Flame-retardant breathable moisture barriers for firefighters' protective clothing

In a cooperation project, Trans-Textil GmbH and the STFI developed laminates with improved flame-resistance for moisture barriers in firefighters' protective clothing. The composite materials are produced using hotmelt technology and fulfill the relevant protective clothing standards. Integrated in protective clothing systems, they protect from extreme heat and external moisture, thereby lowering the physiological load on the wearer.

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Generally speaking, firefighting clothing (Fig. 1) and multifunctional protective clothing for industrial workers exposed to heat contain moisture barriers in the form of breathable membranes in the laminate system. These moisture barriers provide reliable protection against wind, rain, fire-extinguishing water, liquid chemicals and other dangers of emergency situations. Together with the textile components and purposefully selected processing technology they fulfill the requirements of such standards as DIN EN 469 ‘Protective clothing for firefighters – Requirements and test methods for protective clothing for firefighting’ and DIN EN 343 ‘Protective clothing – Protection against rain’ standards, the HuPF manufacturing and testing specification for universal firefighters turnout gear and station wear, the requirements of industrial laundry services and other specifications pertinent to the multifunctional concept.

The moisture barriers fulfill a further function for the wearer of the apparel in their ability to transport moisture vapor away from the body and pass it to the exterior. In professional personal protective equipment this ‘breathability’ means not only wear comfort, but also helps conserve physical strength and mental acuity in exacting emergency situations, thus making an important contribution to the safety of the wearer. For this reason a central concern in designing the respective laminate systems is to lighten the physiological load on wearers by incorporating lighter and more breathable textiles and membrane systems.

To reduce heat stress and above all to fulfill protective requirements in choices of weight-reduced textiles, the Saxony Textile Research Institute (STFI) and Trans-Textil GmbH joined forces to develop new breathable flame-retardant moisture barriers in a project with funding from the German Central Innovation Program for SME’s (ZIM). Production was performed with the help of hot melt technology. The goal of the technological development was to improve the flame-resistance of the laminates while fulfilling or surpassing further appropriate statutory requirements. As experience shows, the overall performance of a laminate system is due to a combination of synchronized textile components, sophisticated membrane systems incorporating thermostable polyurethane or dual-component ePTFE, special reactive hot melt adhesives and precisely controlled processing technologies. In numerous test series, the project partners developed various membrane options and compared them with proven membrane systems and special flame-retardant membranes, initially individually and then in combinations involving flame-retardant adhesives and textiles.

Adhesive screening

Based on research into available reactive PUR hot-melt adhesives with flame-retarding characteristics, the adhesives alone were superficially applied to silicone paper in a preliminary step, after which the combustion behavior of the foils produced in this way was examined in accordance with ISO 15025. On the basis of the findings thus made, a selection was made of adhesives for application to membranes. A thermostable membrane without flame-retardant characteristics served as a benchmark in this respect along with an adhesive without flame-retardant characteristics as used by Trans-Textil in protective fabric materials.

In each case an adhesive was applied to the membrane by means of gravure roller in STFI’s hot melt multipurpose coating and laminating machine (Fig. 2) and on a larger scale in Trans-Textil’s hot melt lamination unit using the screen printing method (Fig. 3). Adhesive runnability during application and the resulting application pattern were appraised. A test made of the combustion behavior of the membrane options with or without adhesive showed that combustion behavior was influenced by the adhesives to only a very slight extent, this primarily being dependent on the properties of the membrane concerned.

Membrane and laminate development

Production of the newly-developed membranes was transferred from the bench scale to a pilot-scale continuous system, whereby a main requirement was to achieve flame-retardance without inclusion of halogen or antimony in the composition.

A suitable lamination technique was developed using STFI’s hot melt multipurpose coating and laminating machine and then taken to the lab scale on the basis of screen printing technology in Trans-Textil’s hot melt lamination unit. The dot bonding technique was deployed in both processes, enabling extremely precise process control and adhesive

Fig. 1
Firefighters’ turnout gear (Trans-Textil)
application: this optimum distribution of hot melt adhesive compromised breathability to only a minimal degree. The flame-resistance of the trial variants produced in this way was determined, yielding findings for further optimization of the membranes. One particular membrane variant that fulfilled the intended functionalities to an outstanding degree was taken as the basis for further work on transferring the membrane laminating technology to the industrial scale. Not only the membrane variants and pre-selected adhesive types underwent the production trials but also the lamination of nonwovens and woven fabrics based on flame-retarding fibrous materials with differing compositions and weights per unit area; this was followed by testing to determine compliance with respective requirements. Water vapor permeability, water impermeability and laminate cohesion were tested in the case of laminate variants with good flame-resistance. The majority of the functional samples met and surpassed the respective requirements, even after 5 washing and drying cycles. The laminates also displayed excellent cohesion (Fig. 4).

Test results
Selected functional samples of the moisture barriers (liners) were laminated together with an outer fabric and an insulating inside lining to form 4 assembly demonstrators. After 5 washing and dry cycles each, STFI tested them in terms of heat transmission on exposure to flame according to ISO 9151, radiant heat transfer according to ISO 6942 and water vapor permeability according to DIN EN ISO 15496. In the assembly demonstrators, water vapor transmission resistance (Ret value) was determined in accordance with EN 31092 by the Swiss Federal Laboratories for Materials Testing and Research (EMPA).

All the functional samples fulfilled the \( \leq 13 \text{ m}^2\text{Pa/W} \) requirement of the German HuPF specification for firefighting clothing plus the 4 demonstrator components met the Ret value envisaged in the specified requirement profile. All the combinations achieved performance level 2 requirements (heat transfer index HTI24 \( \geq 18 \) and HTI24-HTI12 \( \geq 4 \)). With regard to radiant heat transfer 3 of the 4 variants met performance level 2 test requirements ((RHTI24 \( \geq 18 \), RHTI24-RHTI12 \( \geq 4 \)). The flame-retardant membranes examined in the screening had a good protective effect due to their flame-resistant components but in contrast to the newly-developed moisture barriers are not suitable for use as breathable moisture barriers due to properties such as poor water vapor permeability. Tests conducted to determine the water impermeability of seams after 10 washing cycles proved positive, plus the alternative flame-retardant agent used in the membrane was not shown to have a negative effect on the water impermeability of the seams.

Summary and outlook
Deployment of flame-retardant membranes and adhesives improves reliability in the fulfillment of statutory requirements applicable to firefighting clothing and protective apparel for workers exposed to heat, and makes it possible to compensate for possible fluctuations in the flame-resistance of textile carrier materials. The laminates (Fig. 4) and assembly demonstrators produced in the project displayed excellent flame-resistance and very good values concerning heat transmission on exposure to flame, radiant heat transfer, water vapor transition resistance and water impermeability. Developing membrane technology further opens up options in terms of reducing the weight per unit area of textile carrier components, and will thus help provide improved wear comfort at a high protective effect. On the basis of the findings of the joint project, Trans-Textil will be pursuing the topic further to enable industrial-scale production of new breathable membrane systems offering flame-retardant characteristics, high water impermeability values, and lasting bond strength in use and care processes.

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