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Textile laminate with integrated heating and humidity monitoring functions in protective clothing

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INTRODUCTION & AIM

This article presents a textile laminate system that incorporates heating and relative humidity measurement functions. The laminate was specifically designed for specialised protective clothing for workers. The aim was to develop a manufacturing method for a layered textile laminate incorporating a heating and measurement system that would not compromise the user's comfort. The laminate should exhibit appropriate thermal resistance values and increased durability of printed electrically conductive traces, as well as directional water vapour transmission from the underwear under varying conditions of relative humidity and moisture content within the garment structure. This was achieved by sequentially modifying the textile laminate layers to combine functions such as moisture barrier, water vapour transmission, heating and humidity measurement in an appropriate way. Inkjet printing technology was employed to this system. The system was powered by a 3.7-volt lithium-ion battery and used Wi-Fi communication. This article presents a measurement data acquisition system and a web-based application for monitoring and managing the thermal properties of the laminate. Environmental tests were conducted at various relative humidity levels to determine the system's effectiveness.

MATERIALS & METHOD

1. Materials structure

The laminate has a three-layer construction with two outer layers of knit fabric. The top knit fabric (12), which is preferably made of polyester (PES), is intended for the top (A) side of the laminate. The lining fabric (14), which is made of polyester (PES) fibres, is intended for the lining (B) side of the laminate and is designed to be in direct contact with the body due to its soft feel. Lining fabric 14 is laminated on the inside with a nonwoven fabric or foam to form the outer lining B side of the laminate. It is coated to increase flame resistance and give the knit fabric hydrophobic properties. This evens out the surface (142), allowing electrically conductive structures to be printed.

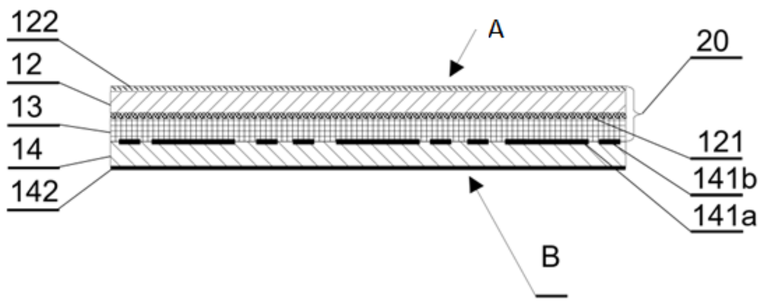

Fig. 1. Textile laminate in cross-section showing its layered structure

Figure 2 illustrates the individual steps involved in manufacturing textile laminates. Production is carried out in accordance with the relevant technological parameters, such as time, speed, quantity, temperature, chemicals used and pH level.

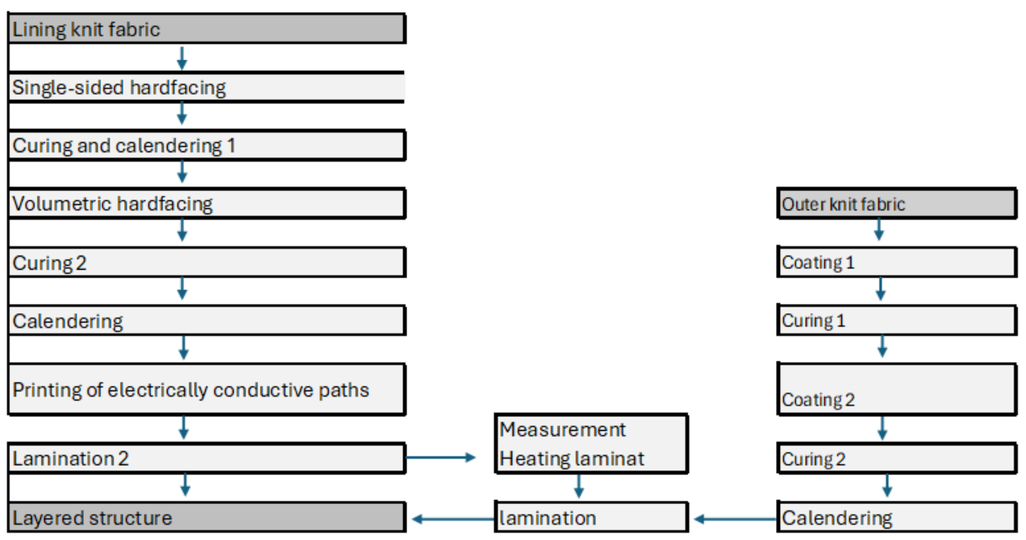

Fig. 2. Textile production process

The tests were conducted in accordance with the standard EN 31092:1993 + EN 31092:1993/A1:2012.

RESULTS & DISCUSSION

During intense physical activity, the average rate of sweat production should be 2 l/h and should be completely evaporated from the skin in order to maintain thermal balance. However, when the ambient relative humidity rises to 60%, this becomes impossible and sweat drips down the body. Therefore, the tests were carried out in laboratory conditions, taking into account relative air humidity thresholds of 40% and 80%, and the amount of moisture supplied to the inner layers of the materials, thus simulating sweat production. The value of 1.5 ml was calculated from the threshold values for sweat production from the human body with an average surface area of 1.8 m², taking into account the surface area of the tested material samples. General results presents in table 1.

Table 1. Results of thermal resistance [m^2K/W] measurements of laminates carried out under the specified measurement conditions

No	Thermal resistance of tested laminates/measurement conditions			
	Relative humidity RH40%		Relative humidity RH80%	
	Heating module OFF	Heating module ON	Heating module OFF 1,0ml of sweat introduced into the bottom layer of the laminate	Heating module ON 1,0ml of sweat introduced into the bottom layer of the laminate
1	0,071	0,136	0,060	0,108

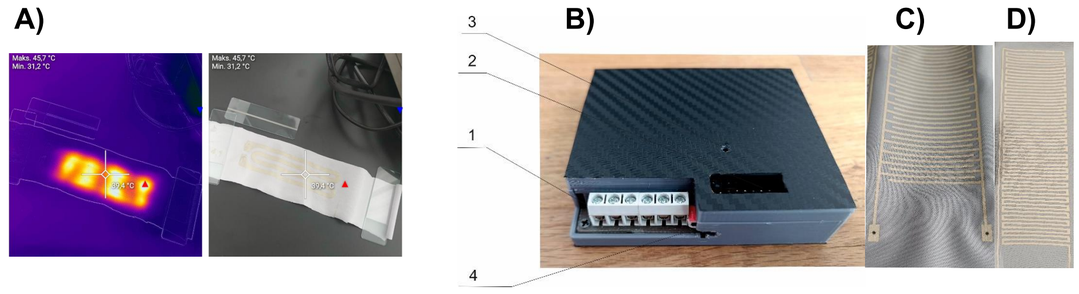

Fig.3. The laminate heating system provides warmth to the user and also ensures that moisture evaporates from the laminate into the environment. A) thermographic photo; B) Electronic setup (1- textile radiator connector, 2 – sensor connector, 3 – Wi-Fi connection reset, 4 – charging connector) ; C) basic measuring module; D) basic heating module

The relative humidity measurement system enables the continuous monitoring of the laminate's moisture level, ensuring maintenance-free control of the heating system. The application is designed to make using the clothing system easier and ensure user safety. As it is a web application, it can be used on various types of device, including mobile and stationary ones. Two-way communication with the wearable device takes place via Wi-Fi. The screen of the application is presented in Figure 4.

1. **Name** – the name given to the device, by which it is recognised by the system. Clicking on this field will display the history of information transmitted by this device.
2. **Humidity/Threshold** – the level of the last measured humidity together with the alarm threshold set by the user.
3. **Update** – the date and time of the last reading from the device.
4. **Refresh -** the time the device should wait between sending subsequent data to the server,
5. **Battery voltage** – the voltage level of the battery installed in the device,
6. **Comment** – a comment entered by the user,
7. **Number** of active heating zone.

CONCLUSION

The full version of the article will present detailed information about the production stages and testing of the entire system.

REFERENCES

EN 31092:1993 + EN 31092:1993/A1:2012 Textiles. Physiological effects. Measurement of thermal and water-vapour resistance under steady-state conditions (sweating guarded-hotplate test).

Patent no. P.443518, Method of producing textile laminate, A. Bednarek, 2024.