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Sustainability aspect of waterproof breathable fabrics

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Abstract:

The article is about the developments which took place in the recent times in the field of waterproof breathable fabrics. Waterproof Breathable fabrics shows the contradictory property of waterproofness as well as it allows the moist vapours from body to diffuse to the environment. There is a large variety of waterproof breathable fabrics which includes densely woven fabrics, micro porous and hydrophilic membranes and coatings, their combinations etc. Multilayered breathable fabrics are also being developed in recent times to enhance the functional characteristic of the fabric. The area has experienced a huge growth in the past few years as the waterproof breathable fabrics proved very effective in a number of fields such as active sportswear, mountaineering, military and some of the protective clothing also. Some of the leading manufactures such as ASF Group,Marmot™, Patagonia™, and The North Face™etc are working in this field to develop new products with the changing scenario.

***Keywords**: Breathability, bi-component laminates, ceramic, DWR, TS-PU, Temperature-Sensitive Copolymer, HPMC, Biomimetics.*

1. Introduction:

Breathability as explained in terms of fabric is different as understood in general which means the material should be actively ventilated[1,2]. Waterproof Breathable fabric should allow the water in vapour form to diffuse through it but at the same time it should restrict the entry of water in liquid form such as rain etc and with this contradictory functional requirement the fabric should comfortable enough to the wearer when converted into a garment. Waterproof Breathable fabric gives protection against weather like wind, rain and loss of body heat.The breathable fabrics find its application in the field of sportswear; (where the basic requirement is thermal, sensorial and body movement comfort of fabric and protection from adverse weather), hygiene, agriculture, protective clothing, and construction industries etc [3,4].

There are different categories of waterproof breathable fabrics as listed below;Classification based on conventional methods of production is, Densely woven fabrics, Micro-porousand Hydrophilic membranes, Micro-porous and Hydrophilic coating. Further it can be classified as, combination of micro-porous and hydrophilic membranes and coating and retroreflectivemicrobeads. Also based on recent developments, it is smart breathable fabrics and fabrics based on biomimetics. The development of micro-porous polymeric film made up of PTFE by Gore-Tex, which is an established brand name in the field of breathable fabrics since 1976 was considered the most significant development in this field. After Gore-Tex, numerous product brands have developed their patents in the same field [5].

Scope for development in any engineering field is always limitless. Research and Development is an easy task if the problem is well known. Problems can be cost effective production, alternative method of production, better functional characteristic in the product, economic and environmental friendly solution etc. As far as waterproof breathable Fabrics are concerned the formulation and application of micro-porous and hydrophilic membranes and coatings have been well researched in different fields of applications. Smart breathable fabrics and fabric based of biomimetics, which has recently gained popularity, has started to show a great potential [1]. The use of polyester microfilaments in densely woven structure has also proved its worth in waterproof breathability, thermal insulation and wind proof character of fabric [5,6]. A great scope for development also arises with the development of new ideas in the field. The leading manufacturers in the field has developed new product range such as THERMOBALL by The North Face which can offer the light weight, loft, warmth and compressibility of down, NanoPro and NanoProMembrain by Marmot[7] also some other names are there such as Patagonia, ASF Group [8].

2. Recent Developments

2.1 Modification in the existing products and processes

i. Bi-component Micro-porous and Hydrophilic Laminates

Using two components together is always beneficial as the advantages of both components can be utilized in one system that is why; Bi-component waterproof breathable fabrics are gaining interest in the market these days. This is because their combined system is proved effective in diffusion of perspiration vapours as well as condensed liquid perspiration. Hydrophilic systems do not transport perspiration vapour, but only the liquid perspiration formed when the vapour condenses where asMicro-porous hydrophobic systems transport vapour, but do not transport condensed perspiration [8]. By using a Bi-Component System that uses both hydrophilic and hydrophobic micro-porous elements most effective waterproof breathable system can be made. In this system Micro-porous PTFE membraneand hydrophilic Polyurethane (PU) are used together as a bi-component. The micro-pores of the PTFE are filled with hydrophilic PU. There is some evidence that an air layer exists between the PTFE and PU that provides insulation, increasing the temperature differential between the inside and outside of the fabric, and this can reduce condensation. The durability of this bi-component can be only due to use of high hydrophilic PU else chances of damage are more. This is also called Modern Gore-Tex and it is impermeable to air [9].

ii. Use of Ceramic in Coatings

Polyurethane (PU) is used conventionally as micro-porous coating on the fabric. In recent times, Ceramic is being used in coating which provide many more holes to transport the perspiration vapours away from the body by improving moisture vapour transmission of the fabric. Due to the addition of ceramic in the coatings finer holes are being formed and it adds about 20% more waterproof protection [8].

iii. SuperShed™ DWR Application[8]

This newly developed DWR technology uses a water repellent agent and a collateral process technology that densely aligns water repellent groups and bonding them firmly to the nylon fabric. This Technology was rated 80 using the water repellency spray test method even after over 100 repeated washing. Generally the DWR wears off with time are re-treatment is recommended when necessary. With this improved technology the treatment stays for a longer period of time in the fabric.

iv. Reduced Pore Size

Earlier the micro-porous membrane pore size was 2-3 micrometers which is reduced by 30% in this new technology which is recently launched by one of the leading manufacturers (Marmot) of waterproof breathable fabrics and it is named as NanoPro™. These very small pores which are densely packed improve the waterproofness and breathability of the fabric. This pore structure is also air permeable allowing for dynamic air exchange. Dynamic Air Permeability allows for air exchange to more quickly shed moisture vapour without compromising waterproof performance or wind protection [9,10].

2.2 Smart Breathable Fabrics

Smart Fabrics and Interactive Textiles are defined as having an in-built ability to respond to external stimuli, including electrical, mechanical, thermal, chemical or magnetic. Current smart textile systems aiming to reduce the discomfort caused by moving between hot and cold environments generally rely on temperature as a stimulus. Temperature sensitive polymers can be used in membranes and coatings in combination with fabric which gives waterproof breathability in which WVP changes with change in temperature.To design fabrics which can use humidity as a trigger to react to changes in the micro-climate in order to keep the wearer dryer for longer and get dry quicker can be more comfortable to wear [11].

2.2.1 TS-PU (Temperature Sensitive Polyurethane)

Temperature-sensitive polyurethane (TS-PU) is one novel type of smart polymer. The water vapour permeability (WVP) of its membrane could undergo a significant increase as temperature increases within a predetermined temperature range. Such smart textiles would not only be waterproof at any temperature, but also provide variable breathability in response to the climate temperature [12].

2.2.2 Temperature-Sensitive Copolymer

A smart breathable cotton fabrics using a temperature-sensitive copolymer - poly (N-tertbutylacrylamide-ran-acrylamide:: 27: 73) was developed by Save et al.

Recipe Used:

- Copolymer(aq.) -20 wt%
- 1,2,3,4-butanetetracarboxylic acid (cross-linker)-50 mol%
- Sodium hypophosphite (catalyst)-0.5 wt%

Followed by drying (120°C, 5 min) and curing (200°C, 5 min).

The coatings after integration to the cotton substrate retained temperature-sensitive swelling behaviour and showed a transition in the temperature range of 15-40Â°C. The coated fabrics showed a temperature-responsive water vapour transmission rate (WVTR) [6,13].

2.2.3 Hydroxypropyl methyl cellulose

Hydroxypropyl methyl cellulose (HPMC) is an intensively investigated temperature-sensitive polymer which has a simultaneously hydrophilic and hydrophobic structure and demonstrates a low critical solution temperature (LCST) at about 55.65 °C.In an aqueous solution, the macromolecular chains of HPMC experience reversible solubility and exhibit a significant hydration-dehydration change in response to temperature stimulus. These polymers have both hydrophilic and hydrophobic groups in their structure. Below LCST, the hydrophilic interactions dominate and polymer becomes soluble in water, while above this temperature hydrophobic interactions dominate and polymer becomes insoluble in water. The gel change shape by swelling in water below transition temperature and de-swells above transition temperature.The coatings after integration to the cotton substrate retained temperature-sensitive swelling behaviour and showed a transition in the temperature range of 30-40°C.The coated fabric is exposed to external temperature, it will display swelling/shrinkage or hydration/dehydration properties, and cause changes in the water vapour transmission rates (WVTR), permeance and permeability of the fabrics [14].

2.3 Fabrics based on Biomimetics

Biomimicry or biomimetics- is a new way to think of how we may be producing new materials in the future. Biomimicry is derived from the Greek word 'bio' –meaning life and 'mimetic' meaning 'mimic.' Biomimetics is the science of applying nature's principles to human engineering and design. Biomimetics is the mimicking of biological mechanisms, with modification, to produce useful artificial items [2]. And biomimetics clothes are those which mimic the wonders of biological world and perform more effectively

2.3.1 The Pine Cone Effect

Humidity-responsive adaptive textiles respond to levels of humidity in the micro-climate, so that breathability improves as the material begins to saturate. The fabrics based on pine cone can be used for a more effective waterproof breathability. Pine cone opens and closes its spines according to the weather,If it's going to rain, the spines close up to protect the seeds inside and if it's going to stay dry, the spines open up to improve the chances of the seeds escaping [13].Researchers at England's Bath University and the London College of Fashion are trying to design biomimetics clothes that could work the same way. The fabric could be made with an outer layer of tiny spikes, only 1/200th of a millimetre wide. When it's hot, the spikes would open up to let out the heat, cooling you down. When it's cold, the spikes would flatten back down to trap air and provide more effective insulation [13].

Nike introduced similar concept to produce its 'Macro React' range with a Fish-scale Pattern. It was first worn by tennis star Maria Sharapova at US Open 2006 and later by Roger Federer at Wimbledon. When someone wear this clothing, upon perspiration, the flaps in the fabric swings open to release heat and moisture to keep one dry and cool. The same clothing is made way for golf dresses.

Also the introduction of INOTEK Fibres developed by MMT Textiles, which works on pine cone effect, has brought a new revolution in the field of waterproof breathability. The fibres alleviate the feeling of dampness by increasing the permeability of yarns and textiles as moisture builds up around them. The manufacturers in the field ofsports clothing, base layers, underwear, socks and bedding fabrics can bring new products that has improved comfort which can be delivered by keeping them dryer for longer and getting them dry quicker in extreme conditions. The U.S. Army Natick Soldier Research, Development and Engineering Centre in Massachusetts have tested a range of textiles using INOTEK patented fibres and validated all the resulting data. They verified its performance via a series of tests carried out on 100% INOTEK fibres, its blend with natural fibres like Merino wool and commercial fibres like Tencel, all the test samples showed significantly improvement in permeability at 98% Rh against relevant test and control samples. The breathability of INOTEK textiles improves gradually from the first point of elevated relative humidity up to optimum performance at the point of saturation [12,13,14].

INOTEK fibres work just opposite to the wool fibres. As the material starts absorbing moisture the fibres start to close (mimicking the pine cone) and reduce in volume causing yarn to thin three-dimensionally in the cross-section. Microscopic air pockets are opened in the material and this increases its breathability. In contrast to pure wool, an INOTEK/wool blended yarn can reduce its thickness by up to 10% of its original width in damp conditions.The reactive response to humidity is also reversible. INOTEK fibres revert back to their original state in dry conditions, reducing air permeability and increasing insulation of the textile as in case of pine cone.

INOTEK fibres can find application not only in apparel sector but also in health and hygiene sector such as bedding, where more efficient moisture management would be of huge benefit and wound dressing, where this unique breathable technology could control moisture levels beneath the dressing, enhancing comfort whilst offering the same level of protection from infection etc [11,14].

2.3.2 Transpiration within a Leaf Effect

Transpiration is a process that involves loss of water vapour through the stomata of plants. The loss of water vapour from the plant cools down the plant when the weather is very hot.When the plant loses water through transpiration from the leaves, water from the stem and roots moves upward, or is `pulled', into the leaves.

(i) AZKO NOBEL’s Stomatex

The clothing is made of neoprene fabric along with foam insulation which has tiny hole like dome, as like the transpiration process within a leaf, which provides a controlled release of water vapour to make the clothing comfortable. Stomatex is claimed to respond to the level of activity by pumping faster as more heat is produced, returning to a more passive state when the wearer is at rest. Stomatex is used in conjunction with Sympatex, Akzo Nobel’s waterproof breathable membrane, to produce a breathable waterproof insulating barrier for use in clothing and footwear. The manufacturer claimed it as ‘the most comfortable clothing and footwear systems in the world today’ [2,12,14].

3 Conclusion

The technology has witnessed significant developments in the field of waterproof breathable fabrics in recent times including biomimetics clothes and there is a long way to go in the future. The scopes are unlimited and resources are infinite. Any change in the technology and methods can lead to the development in the field of Waterproof Breathable Fabrics which can be used effectively and efficiently in near future.

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