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Active Knit Fabrics - Functional Needs of Sportswear Application

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ABSTRACT

Sports textiles are the important arena for the new product development to impart the functional characteristics. The knitted fabric is highly suitable for next to the skin wear, while under low loading conditions it acquires high extensibility which allows it to fit snugly and without discomfort on any form on which it is pulled. With these unique features, the knitted goods are mostly preferred than other fabrics. The sports garments and its protective accessories/wears manufactured from the knitted fabrics have higher functional properties. If there is a change in the wearer's physical activity and external environment, the functional clothing creates a stable microclimate next to the skin of the sports person. The balancing of such a climate is achieved by means of textile structure also. The layered knit fabrics are suitable for functional and technical applications rather than single layer knit fabrics. The double and multi layered knit fabrics are used in sports for their unique transmission characteristics such as water vapor permeability, air permeability, thermal conductivity and moisture management property.

Keywords: Sports textiles, water vapor permeability, air permeability, thermal conductivity and moisture management property

1. Introduction

The 7% of the world market is sports textiles in technical textile market. The last five years, Rapid grown in global retail industry –Sports apparels is expected to reaches approximately US $125 billion in 2017 with a CAGR of 6% over the next five years.[41] Increase in demand the sports apparel industry to boost the market and also include the technological innovations. The two different raw materials hydrophobic and hydrophilic textile materials are used to develop the functional knitted structure to produce the leisure wear, sportswear which improves the comfort of the wearer. The types of fibers play an important role for the sports product development. The sum of the mass of the dry fiber and the addition of mass of the water is the mass of the textile fiber. Owing to absorption the fibers become swell. This is because of the entry of water molecular between the tightly packed molecules in the fiber. Most of the available intermolecular spaces are long and narrow so

the swelling of the fiber take places in fiber width direction. The change in dimension is in the width wise direction is varied for the textile fibers. The noncircular cross sectional view of a number of textile fibers, the change in cross sectional area of the cotton is better measure than change in diameter. The volume change is also linked to the water that has been absorbed by the cotton fiber. So the swelling of the cotton increases with increase in relative humidity in atmosphere[1].

There are many methods to combine the hydrophobic and hydrophilic textile fibers in fabrics. A new product was invented by the authors [2] with high absorbent fabric. The fabric consists of larger stripes of hydrophobic and lesser hydrophilic stripes on the entire surface of the fabric were produced. So, the absorption of the moisture is high. The spun and filament yarns of same linear density are used for the production of moisture management knitted fabrics by the principle of alternate filament and spun yarn courses knitting by Miller & Cravotta [3]. The polypropylene fiber alone is not suitable to the design of the clothing for the active leisure and sportswear [4]. The wetting degree of the polypropylene fibers is very low; the surface tension force of the water drop maintains their shape. So the surface of the fiber is not moistened by the water and there are no possibilities of transporting the moisture drops to the outer layer, where it is absorbed by the natural fiber in the fabric assembly.

The functional knitted structure of two different fabric layers based on different textile components (hydrophobic and hydrophilic textile material) is used to produce leisure wear, sportswear and protective clothing to improve the comfort. The separation layer is polypropylene in contact with skin and the absorption layer will be the outside layer as cotton is used for the knit fabric [5]. The desirable characteristics required for the functional sports and leisure wear are as most favorable heat and moisture regulation, quick moisture/liquid absorption and transport capacity, good air and water permeability into the clothing, preventing the long term feeling of dampness, low water absorption in the skin by the layer next to the skin, rapid drying of clothing fabric to prevent the spread of cold, pleasurable to skin, non-abrasiveness and non- roughness, stable in its dimension even if the fabric is in wet, sportswear to be durable, light weight and easy care, soft and pleasant touch of clothing and other wears, functional design and smartness [6].

The designing of knitted clothing for sports is a very important one. The permeability properties of the sportswear fabrics depend on various factors. The single jersey fabrics were developed with Dref-III friction spun yarn. If one factor is constant (sheath percentage / fiber fineness / yarn fineness) when the value of other two factor increases the air permeability and water vapor permeability of the fabric increases and the fabric thermal conductivity decreases [7]. The single jersey, single pique and double pique knitted structures were produced by author Elena Onofrei [8] using the combination of plain, tuck and float stitches in the structures. The fabric permeable properties such as air permeability, water vapor permeability, thermal property and moisture management properties are studied and found that the single jersey structure is selected for summer garment for moisture management property. The dual layer knitted fabrics were produced for excellent thermal insulation and breathability by the authors to develop the underwear and sportswear garments for outdoor games. The fabric consists of first inner layer as a hydrophilic yarn of wool and/or wool/silk yarns and second layer or outer layer, the hydrophobic yarn of polypropylene is used to bind the first and second layer of the fabric to produce dual layer fabric [9].

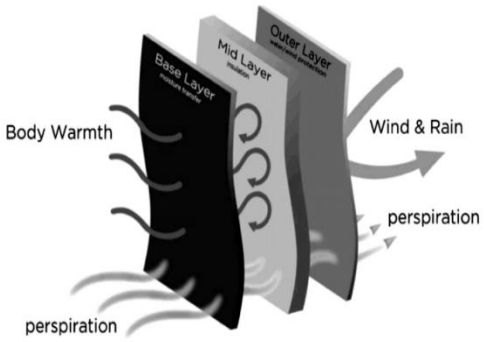

Figure 1. Multi-layer Clothing system,

Two principles primarily govern the design and engineering of the sportswear, i.e. application of compression on specific muscles to increase blood flow and application of principles of aerodynamics to reduce wind or air drag in high speed sports. Both principles can be used in combination or individually, depending on the requirements.[10] Technologically advanced knit fabric also used in sports application. The men's polo ($85) is constructed with 3-D knit fabric, which is engineered one and Dri-FIT fabric. This kit fabric have superior sweat wicking and comfort. The new Luxe raglan polo ($75) is designed for women's sportswear. This new fit polo has modern look, ventilation and good mobility through designed fabric panels. The combination of aesthetic and performance is given by hyper warm apparel. A thermal mapping identified area provides optimal warmth, constructed with different knit density. The Dri-FIT fabric is used in specific area to protect overheating and wick the moisture for comfortable[39]. The aerodynamic drag is also an important factor in sports because wind or air resistance is reduced through a number of mechanisms such as manipulation of surface morphology of the materials reducing air and/or water permeability of fabric; and altering shape of patterns and placement of seams and fasteners on the clothing. Even a small reduction in wind or water drag can result in a significant performance increase in speed sports [10].

2. Utility Characteristics of Fabrics

The term utility characteristics are defined as the changes in the comfort fit and wearing functions of the garment when the fabric engages a thermal, mechanical, electrical, or chemical force during the utilization of the garment. All the mass forces in the fabric such as liquids, gases, and solids are termed mechanical forces. The hand characteristics have been derived from the types of mechanical forces with respect to fabric characteristics. There are two types of utility characteristics such as transformation and functional characteristics. The transformation characteristic of the fabric is that it changes the property of the fabric. The dimensional properties of the fabric are altered without demolishing the fabric. The changes which disintegrate the fabric are termed durability characteristics. The transmission of mass or energy through the fabrics is termed the transmission characteristics. The transmission of mass or energy is from the one surface of the fabric to the other surface of the fabric. Air permeability (includes all gasses and vapors), moisture transmission, heat transmission (thermal conductivity) and light permeability are the transmission characteristics [11].

3. Water Vapor Permeability of Knit Fabrics

The important phenomenon in a physiological comfort is the ability of the clothing to transport water vapor from the body. The sweat from the body is to be removed from the surface of the skin to the atmosphere via clothing (next to skin). When the sweating is stopped from the skin, in order to reduce the humidity on the surface of the skin the textile fabric should release the vapor held in the atmosphere [12]. The water vapor permeability indicates the quantity of water vapor that has been moved through a unit area of the fabric in a certain point in time, as a result of the pressure gradient between the two sides of the sample. The measurement of water vapor permeability is a slow and somewhat delicate operation.

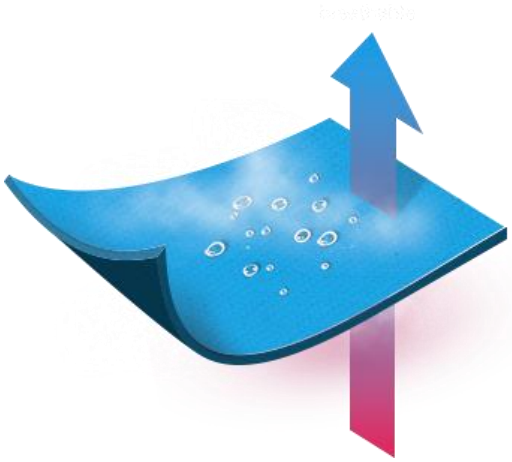

Figure 2. Breathable sports fabric,

The water vapor permeability of textile assemblies are evaluated by different methods, such as the dynamic moisture permeable cell in ASTM F 2298, the inverted cup method, the upright cup method in ASTM E 96-66, the desiccant inverted cup method in ASTM F 2298, the control dish method in BS 7209, and the sweating guarded hot plate method knowing as the skin model in ISO 11092 [13]. The testing of water vapor permeability of the fabrics is done by the team is based on the evaporative dish method (Turn table equipment) based on the British Standard, BS 7209 that was used to determine the water vapor permeability (MVTR) of layered knit fabrics [14].

The quantity and the rate of humidity absorption of double layer knitted fabric depend on the fibers used in the fabrics [12]. The water vapor permeability of the 100% cotton fabrics reduces with time because of swelling behavior of hygroscopic fiber. The swelling phenomenon of the cotton materials, because of moisture absorption, blocks the pores in its structure. So the swelling phenomenon affects the vapor transmission by diffusion over the time period. The result of water vapor permeability index through cotton reduces with time [15]. The vapor diffusion of air is higher than textile material. The air has 0.239 cm^2/sec, and the cotton has 10^{-7} cm^2/s and 10^{-9} cm^2/s for polyester [16].

The fabric characteristics and its structure play an important role on the water vapor permeability property. The fabrics made from the same yarn are compared. The property of water vapor permeability depends on the functions of the fabric thickness, density of the fabric and fabric bulk density [17]. Prahsarn et al [18] studied the effect of fabric thickness, density, porosity and fiber-cross section on moisture vapor transport properties of the fabric. The various polyester fabrics differing in construction, yarn type, and fiber feature are taken for the research work and found that the fabric construction has a dominating influence on moisture vapor transport behavior especially in low density open textile structure. The fabric thickness serves as an important factor since it determines the distance through which the moisture vapor and heat pass in traversing from one side of the fabric to the other surface of the fabric. The structure used in the knit fabric influence the water vapor permeability of the fabric but not in the same order as air permeability. The kind of raw materials in the double layer knit fabrics is an important factor. The fiber wetting and wicking properties also influence more. The authors reported the fiber composition and structural parameters of double layer knits on the water vapor permeability in their study, it is impossible to predict the water vapor permeability using yarn area linear filling rate [12].

4. Air Permeability of Knit Fabrics

The air permeability of the fabric, the ability of air to flow through the fabric is determined. It is a biophysical feature of the textile. The Textest FX-3300 air permeability tester is used by the author for the testing of air permeability of the fabric according to the standard ISO 9237 [17]. Another standard methods to test the air permeability of the fabric is Standard EN ISO 9237:1997 and ASTM D 737-75 [20] [7].

The air permeability of the fabric is inversely proportional to the specific area of the fiber diameter. The knit fabric produced with finer yarn has more number of fibers in the cross section. When available surface area of the resultant yarn cross section increases the air permeability of the fabric reduces [19]. The flow of air through the

textile structure is mainly affected by the characteristics of pore in the fabric. Many factors influence the pore dimension of the fabric. The pore distribution in the fabric and the dimension of the pore is a function of fabric geometry. The main factors affecting the porosity of the fabrics are the yarn linear density, yarn diameter, course density and wale density. And the air permeability of the fabrics depends on the finishing treatment given to the fabric. As per the application of the fabric, the air permeability is an important one. The designing of garment and protective wear in the sports the air permeability characteristics is desirable [12].

The thickness of the fabric is one of the influencing factors, which determine the air permeability of the fabric [20]. The air permeability of the fabric also depends on the loop length of the fabric. The assessment of porosity of double layered knit fabric fraught with the structural parameter. Loop length is used to determine the pore size of knit fabric. When the loop length increases, the pore size in the fabric also increases. When the pore size/length of yarn in the loop increases the air permeability of the fabric also rises. The loop length is a common rate for the comparison of similar pattern of the double layered knit fabrics. But in the different pattern of the fabric the loop length may not be used for the common rate for the comparison purpose. Here the pore size depends on the length of the yarn in the loop. When the length in the loop increases the empty area also increases, which widen the pore size and permits air inside. So when the comparative fabrics have different pattern the yarn area linear filling rate is used to predict the air permeability of the fabric. The influence of the surface porosity on air permeability is significant [12].

The layered fabric made of outlast and coolmax materials are compared for the air permeability of these fabrics. The outlast layered fabric shows higher air permeability. This is because of the lower thickness of the fabric. There is an increase in resistance to air flow in coolmax fibers. This is because of higher surface area of the fibers, so the lower is the air permeability [17]. The knit fabric structure has the greatest influence on the permeability property of the fabric. The air permeability of the fabric is based on shape, value of the pore and number of channels in between the threads. In comparison to various derivative structures of plain and rib, the moss stitch and full cardigan fabrics have higher permeability to air [21].

In many sports clothing, the relative air velocity around the body surface is significant by the travelling speed. So the wind accelerates the heat loss from a warm surface. In order to reduce the micro climate cooling the surface layer of the body should provide high resistance to air penetration or lower air permeability. The outer garment of the sports clothing ensembles, preferably made with low air permeability fabric. The body heat loss by the wet fabrics and layers reduces insulation. In particular, the outer garment surface layer should be waterproof or water repellent [22].

5. Thermal Property of Knit Fabrics

Fundamentally, the heat transfer process through the fabrics is the thermal conductivity. The thermal resistance value of the fabric is measured along with the relative water vapor permeability by using the Permetest instrument. The permetest instrument consists of measuring head. This measuring head is heated up to the 35˚C (core temperature of the human body). The ambient condition was maintained (25˚C temperature, 65% RH and 1.6 m/s air velocity) [23]. The Alambeta instrument also used to evaluate the thermal properties of the fabric. ISO EN 31092-1994 standard is followed in the evaluation of the thermal properties of the textile structure by the researchers with the measuring head temperature in the instrument maintained approximately 32˚C and the contact pressure of 200 Pa [17]. SASMIRA thermal conductivity equipment also used to measure the thermal conductivity of the fabric in ASTM 1518-77 [7]. The measurement of heat transmission in particular direction is very difficult, because the heat dissipates in all the direction in the fabric. The tog meter and guarded hot plate methods are used to

overcome the above problem. The two plate tog meter and single plate tog meter are used in practical.

The air in the textile structure is the most important factor for the thermal conductivity. Still air has the lowest thermal conductivity value when compared to all the textile fibers (λ air = 0.025). So the air transports the very low quantity of thermal energy by conduction and reduces the thermal conductivity of the fabric [17]. The investigation of heat exchange process in the knitted fabric is influenced by the knitted fabric structure and raw material used. The thermal conductivity of natural fibers has higher values than protein fibers. The thermal conductivity (W/(m K)) for the cotton fiber in Longitudinal direction is 2.88 & Transverse direction is 0.243. The thermal conductivity (W/(m K)) of the polyester filament in transverse (KT) is 0.157 and longitudinal (KL) is 1.26 [24] [25].

The heat transport performance of the sports clothing is very important. The fabrics used in the sports are to maintain the body temperature during the activities. The sportsman can feel cooler in summer and warmer in winter due to the heat transport properties of the fabric used in the sports. The fibrous materials used in the sports textiles; due to its bulkiness as air is entrapped within the fabric. This affects the heat transport properties of the sportswear. The moisture transport performance of the sportswear is improved by changing the cross section of the fibers used in the clothing and by usage of special chemicals in the fabrics. The fabrics made of such special chemical and fibers keep the body dry by transporting the vapor/liquid form the body surface to the atmosphere [6].

During heat transmission through the fabric, decreases the heat conduction of the fabric when increases the thickness and surface mass of the fabric [26]. The available specific area is proportional to thermal conductivity of the fabric [19]. The yarn characteristics and fabric structure affect the thermal conductivity of the materials to a great extent. The thermal resistance of the fabric is not only dependent on the thickness of the fabric also by the fiber thermal conductivity. The surface characteristics of the fabric/texture also have the great influence on the cool/warm feeling of the garment [17]. As Nida Oglakcioglu & Arzu Marmarali [27] reported that the thermal conductivity values increase from single jersey, 1x1 rib and 1x1 interlock fabrics of cotton and polyester.

In flat knitting machine 1×1, 2×2 and 3×3 rib fabrics were knitted with three yarns per feeder. The slack, medium and tight knitted rib fabrics were produced. As the fabric gets denser or tighter, it decreases the heat loss due to decreasing the convective heat loss because of decrease of air circulation through the fabric. The other one increases the heat loss due to increased conductive heat loss because of increased conductivity. The air entrapped in the fabric is less and has more contact between the fibers. The slack, medium and tight knitted fabric natural and forced convection heat transfer coefficient increases, when the tightness factor of the fabric increases. The fabric become tighter, the heat lost through the fabric is decreased, due to lesser air permeability. When increase is in order of rib from 1x1 to 3x3 the heat lost decreased. Owing to the increase the air entrapped in the fabric, increases the conductive heat. The air entrapped between the face and back loop of the rib fabric decreases when the rib number increases to 2x2, 3x3, 4x4. This is because of the increase in the curvature due to increase in rib number of the fabric. When rib number increases the heat lost by the fabric also increases. The heat lost in the fabric, due to fibers and air gaps is more important than air circulation [28].

The knitted fabric structure is the main influencing factor for the heat interchange/ exchange process. The plain plated fabric transmits the heat faster through the fabric as compared with the combined structure. Combined structure is produced from the double bed knitting machine. The loops are produced from two beds so the loops are arranged in two layers and connected in random places. So, the amount of air in the combined knitted fabric is greater

as compared to plain plated fabric. Because of higher amount of air in the fabric structure the heat transfer process is slower. Here the air acts as an insulator in the fabric. So this type of fabric is not suitable for winter seasons [29]. In multi-layer systems, the thermal resistance is mainly based on the heat-insulating layer. The thermal resistance value of the heat-insulating layer in the combination of multi-layer system is based on the fabric thickness [30].

6. Moisture Management Property of Knit Fabrics

The human body produces moisture in the form of perspiration; it should be removed from the surface of skin to the fabric of the next-to-skin clothing. The fabrics should allow moisture in the form of sensible and insensible perspiration to be transmitted from the body to the atmosphere in order to cool the body. After the body has stopped sweating, the textile fabric should release the vapor held in the atmosphere in order to reduce the humidity on the surface of the skin [31]. For achieving the satisfactory comfort level of the wearers, the degree of contact of the fabric to the skin, types of fibers used in the fabric are the major ways to change the surface alteration.

The fabrics made with differences in fiber, influences the dynamic surface moisture level. The dynamic surface moisture occurs in relatively low surface value and act in a way to reflect the instantaneous change that occurs because of microclimate and exercise [32]. The fiber morphology, nature of the raw materials (hydrophobic or hydrophilic), yarn characteristics, some extent fabric characteristics and structure are the essential factors for the behavior of diffusion ability. The fabric thickness and its cover are other influencing factors for the water diffusion ability. A less dense and thinner fabric improves the diffusion ability. The special morphology structure of the fiber and the raw material (hygroscopic nature) promote the water diffusion ability. And the characteristics of the fabric and the structure can contribute significantly to improve further diffusion ability of the fabric and the amount of water up-take [17].

The water content changes with respect to time on the fabrics top (Ut) and bottom (Ub) surfaces. The water content of the top surface is lower than that of bottom surface of the fabric. This indicates that the water introduced in the top surface is quickly transferred to the bottom surface of the fabric. Based on the water content changes measurement phenomenon in between top and bottom surface of the fabric, one of the moisture management index is called accumulative one-way transport index (OWTC). This one way liquid transport capacity is an important one in transmission property of knit fabrics for sports application. High OWTC values, show the liquid in the wet surface of the fabric its quickly transports to next surface of the fabric as stated by Nilgun Ozdil & Gamze Supuren [33] and Junyan Hu et al [34].

The two set of plated fabric were produced by the authors, a) the polyester trilobal on knit face and functional fiber yarns on back of the face, b) the polypropylene on knit face and same functional fiber yarns on back of face. The distribution of capillary pores and surface tension of the pathways determine the drying behavior of the fabric. The polypropylene face knitted fabrics are inferior in wicking ability but better in drying compared to polyester face knitted fabric [35]. The speed of the liquid spreading and the area of the liquid depend on the structures in the fabric and raw materials used in the fabrics too. The most effective moisture removal from the body surface is with the special profile polyester fibers as compared to polypropylene, polyamide and ordinary polyester. The garment produced from this fiber gives dry feels in the human body. The largest area of the liquid spot in the outer layer of the fabric means, the moisture will vaporize most rapidly.

In weft knitted fabrics the dynamics of a liquid spot of combined knit structure is faster than the plain weft knitted plated fabrics reported by Bivainyte & Mikucioniene [4]. The most important factors influencing the liquid spot dynamics

are the raw material, the wale density, course density and structure of the fabric. The type of floats stitches lie between loops and the arrangement of natural/man-made yarn stitches/loops in the inner and outer surface of the knit fabrics. In steady dynamics of spot area condition, the liquid spot on the inner and outer surfaces of the fabrics made from cotton/synthetic combination is greater than the manmade bamboo/synthetic combination fabrics. The greater area of the liquid spot means the knitted fabrics will dry rapidly. The researchers found in their study, that the liquid spot spread area on the plain plated fabric and combined structure is similar in size. The only difference between the fabrics is the rate/speed of the spreading of the spot on the surfaces of the fabric.

The ribbed surface structure of the fabric demonstrated the highest water intake capacity and best initial water wicking rate. This behavior is most probably the capillary system in the fabric, removing and transporting water through the structure. The in-plane wicking ability of the fabric is low in high thickness fabrics [17]. The pores in the structure become open which reduces the liquid water travel through the pores [36].

Garments made of plant branch structured knit fabrics shall facilitate the transport of sweat from the skin to the outer layer of the fabric very fast and make wearer more comfortable. The knit fabric with larger pore size in the middle layer fabric improves the wicking property of fabric. The grouped yarn in the back of the fabric can increase the initial water absorption rate; this is because of faster water absorption in bimimetics of plant structures. The type of yarn and stitch density of the fabric in front & back influence the liquid water transport in the fabric. But the interaction of the structure and yarn types does not influence the water absorption rate. The effects of various yarns and the interaction between the structure and types of yarn are highly significant in one way transport capacity of the fabric. The compactness of the knit fabrics is affected by the yarn's linear density. The summer wear or sports wears used has the desirable lower air resistance, which improves the sweat evaporation at the skin and fabric surface through the penetration of cold air in to the fabric [37]. The team of researchers found that there are different categories of yarns used in the outer and inner layer of the multi-layer fabrics, which influences the moisture management properties of the fabrics [38].

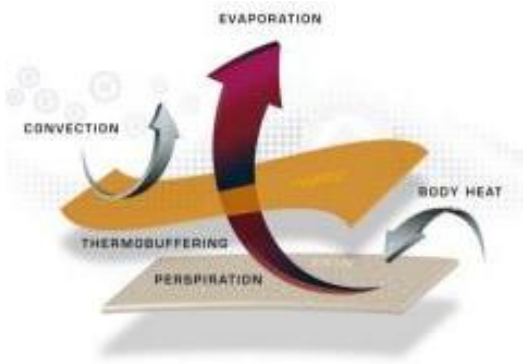

Figure 3. Moisture management fabric,

7. Conclusion

The utility attributes of knitted sports clothing, the above mentioned transmission characteristics are influenced by the various aspects in fiber, fabrics and technologies involved during manufacturing. So the selection of knit fabrics for the new design/development of sports products in this field of sports textiles involves technological approach. The layered knit fabric provides exclusive comfort to the spots persons and evolves rapidly.

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