NEW TEXTILE COMPOSITES WITH THERMO-REGULATING PROPERTIES FOR AUTOMOTIVE INTERIOR APPLICATIONS

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Abstract

Energy can be saved and the thermal comfort inside the passenger compartment can be enhanced by the application of textile composites with thermo-regulating properties. The thermo-regulating properties are provided by the application of phase change material (PCM) – a highly productive thermal storage means. In order to create the textile composites with thermo-regulating properties the PCM is contained in a polymeric film that is laminated to a textile carrier. A study has indicated that the application of the developed composites is especially beneficial in car seats, headliners and instrument panels.

In the paper, specific solutions for the application of the textile composites in car seats, headliners and instrument panels will be introduced and test results, received in rigorous field tests, will be discussed.

Introduction

On hot summer days, the temperature inside the passenger compartment of an automobile can rise substantially, especially when the car is parked outside and is exposed to direct sun irradiation. In order to stabilize the interior temperature while driving the car, many models are equipped with air-conditioning systems; however, providing a sufficient cooling capacity requires a lot of energy.

Energy can be saved and the thermal comfort inside the passenger compartment can be enhanced substantially by the use of new textile composites with unique thermo-regulating properties. The thermo-regulating properties are provided by the application of phase change material (PCM) – a highly productive thermal storage means.

Phase Change Material (PCM)

Phase change material (PCM) possesses the ability to change its physical state within a certain temperature range. When the melting temperature is obtained in a heating process, the phase change from the solid to the liquid state occurs. During this melting process, the PCM absorbs and stores a large amount of latent heat. The temperature of the PCM and its surroundings remains nearly constant throughout the entire process. In the reverse cooling process, the latent heat stored in the PCM is released into the environment in a certain temperature range, and a reverse phase change from the liquid state to the solid state takes place. During this crystallization process, the temperature of the PCM and its surroundings remain nearly constant. When the phase change is complete, a continued heating / cooling process leads to a further temperature increase / decrease. The absorption or release of high amounts of latent heat without a temperature change is responsible for the appeal of the PCM as a suitable heat storage mean.

In order to compare the amount of latent heat absorbed by a PCM during the actual phase change with the amount of sensible heat absorbed in an ordinary heating process, the ice-water phase change process will be used for comparison. When ice melts, it absorbs an amount of latent heat of about 335 J/g. When the water is further heated, it absorbs an amount of sensible heat of only 4 J/g while its temperature rises by one degree Celsius. Thus, water needs to be heated from about 1°C up to about 84 °C in order to absorb the same amount of heat which is absorbed during the melting process of ice.

In addition to ice (water), more than 500 natural and synthetic PCMs, such as paraffins and salt hydrates are known. These materials differ from one another in their phase change temperature ranges and their latent heat storage capacities.

Suitable Locations for the PCM Application in the Passenger Compartment

In order to determine where the PCM should be located inside the passenger compartment to thermally control the automotive interior, a preliminary study of the temperature development in different locations of the passenger compartment has been carried out. As a result of the study, the following locations were selected for the PCM application:

- headliner;
- instrument panel;
- seats.

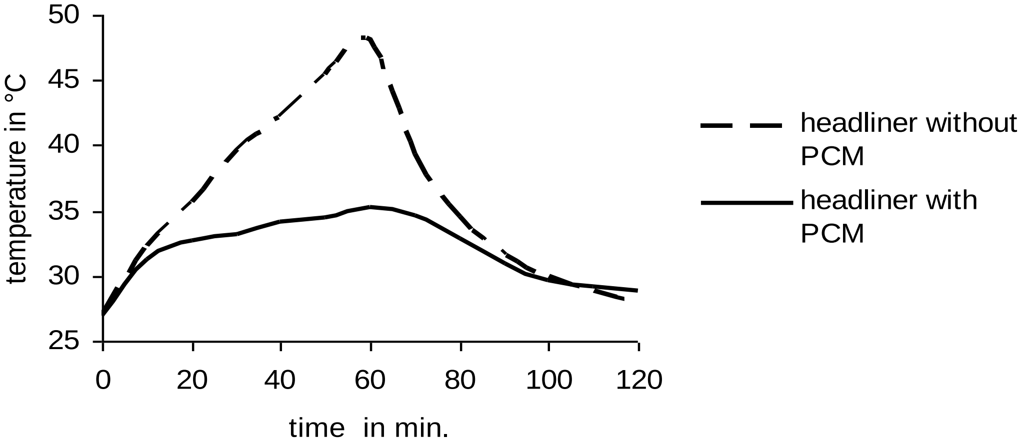
PCM Application in the Headliner

In the headliner application, a non-combustible salt hydrate-PCM is used via embedding in a one millimeter thick polymeric film. A textile composite has been created in which the PCM-film is arranged between the décor fabric at the bottom of the headliner and its intermediate foam layer. The PCM starts to absorb latent heat when its temperature rises above 30 °C. The PCM integrated in the headliner possesses a latent heat storage capacity of about 240 kJ. This amount of latent heat absorption of the new PCM-treated headliner is equivalent to the heat absorption of a common headliner whose temperature rises by about 100 °C.

In a closed passenger compartment, hot air, which builds up mainly by exposure to sunlight through the windows, moves to the top and heats up the headliner. As a result, the headliner’s temperature rises continuously. If PCM is applied to the headliner, it will absorb the heat without a further rise in its temperature until the PCM’s melting point is reached. Based on the latent heat absorption by the PCM, the normal rise in the headliner’s temperature is delayed significantly. The thermal control feature of the PCM keeps the temperature inside the passenger compartment at a comfortable level without the need for an external energy supply. This is especially beneficial when the car is parked outside and exposed to direct sun irradiation. During the parking period, the passenger compartment in which PCM is applied to the headliner does not overheat. As a result, a lower cooling capacity is needed at the beginning of the driving process, which especially helps to save energy.

Calculations were made for a midsize car with an interior volume of about 2.5 m³ and a headliner area of about 1.5 m². Furthermore, an air-conditioning unit with an approximate air flow of 250 kg/h and an initial air temperature of about 9 °C were considered. Based on these assumptions, energy savings of about 25 % have been calculated. The heat stored in the PCM might be released through the roof into the environment during driving periods of the car or as a result of the overnight cooling.

The temperature development in the headliners with and without PCM during a 60-minute parking period and a following 60-minutes driving period is shown in Figure 1.



A side benefit of the newly developed headliner with PCM is the improvement in the headliner's noise absorption. Fig. 2 shows test results received for headliners with and without the PCM-film application.

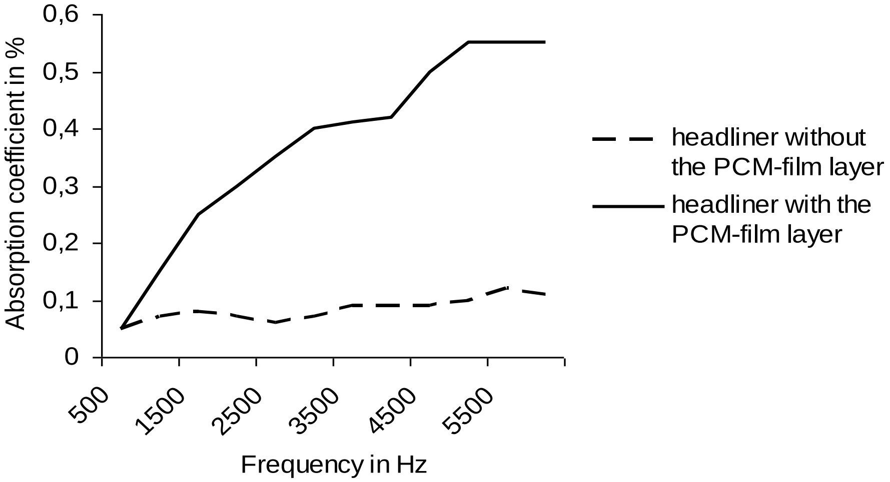


Fig. 2: Noise absorption of the headliner

PCM Application in the Instrument Panel

In its instrument panel application, the PCM is embedded in a polymeric film which is attached to the back side of the PVC-cover material. The selected non-combustible salt hydrate- PCM absorbs latent heat when its temperature rises above 35 °C. Due to the high demand for the latent heat absorption, a much larger amount of PCM is used in the instrument panel in comparison to the headliner. The latent heat storage capacity of the PCM applied to the instrument panel totals about 600 kJ.

Applied to the instrument panel, the PCM absorbs heat that penetrates mainly through the windshield into the passenger compartment. During the latent heat absorption of the PCM, the temperature of the instrument panel remains nearly constant at a comparatively low level. Because of the constant low temperature of the instrument panel, it releases less heat into the passenger compartment, which leads to improved thermal comfort, reduces the cooling requirements for the passenger compartment, and, therefore, results in energy savings. Additional energy savings of about 15 % are estimated for the PCM application in the instrument panel. By using PCM in the headliner and the instrument panel, overall energy savings of up to 40 % are obtained. Furthermore, due to a reduction in its temperature fluctuations, the aging process of the instrument panel's cover material is delayed substantially.

PCM Application in the Seat

In the seat application, the PCM is embedded in polymeric film patches that are arranged on top of the seat's foam cushion. The applied PCM absorbs latent heat when its temperature rises above 30 °C. It possesses a latent heat storage capacity of about 100 kJ.

By the PCM application to a car seat, the thermal seating comfort is improved significantly, especially on hot summer days. The PCM absorbs surplus heat stored in the seat cover and heat released from the driver's body as soon as the driver starts occupying the seat. The heat transfer away from the seat's surface and the heat absorption by the PCM arranged inside the seat leads to an instant drop in the microclimate temperature until a comfortable level is reached and is maintained. Fig. 3 shows the temperature development in the microclimate for seats with and without PCM-treatment.

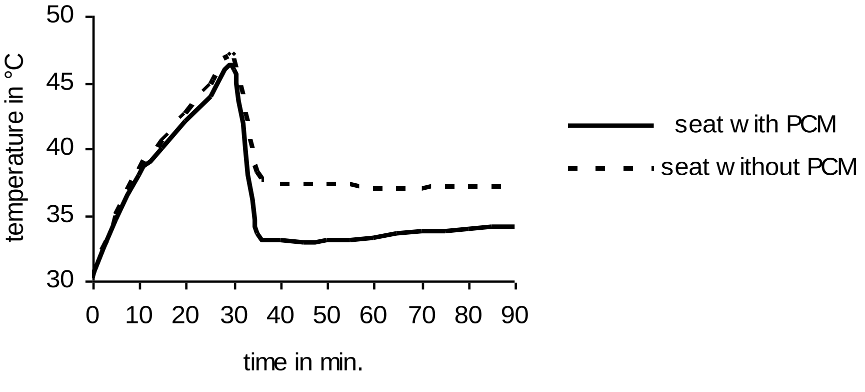


Fig. 3: Temperature development in the seat's microclimate

In the 30-minutes parking period at the beginning of the test, the cover of the empty seat absorbs a substantial amount of heat which leads to a rise in the microclimates temperature. When the driver starts sitting in the seat the heat from the cover material is normally transferred to the driver's body which initially leads to a decrease of the microclimate temperature. Afterwards, the microclimate temperature remains at an uncomfortably high level of about 38°C. If PCM is used inside the seat, the heat absorbed by the cover material is transferred to it as soon as the driver starts sitting in the seat. The weight of the driver's body compresses the seat's cover layer which leads to a sufficient heat transfer to the PCM and away from the body. The heat transfer to the PCM results in a substantial drop in the microclimate temperature. The microclimate temperature remains then at a comfortable level of about 33 °C.

By keeping the microclimate temperature in the comfort range, the driver's body perspires less than usual under such circumstances leading to an improvement in the overall seating comfort. Test results of the development in the microclimate's moisture content are summarized in Fig. 4.

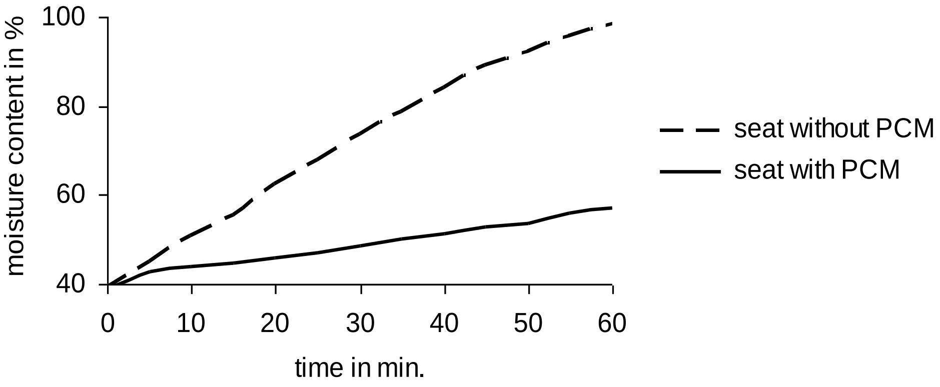


Fig. 4: Development of the moisture content in the seat's microclimate

Summary

The investigations have shown that PCM offers substantial benefits in applications involving the thermal management of an automotive interior. The PCM application in the headliner and the instrument panel provides a suitable mean to thermally control the automotive interior without the need for an external energy supply. Based on the thermal control feature of the PCM, the necessary cooling capacity of currently used air-conditioning equipment can be reduced, which leads to substantial energy savings.

In addition, the PCM application increases the thermal comfort inside the passenger compartment, and could delay the aging process of the cover material of the instrument panel. Applied to the seats, the PCM improves their thermal comfort substantially, especially on hot summer days. The PCM-film application in the discussed components is durable, maintenance free and does not require the use of any external energy supply.