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TECHNICAL ARTICLE

Waterproof breathable coating on textiles

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Abstract

Waterproof fabric protects the external factor by preventing the penetration of liquid whereas water-repellent fabric will only delay the penetration of the liquid. Initially, they were coated using animal fat, wax etc. but such coated fabrics are uncomfortable to wear. Comparatively, water-repellent fabrics are more comfortable but at the same time, their water-resistant property is very short-lived. To overcome this breathability was introduced to this kind of fabric to make it more comfortable. The term breathable means properly ventilated. Here, breathable fabric passively allows the water vapour to diffuse and then to prevents the penetration of water through it. Traditionally, the fabric was made waterproof by coating it with a continuous layer of impervious flexible material, but such coated fabrics were very uncomfortable to wear, as they are relatively stiff and do not allow the escape of perspiration vapour. To avoid this problem, the fabric is also made moisture-permeable to increase its degree of comfort. Moisture permeable means to make the fabric breathable. There are numerous benefits of the use of polyurethane to get a waterproof finish. Waterproof breathable fabrics have gained huge popularity in several applications-including outdoor apparels, workwear and sportswear products due to the levels of protection and comfort they provide.

Keywords: Coating, Polyester, Polyurethane, Waterproof, Textiles

Introduction

Conventional garments have become the second skin to the human for protection purposes over time it has become a sign of social as well as a cultural symbol. Clothing that protects against extreme conditions has been used by humans for ages. A person will feel comfortable in a climatic condition only when the energy produced and energy exchanged with the environment is evenly balanced. And this allows the heating and cooling of the body to be within the tolerable limit.

In bad weather, the outerwear must be wind and waterproof because it is always expected that the clothing protects such things. And for this purpose, a water-proof material is usually expected to guard us against rain, snow, and wind completely preventing the penetration and absorption of the liquid water from the atmosphere. Such waterproof fabrics tend to be an excellent barrier between our bodies and humidity. So, it helps to give excellent protection from this kind of element, but they are not able to transport the perspiration through the clothing to the outside causing a person to get wet from inside the clothing.

Clothing as protection is also known as the second skin of human beings. Clothing that protects the wearer from external factors is been used for ages. This kind of clothing helps to prevent the wearer from certain external factors like wind, water, snowfall etc. For such kind of protection from the external factors initially, leather was used which was later replaced by fabric by providing waterproof finishing to it. So, it is expected that the clothing should behave like skin and be comfortable for the wearer.

Generally, the use of natural or synthetic materials or their blend to manufacture different types of clothing is done. Amongst all the fibres Polyester is one of the most common

and widely used synthetic materials. It has achieved this position in the market due to its excellent properties like high strength, abrasion resistance, wash and wear, wrinkle-free characteristics and so on. Its use in apparel and technical textile is limitless. During any physical activity to maintain the body temperature body perspires and if it doesn't escape the wearers' cloth it becomes uncomfortable. A waterproof breathable material combines waterproof properties and moisture permeability in a functional fabric, and it plays an important role in special protective clothing where it will not only prevent the penetration of liquid from the atmosphere but at the same time will allow the water vapour from inside the clothing to the outer atmosphere at the same time [1].

Waterproof breathable fabric

R. Perumalraj, in his article Waterproof breathable fabric, clearly stated that Waterproof breathable fabric is designed to protect from the wind, rain and loss of body heat. The breathable fabric will passively allow the water vapour and prevent the penetration of liquid water for comfortable clothing. It allows the fabric to breathe under extreme conditions by keeping the wearer dry and comfortable while performing any activity. He has clearly explained the need and requirement of such material by clearly giving the example that a normal core body temperature if exceeding the limit while performing any activity can cause adverse effects such as disorientation and convulsions. If the sufferer is engaged in a hazardous pastime or occupation, then this could have fatal consequences. The author explains how these waterproof breathable fabrics will allow the body to remain at the physiologically required temperature by permitting the passage of water vapour from perspiration during the activity [2].

A. Mukhopadhyay and V. K. Midha have stated that the breathability of such fabric is dependent on the temperature gradient across the waterproof breathable fabric, the humidity of the clothing microclimate and the interaction between the waterproof material and the clothing layer. They have explained how conventional waterproof fabric differs from waterproof breathable fabric due to their special property of waterproofness along with breathability. These types of fabric have been developed to minimize the wearers' heat stress by requiring moisture management while blocking the passage of the external water molecules [3].

Characteristics of waterproof breathable fabric

David A. Holmes in his article explains about characteristics of waterproof breathable fabrics in different atmospheric conditions and the difference in their behaviour in the case of different fibres. Through this work, it was stated that the performance of waterproof breathable fabric cannot be judged alone based on atmospheric conditions but also several other factors like durability, and physiology should be considered. The results observed during the studies stated that the main variables like fabric construction and the water vapour pressure gradient which is present in between the fabric faces affect water vapour permeability. So accordingly, the tightly woven fabrics had the highest water vapour permeability values because they had a high ratio of inter-fibre and inter-yarn spaces The coated fabrics were recorded with the lowest water vapour permeability values coating thickness was very high whereas membranes have higher permeability as they are thinner as compared to the coated material. The micro-porous membranes showed higher permeability as they contain physical holes [4].

Factors affecting waterproof breathability of fabric

J. C. Gretton, D. B. Brook, H. M. Dyson, and S. C. Harlock have discussed the factors that are responsible for Water Vapour transmission through the clothing ensemble. They explained that water vapour transmission is dependent on the thermal resistance of the clothing layers as well as their water vapour transport properties. The major purpose of their experimental work was to develop a reproducible method to examine the effect of a temperature gradient on moisture vapour transport through waterproof breathable fabrics and simulated clothing systems. They used the evaporative method based on BS 7209 for exerting a temperature gradient across the sample. It was observed that when a temperature gradient was applied across the single-layer samples, the transport properties of these fabrics improved [5].

Types of water breathable fabric

S Sakthivel, A Zaid Hamza and S D Kiruthika in their article Application of waterproof breathable fabric have explained the different types of method applications and designing of waterproof and breathable fabrics. They have explained different methods, which can be used to obtain fabrics that are both breathable and waterproof. These can be divided into three groups [6].

Woven fabrics

In the 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. The woven fabric is dense with the least quantity of pores and it's treated with a durable water-repellent material for making it waterproof. The pore structure does not allow water droplets to penetrate through the fabric from the outside. On the other hand, fibre fineness combined with inherent moisture absorption and the ability of the fibre to swell with increasing moisture content helps to make it both waterproof and moisture permeable or breathable. Nowadays, man-made fabrics such as polyester, polyamide, acrylic, and viscose are widely preferred for manufacturing tightly woven fabrics. The pores of these tight constructions are very small for water molecules to penetrate through but are at the same time large enough to allow water vapour to pass through.

Membranes

Membranes are thin films made from polymers. There are two membranes that can be used to provide waterproof breathable properties to the fabric.

Microporous membranes

The microporous membranes have very small holes on their surface which are smaller than raindrops but are larger than water vapour molecules. Some of the membranes are made from PTFE polymer, PVDF, etc.

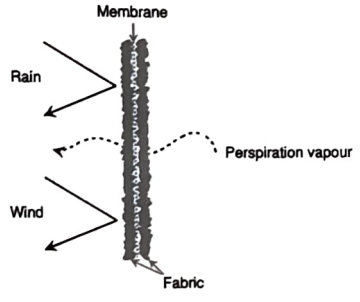

Figure 1: Micro Porous Membrane [6]

Hydrophilic membranes

The hydrophilic membranes are thin films of chemically modified polyester or polyurethane. These polymers are modified by forming an amorphous region in the main polymer system. This amorphous region acts as intermolecular pores allowing water vapour molecules to pass through but preventing the penetration of liquid water due to the solid nature of the membrane.

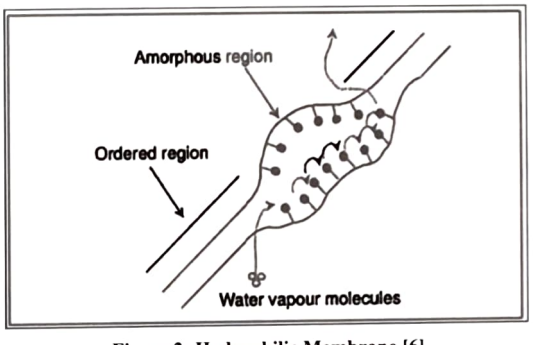

Figure 2: Hydrophilic Membrane [6]

Coatings

Coated fabrics with waterproof breathable fabrics consist of polymeric material applied to one surface of the fabric. These consist of a layer of polymeric material applied to one surface of the fabric. Like membranes, the coatings are of two types; microporous and hydrophilic. These coatings are much thicker than membranes. Contains very fine interconnected channels, much smaller than the finest raindrop but much larger than a water vapour molecule [6].

Supriya Pandit and Smita Bait have discussed powerful tools for the advancement of textile technology i.e., lamination and coating. It helps to produce special kinds of fabrics like water-proof-resistant tarpaulins, coverings, and large tents. But Waterproof breathable fabrics are the ones that will protect the wearer from the harsh weather without hampering their efficiency. The garment is considered breathable and comfortable when it allows the passage of water vapour. Different methods of achieving waterproof-breathable fabrics are mentioned but one of the different methods of achieving waterproof-breathable fabrics is the application of polyurethane paste by coating on the substrate. The principle behind the working of this type of coating is adsorption and diffusion and desorption of water vapour. The study made on this is an attempt to substitute current solvent-based PU emulsion coating technology with water-based PU emulsion because adverse health hazards are caused due Solvent-based emulsion coating causes due to solvent evaporation occurring during the curing stage. Here untreated polyester was taken which was padded with a water-repellent finish for the conduction of the experiment. Later on, Coating technology was used for the application purpose of water-based polyurethane to polyester fabric. Different concentration was used to make a comparative study. The performance of treated waterproof breathable coating was studied and compared with the available commercial solvent-based waterproof breathable fabric and it was observed that Water-based PU emulsions can be a good alternative to solvent-containing PU emulsions. And the effect of variation in PU concentration in coating paste on the breathability of polyester was evaluated and it was found that fabric coated with 95% PU concentration, 150°C curing temperature and 5 min curing time shows the highest breathability, air permeability and waterproof Performa [7].

The durability of textile coatings must be long-lasting. Conventional materials based on either microporous or hydrophilic coatings cannot have the expected durability. The breathable coating materials can be termed smart in which smart technology is used to enhance durability as well as functionality. On the other hand, breathable fabrics based on shape memory polymers are also discussed. The evolving technology behind designing breathable fabrics is continuously achieving improved functionality which is also cost-effective manufacturing processes for a variety of applications the smart breathable coated fabrics based on biomimetic and shape memory polymers are regarded as active smart, and those based on conventional microporous and hydrophilic coatings can be called passive smart [8].

Microporous coating

The microporous coating is very similar to that of a microporous membrane. This type of coating contains very fine interconnected channels which are smaller than the finest raindrop but are much larger than the water-vapour molecule. Ilhan Ozen, in his experimental article, has discussed the work regarding the waterproof breathable fabric which consists of microporous breathable film on the plain/twill weave fabric. To work in the most cost-effective way the fabric was initially treated with a conventional fluorine-based water-repellent finish and later layer structure was generated on it by bringing the treated fabric together with the microporous breathable film. The evaluated results showed that the water resistance achieved was dependent on the weave type and the structure generated. Waterproofing requires filling the pores of the fabric, so waterproofness in densely woven plain fabrics is more as compared to that of twill fabric. So, from this work, it was clearly stated that to resist the water up to the required extent tightly woven water-repellent finished fabric layered with

the microporous breathable film will have more restive properties as compared to a conventional water-repellent finish fabric alone [9].

Hydrophilic coating

The mechanism is the same as that of the hydrophilic membrane the only difference in both is that the membrane passes water vapour through the permanent air-permeable structure whereas the coating transmits the vapour by molecular mechanisms which involve adsorption-diffusion and desorption.

Along with the above consideration, several diverse methods have also been explained on how to create the interconnecting course structure in solid polymer film and coating. These are some of the easiest methods of generating microporous membranes and coating and they are as follows:

- Wet coagulation process
- Thermo coagulation (only for coating)
- Foam coating (only for coating)
- Solvent extraction
- Solubilising one component within the mixture (only for coating)
- Radiofrequency (RF)/ion/UV or E beam radiation
- Melt blown/hot melt technology
- Point bonding technology.[9]

Methods of coating

Fluid coating

In this coating material is in the form of paste, solution, or lattices

- Knife coaters: Wire wound bars, round bars, and so forth. These are posted metering devices.
- Roll coaters: Reverse roll coaters, kiss coaters, gravure coaters, dip coaters, etc. These are pre-metered application systems.
- Impregnators: The material to be coated is dipped in the fluid, and the excess is removed by squeeze roll or doctor blades.
- Spray coaters: The material is sprayed directly on the web or onto a roll for transfer.

Coating with dry compound

In this coating technique, the dry compound could be a solid powder or film.

- Melt coating: Extrusion coating, powder coating,
- Calendaring: It is done for thermoplastic polymers and rubber compounds, the Zimmer process, and Bema Coater.
- Lamination.

The choice of a coating method also depends on several factors:

- Nature of the substrate on which coating is to be performed
- Form of the resin being used for coating and viscosity of the coating fluid
- Product to be made after coating and the accuracy of coating as per requirement
- The process should be economical

Certain important thing related to the preparation of the fabric of coating is also well mentioned. To get trouble and a defect-free coating it is necessary to prepare the fabric first. During coating and lamination, the fabric is heated so the fabric selected for coating purposes should be properly pre-treated involving a heat setting. The fabric must be well set otherwise it may lead to a non-uniform or uneven coating on it. At the same time, it is also important to remove size, waxes, oils, and other hydrophobic finishing chemicals which may cause difficulties during coating [10].

Jianzhong Shao, Chenglong Wang, Jinli Zhou and Lili Wang experimented with using a novel waterproof and moisture-permeable coating agent by modifying a waterborne polyurethane agent with silk fibroin and polyvinylpyrrolidone and the blended agent was applied on polyester fabric using coating technology to achieve a desirable waterproof and breathable effect. Waterborne polyurethane was used due to its nontoxicity, non-flammability, excellent abrasion resistance, and flexibility another one used is polyvinylpyrrolidone or PVP it is a water-soluble polymer, which has good biocompatibility and is used applied as a biomaterial or additive to drug compositions for several years. PVP exhibits excellent transparency along with biocompatible nature. The novel coating agent was characterized by FTIR, SEM, Thermogravimetry and X-ray Diffraction techniques. The evaluation of moisture permeability and water repellence of polyester coated using this novel waterproof and moisture permeable coating agent was made. The results thus obtained showed that the thermostability of the blended film was increased and the compatibility was improved by adding the PVP component, and there was a significant improvement in the moisture permeability and waterproofing of the coated polyester fabrics. An optimized recipe was used to conduct this coating process to achieve the optimum results. It was also observed that the physical and mechanical properties of the coated polyester fabric were not considerably affected [11].

Designing waterproof breathable fabric

Mukhopadhyay and Midha have explained that certain considerations needed to be considered while designing a waterproof breathable fabric [3]. It is stated below

- Waterproofness
- 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 saleability with good adhesion
- Strength of coating
- Good washability /dry cleanability
- Resistance to insect repellents
- Good hydrostatic resistance

Kale et. al. in their article Optimization study for waterproof and breathable polyester fabric in which a study done on polyester fabric was coated with polyurethane formulation along with chlorine with water repellent compound for making water-breathable fabric. The water-repellent properties of the coated fabric were analyzed by measuring water vapour permeability status contact angle hydrostatic pressure and rain test along with the physical characteristics of the coated fabric like its mechanical strength stiffness and crease recovery. And after making a comparative study regarding the performance and the durability of waterproof breathable fabric they got satisfactory results. And on this basis of the study, it was easy to decide on the end-use application as there was a certain limitation of conventional waterproof breathable fabrics. So, to overcome the limitation of the conventional waterproof breathable fabric they coated the material by optimizing the concentration of the chemicals and the other auxiliaries for getting the optimum result [12].

Limitation of the conventional waterproof breathable fabric

Kanjana and Nalankilli G. The review article smart waterproof breathable sportswear: A Review has explained in detail the limitation of conventional waterproof breathable fabric and how we can overcome these limitations for designing waterproof-breathable fabrics. Further explanation was made on the smart coating for sportswear to enhance the efficiency of the wearer without causing any stress Trending technology of smart coating involves the application of PCMs, SMPs, and SRPs which improves the functionality of the material used for the sportswear is mentioned. The future trend for smart coating for sportswear is more likely to be adopted as there is a variety of conventional textile fabrics and novel coating substances thus doors for innovation remain to be opened for such things [13].

Applications of waterproof breathable fabric

Waterproofs are breathable and have several applications. Depending on the activity the efficient material is used. They are used in the clothing industry on a large scale, especially in sportswear, workwear leisurewear, used for making jackets, gloves, hats, rain pants, socks shoes and many more. They are also used in extreme condition or cold places to make the weaver comfortable at such places waterproof jackets are used which protects from both wind and water, used in agrotech for making a ground cover for weed control, packaging material for goods, coverings etc. In medical textiles, they are used for making bed sheets, pillow protectors, stretchers, hygiene products, modern wound dressings, wheelchair cushions, and surgical drapes they provide comfort and repellency at the same time [3, 13].

Conclusion

The above literature summarizes that clothing as protection is also known as the second skin of human beings. This kind of clothing helps to prevent the wearer from certain external factors like wind, water, snowfall etc. Amongst all the fibres Polyester is one of the most common and widely used synthetic materials. Waterproof breathable fabric is designed to protect from the wind, rain and loss of body heat. It allows the fabric to breathe under extreme conditions by keeping the wearer dry and comfortable while performing any activity. These types of fabric minimize wearers' heat stress by requiring moisture management while blocking the passage of external water molecules. The performance of waterproof fabric cannot be judged alone based on atmospheric conditions but also several other factors like durability, and physiology should be considered. The characteristics of waterproof breathable fabrics in different atmospheric conditions and the difference in their behaviour in the case of different fibres. Waterproof fabrics can be manufactured by several different methods. In the 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.

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