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Studies in Waterproof Breathable Textiles

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Abstract- **Textile products are particularly important for enhancing the comfort. Here, the main focus is on the discomfort due to perspiration. Waterproof or breathable fabrics resist liquid water passing through, but allow water vapour to pass through. Their ability to block out rain and snow while allowing vapour from sweat to evaporate leads to their use in rainwear, waterproof outdoor sports clothing, tents, and other applications. Coated fabric is 'A textile fabric on which there has been formed in situ, on one or both surfaces, a layer or layers of adherent coating material'. Waterproof fabric completely prevents the penetration and absorption of liquid water&the term breathable implies that the fabric is actively ventilated. Water repellent fabrics are those which resist being wetted by water, water drops will roll off the fabric.**

Keywords- **waterproof, water repellent and water breathable.**

I. Introduction

Coated fabric is 'material composed of two or more layers, at least one of which is a textile fabric and at least one of which is a substantially continuous polymeric layer. The layers are bonded closely together by means of an added adhesive or by the adhesive properties of one or more of the component layers'. The second definition is, 'A textile fabric on which there has been formed in situ, on one or both surfaces, a layer or layers of adherent coating material'.

Textile Terms and Definitions defines a 'laminated fabric' (or a 'combined fabric') as, 'a material composed of two or more layers, at least one of which is a textile fabric, bonded closely together by means of an added adhesive, or by the adhesive properties of one or more of the component layers'.[1]

Coating techniques simply try to control resin add-on and preserve fabric aesthetics and properties as much as possible. This is not easy, and fabric handling is always a challenge. Coated fabric handling may be especially difficult because, even after one layer has been applied, the total fabric weight has increased and the surface nature of one side of the material has changed significantly. Control of resin add-on is one of the fundamental principles of fabric coating, and the various methods achieve this in different ways. Water repellent fabrics are those which resist being wettedby water, water drops will roll off the fabric.

A fabric's resistance to water will depend onthe nature of the fibre surface, the porosity of the fabric and the dynamic force behind the impacting water spray.

II. Breathable Textile

Breathability of fabric is the ability of clothing to allow the transmission of moisture vapour by diffusion and therefore facilitate evaporative cooling. This definition of breathability is often being confused with wind penetration or clothing's ability to wick liquid water away from the skin; both of these processes are also referred to as breathability but depend on entirely different fabric properties.

Comfort is associated with the ability of the body to maintain a constant core temperature not only under different environmental conditions but also at different work rates for the body. During rest, most surplus body heat is lost by conduction and radiation, whereas during physical activity, the dominant means of losing excess body heat is by evaporation of perspiration.

Breathable films and coatings are useful for designing fire fighter dress material; it should permit the escape of body perspiration efficiently and reduce the incidence of heat stress which is a major cause of death due to fire fighting. One of the commonest causes of occupational deaths amongst firefighters is heart failure due to heat stress (hyperthermia) caused by loss of body fluid required to produce perspiration.

III. Types Of Breathable Fabrics

Different types of breathable fabrics can be classified into following groups: [2]

- Closely woven fabrics
- Microporous membranes and coatings
- Hydrophilic membranes and coating
- Combination of microporous and hydrophilic membranes and coating
- Use of retroreflective microbead
- Smart breathable fabrics
- Fabric based on biomimetic

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A. Closely Woven Fabrics

In case of closely woven fabric, the surface area and concentration of inter yarn spaces should be as high as possible to maximize water vapour transmission through woven fabrics, and the fabrics should preferably be constructed from absorptive and hydrophilic yarns. For foul weather clothing, however, there is a contradictory requirement that the inter yarn spaces should be as small as possible to give maximum protection against wind and rain, whilst the fabric outer surface should be non-absorptive and hydrophobic to minimize wetting out by rain, sleet, or snow. Tightly woven fabric made out from natural hydrophilic fibre is more efficient in transmitting water vapour under similar construction of non-absorptive, hydrophobic fibres. A further advantage of natural fibre textiles is that they can quickly absorb substantial quantities of liquid water produced inside the clothing as sweat or condensed water vapour.

B. Microporous Membranes and Coatings

In case of porous membranes laminated to a fabric or porous coating, the pore size ranges from 0.1 to 50 mm. The most widely used are PUs, poly-tetrafluoroethylenes, acrylics, and polyamino acids. Among these, PU is the most popular polymer because of toughness, flexibility of the film and capability of tailor making the property of the film to suit the end use requirement.

A number of diverse methods have been used to create the interconnecting pore structure in solid polymer films and coatings. Various methods of generating microporous membranes and coatings are as follows;

- Mechanical fibrillation (only for membrane)
- Wet coagulation process
- Thermo coagulation (only for coating)
- Foam coating (only for coating)
- Solvent extraction
- Solubilizing one component in the mixture (only for coating)
- Radio frequency (RF)/ion/UV or E beam radiation
- Melt blown/hot melt technology
- Point bonding technology.

IV. CHARACTERISTICSOF WATERPROOF BREATHABLE FABRIC

Moisture vapour transport through waterproof breathable fabric and clothing system is dependent on the temperature gradient across the waterproof breathable layer, the humidity of the clothing microclimate, and the interaction between water-vapours and the clothing layers. Fundamental considerations that need to be considered while designing a breathable fabric are:[3]

- Water proofness
- Mass of the fabric
- Durability/flexibility of coating/laminating
- Comfort level
- Aesthetic property
- Water-vapour transmission
- Effectiveness of clothing against wind chill factor
- Durability: tear tensile and peel strength; flex and abrasion resistance
- Launderability
- Tape sealability with good adhesion
- Strength of coating
- Good washability/dry cleanability
- Resistance to insect repellents
- Good hydrostatic resistance

There are several methods by which breathable-waterproof fabric can be prepared, such as microporous, hydrophilic, and the fabric based on microfilaments. The advantage of hydrophilic polyurethane coatings over laminated and microporous polyurethane film is that the former has good adhesion on textile substrate, high gloss, water and solvent resistance, high moisture permeable properties and it is less expensive. E-Caprolactum blocked urethanes have been studied extensively for coating applications by several authors. It has been reported in the literature that polyethylene glycol can be utilized as a relocking aid with e-Caprolactum. Using this approach, in the present study, various polyethylene glycols of molecular weight 400, 1000, 3000 and 6000 were used to prepare hydrophilic polyurethane coatings. These polyurethanes were prepared by the reaction of polyester polyols based on castor oil and E-caprolactam-4,4-diphenyl methane diisocynate (MDI) block prepolymer.[4]

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Microporous polytetrafluoroethylene (PTFE) membrane film laminated to fabrics is a well-known example.Polyester copolymer film also can be laminated to fabrics. Microporous coatings can be applied directly to the fabric. There are well-known techniques for forming microporous films. One method involves coagulating a solution of polyurethane in dimethylformamide (DMF) by leaching with water. The other method is by controlled evaporation of solvents to coagulate a film; methyl ethyl ketone and water are used for this application. The laminated and microporous films have excellent moisture vapour transmission. Hydrophilic urethanes are manufactured by the judicious combination of hydrophobic and hydrophilic urethane components to produce optimum moisture vapour transmission properties without loss of other physical properties. Monolithic hydrophilic coatings can be applied by conventional coating techniques, and they can be less expensive than laminated or microporous films. Each of these systems has advantages and disadvantages in addition to differences in cost. The laminated and microporous films have poor adhesion to textile substrates compared to hydrophilic coatings. On the other hand, the hydrophilic films have low water vapour permeability (WVP) [5]. A major problem with both coated and laminated breathable fabrics is their poor wet abrasion resistance.

V. Fabric Construction For Diffreent Uses

Water-vapour transfer of breathable fabrics depends very much on atmospheric conditions and in garments apart from breathable fabrics, fabric layers underneath also interact with the condensation and alter the transport properties of the clothing system. Therefore, one of the most challenging aspects of developing breathable fabrics is to minimize condensation of water inside the fabric. The condensation problem may be solved by changing some physical properties of a three-layer waterproof breathable fabric. The water vapour transfer out of the fabric can be improved, and consequently the formation of condensation reduced, by decreasing the thickness of the waterproof membrane and outer layer fabric or by increasing the average diffusion coefficient of the outer layer and membrane. A decrease in the thickness of the lining could increase the water-vapour transfer from the hot side to the interface between the dry-wet regions, but this would also increase the condensation. Increasing the diffusion coefficient of the lining will also increase both water-vapour transfer from the hot side and condensation.

Apart from the fabric component, design and manufacture of the garment is of considerable importance, particularly the method of seaming for waterproof garments. A study on tailoring performance of breathable waterproof fabrics manufactured by wet coating, dry coating, PTFE (Poly Tetra Fluoro Ethylene)-laminating, and PTFE-knitted lining laminating processes reveal that the penetration force, frictional force, and penetration energy is much higher on breathable fabrics than fabric substrate and the above parameters also increase with plying numbers. The changes were different with finishing methods, and the results were partially confirmed from the broken shape of the stitch holes.[6]

VI. Applicationsof Breathable Fabrics

Karthikeyan L. et. al. studied Development of Breathable Active Sports Wear, The sportswear textile industry has not only seen in market diversification for fibrous materials but has also contributed towards the elevation of textile science and technology to a level of approaching that of high tech industrial sectors. The performance requirements of many sports goods often demand widely different properties from their constituent fibres and fabrics, such as barrier to rain, snow, cold, heat and strength. At the same time these textiles must fulfil the consumer requirements of drape, comfort, fit and ease of movement.[7]

Medical Textiles, at present in the USA most medical protective clothing, may be as much as 80%, is made from nonwoven materials and used only once. The outer surface of nonwoven is treated with fluorocarbon for liquid repellency. In situation where a total barrier is required, the nonwoven is laminated to a waterproof film, and in some cases waterproof breathable films such as Gore-Tex are used.[8]

In another development, the nonwoven composite fabric provides a barrier to blood and viral challenges, and also provides breathability for comfort. The fabric is particularly suited for use as a disposable surgical gown. The fabric comprises a first microporous ply comprising a microporous formable resin that has been extrusion-coated onto a nonwoven fabric substrate and subsequently stretched to impartmicroporosity, and at least one additional ply positioned adjacent to the first microporous ply.[9]

In survey of physiological function of breathable material and water vapour impermeable constriction, good result found in the water vapour permeable construction by Volkmar T. Bartels and Karl Heinz Umbach.

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In this type of construction of fabric, moisture accumulation also small and ratio of evaporation was high for breathable construction. There is no indication of temperature dependency of water vapour resistance of hydrolic membrane laminates. It is specially tested for water vapour transport properties. They found that, physiological function of water vapour permeable foul weather protection garment is superior to non-permeable clothing and water accumulation is varying on garment between various ensembles also due to evaporation. Volkmar T. Bartels and Karl Heinz Umbach concluded that, water vapour transport properties and the physiological function of water vapour permeable clothing, especially based on hydrophilic components, are much better than for impermeable clothing, also at temperatures down to -20°C.[10]

Padleckienė I. studied breathability and Resistance to Water Penetration of Breathable-Coated Textiles after Cyclic Mechanical Treatments. They have explored different aspects of wear-comfort, namely the breathability and resistance to water penetration properties of some breathable-coated fabrics that are used as outwear.The breathable-coated fabrics, i. e. the 100 % polyamide (PA) woven fabric coated with polyurethane (PU) and the three-ply laminate, consisting of an outer 100 % polyester (PES) woven fabric, an insider hydrophilic PU membrane and 100 % PES knitted lining, were tested. To determine the change of the above-mentioned properties of wear-comfort, the initial fabrics without mechanical treatment and the samples after cyclic mechanical treatments were measured. The test of water-vapour permeability was performed on a Sweating Guarded Hotplate M259b (England) and the resistance to water penetration was measured with a Shirley Hydrostatic Head Tester M018 (England). In the present study theyhave attempted to show the dependences of resistance to water penetration of breathable-coated fabrics on cyclic stretching parameters.[11]

Yiwei Du, Ke Li & Jianfei Zhang studied Application of the Water and Oil Repellent Finishing Agent EX-910E in Polyester Nonwovens. In this, the optimal technological conditions that the water and oil repellent finishing agent EX-910E is applied in polyester nonwovens were confirmed. The technological conditions include that EX-910E usage is 40g/l, the bridging agent F-2921E usage is 6g/l, the pre-curing condition is 100× 2/3min, and the curing condition is 160 × 2.5 min. The results of the experiment indicated that the nonwovens finished by the optimal conditions possessed good water and oil repellent effects.

They concluded that, the density and the thickness of the fabrics also influence the evaluation effect of the water and oil repellence. The water and oil repellent effect of white sample cloth was not ideal because of its low density and thin thickness, and comparatively the water and oil repellent effect of pink sample cloth was better because of its high density and deep thickness. The instrument needed by the water repellent evaluation test in the experiment was self-made according to the standards of “GB/T 14577-93 Textiles-Determination of water repellency of fabrics by the Bundesmann rain-shower test”, and it was not standard enough, which would influence the evaluation effect to some extent. The evaluation of the water and oil repellence could not be quantified, and it contained certain subjective factors, which also would influence the evaluation effect to some extent.[12]

VII. CONCLUSION

Based on fundamental principles and design of waterproof breathability fabrics, it can be categorized as, closely woven fabrics, microporous membranes and coating, hydrophilic membranes and coating, combination of microporous and hydrophilic membranes and coating.The technology is continuously evolving in the areas of a cost-effective manufacturing process, improving material formulation to enhance the properties of film and coating material, controlling pore sizes and their distributions, improving characteristics of hydrophilic solid membrane, and developing altogether a new technology (like biomimetic, smart fabrics) for a variety of applications.Nanotechnology is used to engineer fabric that repels water and oil without compromising the natural breathability and comfort of the fabric.

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