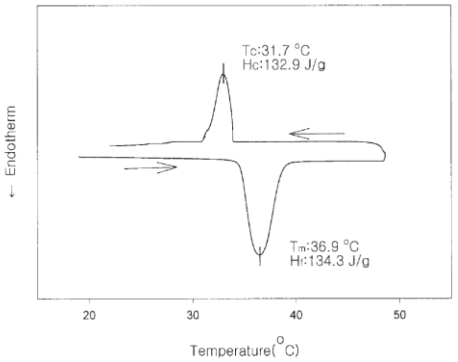

Fig. 2 DSC thermogram of the microcapules

3.2 Designing Hood

This project proposal is to adopt PCMs to create a firefighter’s hood to reduce the likelihood of heat stress.

Needs: gap between hamlet and jacket could be vastly different between wearers. It is easy to be tired and reduce productivity thereby exposing this gap in the neck to heat environment without any protection. Three prototypes were created and tested on male subjects to evaluate fit, mobility, body movements, and protective functions [9].

Prototype 1: Main purpose: Basic and maximum to cover neck, least connect to bodice for max neck coverage and mobility.

Prototype 2: Main purpose: Maximum coverage neck and shoulders

Prototype 3: Main purpose: Maximum coverage neck and supreme coverage of shoulders

Table 1 Examples of three prototype hoods for fire fighters.

		
Prototype 1	Prototype 2	Prototype 3

The application of PCM in the design of protective hoods for firefighters was explored through laboratory research to determine if there was improved thermal regulation. 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 [10].

3.3 Evaluated Procedure This section covers the design, the experimental design and analysis and the results.

A total of three prototypes of hoods using PCMs were created and tested in different labs. Preliminary tests indicate that absorbency or release of heat (energy) while changing states within this hood structure will provide a benefit for the wearer [11]. PCMs have been found to be one of the most efficient ways of storing thermal energy and it is expected that the use of this material in hoods will provide a new use for this developing material technology. Future research will test these hoods in working conditions.

Qualitative research design was used in this study. A self-developed questionnaire was used to interview subjects after they tried out the prototype hood 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 collect deeper insight into consumer interests and the need for future product development.

IV. DISCUSSION

The results of this study show that the use of PCMs could be very beneficial to certain populations including firefighters as the material provides superior temperature control for the body. Current personal protective clothing / bunker gear is hot and heavy which can impede the work of the firefighter. Research has shown a common causal factor in both heart attacks and slips, trips and fall injuries by firefighters is heat stress [4]. Modifying personal protective equipment to reduce heat stress could drastically reduce these injuries and fatalities.

Previous studies have shown that firefighters are interested in updating their personal protective equipment to take advantage of new technology but are hesitant to completely change the traditional look of their equipment [5]. The use of the PCM imbedded textile can achieve increased safety through helping to regulate the body temperature without significantly changing the look of the traditional bunker gear, specifically the hood.

V. CONCLUSION

The absorbency or release of heat (energy) of PCMs while changing states within a certain temperature range was considered beneficial by consumers. Products that include PCMs could be adopted by many customers. Clothing coated with PCM can either reduce heat loss or prevent overheating has been accepted by target consumers. Target consumers have embraced PCM as a thermal balance between heat generated by the body and heat released into the environment. PCMs have been found to be one of the most efficient ways of storing thermal energy.

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