Recent Development in Textile for Sportswear Application

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***Abstract*—In the recent time, all over the world there has been an increase in the participation of active sports. In the highly competitive world of sports has given more number of professional sports persons. In addition, the people also consider sport as a vital part of their day to day activity, as it helps directly to keep them physically and mentally fit. Both the quality and quantity of the active sportswear being consumed globally has increased enormously. Special properties are incorporated in garments using specialized fibres, yarns, engineering design of fabric with various chemical finishes. In a textile preferable used for sport application, moisture and heat management are the key issues that have to be ensured for appropriate thermo-physiological and tactile comfort. Waterproof breathable fabrics can be made for sport textiles application by polymeric coating, lamination, or woven fabric with high cover factor. Today's sports textile is a highly engineered material to maximize the physiological and psychological comfort by the enhancing the moisture management, while taking into consideration of health, hygiene and pleasant feel. The recent developments in the polymers, fibres, fabrics, and finishes used in various active sportswears have been discussed in details.**

Key words: Textile, Sport textile, New Fibres, Comfort

I. INTRODUCTION

In the last three decades there has been a significant increase in the participation of various active sports all over the world. Healthier lifestyles are leading to the greater sports participation. Recently more numbers of sports have been invented and also many of the old sports have been again popular. The highly competitive world of sports has increased awareness among the professional sports persons, who use to demand more specific functions to be performed by sportswear in real time to increase their efficiency [1]. Design of active sportswear is still a subject of research to the academician and industrial profession. To fulfil the demand of the existing and up-coming market, the new fibre, fabrics and finishes are to be developed to satisfy specific requirement of each sport. In this context, man-made fibres have enlarged the sphere of application of these products from the simply apparel clothing to high-tech sport textiles owing to the high potential for scientific creation. The products mentioned, later development concept, technical characteristics, and performance capability, were verified in the some international games, like Olympic [2]. In the first half of 20th century sportswear was not scientifically designed due to the non-availability of speciality fibres. However, later on designing of sportswear has received scientific inputs by utilizing the knowledge synthetic polymer, fibre, fabric, finished, and smart garment design for advanced sportswear suitable for specific application [3]. In textile means for sports, 'performance' has become key issues related to moisture management, temperature regulation, stretch, light weight, wind and water resistance and low frictional surface. A numbers of technological progresses have been made in the past to develop speciality polymer with micro-porous to hydrophilic characteristic, speciality fibres with different shapes and diameter, and single to multi-layer fabrics with different weave structure to improve the fabric comfort and functionality [1]. New consumers of sport textile are emerging that can be categorized into three groups, namely, (i) children, (ii) over 55-age group, and (iii) women, who are involved in aerobics and competitive sports.

II. TECHNICAL REQUIREMENTS OF SPORT TEXTILE

The requirements for an active sportswear can be as classified in two groups, namely (i) *Functional*- light weight, low fluid resistance, high tenacity, strechablility, thermal regulation, UV protection, vapour permeability, and sweat absorption and release, and (ii) *Aesthetics*- softness, surface texture, handle, lusture, colour, and comfort. Apart from these general requirements, sportswear has to perform other functions activity related to a specific sport [4-5]. The required functions to be performed by the different types of sportswear are listed in Table1

III. CLOTHING PHYSIOLOGY AND COMFORT

Clothing physiology is the mechanism of interactions between the human body and the clothing to provide information on the physiological properties of the clothing [1]. Clothing physiology is expressed in terms of comfort, performance capability and the health of the wearer.

TABLE 1: Requirements of sportswear [1]

Different sports	Functional requirement
Shirts for tennis, volleyball, golf (+slacks), football, rugby, baseball uniform, athletic (+shorts), track suits	Sweat absorbing, fast drying, cooling
Skiwear, wind breakers, rain wear	Moisture vapour permeability, water proofing, vapour permeability, water proofing
Skiwear, wind breakers, track suits	Sunlight absorbing and thermal retention Low fluid resistance
Swimming race and skating costume, ski jump and downhill skiing suits, cycling costume	Low fluid resistance for water and air
Swimwear, leotards, skating costume	Stretchability, opacity
Snowboard wear, baseball uniform, football uniform	High tenacity, resistance to abrasion, stretchability

Clothing can be considered to be physiologically appropriate, when it functions correctly during the actual use. The human body has a temperature of 37 °C and it is generally maintained under all the circumstances. During the physical activity in sport, the body temperature goes up and reversely the body gets cool down due to the removal of moisture vapour during the perspiration. To control the body temperature exceeding the comfortable value, the produced heat must simultaneously be dissipated through single or multilayer layers of the fabric. The human body can also produce half a liter to a liter perspiration per hour depending upon the sports activities is being taking place and the textile has to take care of it and it should not be impeded by the surrounding relative humidity. It is not the heat of the body, which causes problems to the wearer, but the hot and humid micro-climate causes uncomfortably situation. Therefore, the moisture vapour should have engineering pathway to pass immediately from the skin to the outer surface of the clothing. Four types of clothing comforts that are essential for active sportswear are (i) thermo-physiological comfort, (ii) sensorial/tactile comfort, (iii) mobility, and (iv) psychological comfort.

(i) Thermo-physiological comfort

Thermo-physiological comfort is exist, when a person in thermal equilibrium i.e. the rate of heat loss from the body is equals to the rate generated heat by the body due to the metabolic action. If the rate of heat loss is insufficient, the person will feel hot and humid resulting heat stress. On the other hand, if the rate of heat loss is too high, the person will feel cold. Therefore, textile has to be designed in such as way that it would allow optimized water vapour, while maintaining required thermal insulation.

(ii) Sensorial/tactile comfort

The sensorial comfort does not have directly relation with the temperature balance, but it is mainly related to the feeling of a person, when the clothing is worn next to the skin. Wet feeling and wet cling are the major source of sensorial discomfort in situations of profuse sweating. If the skin is wet due to the low moisture transport, an unpleasant feeling would occur as the clothing next to the skin will stick to the body.

(iii) Mobility

During the various physical activities in active sports, considerable movements of body parts happened. Therefore, sportswear must provide sufficient degree of mobility so that wearer can do their activity smoothly without any obstacle. In this regard, too much voluminous, weight, or stiff fabric is not suitable for active sports application as they reduce the mobility of the fabric as well as the person.

(iv) Psychological comfort

The feeling of the wearer that he or she is dressed in a means the psychological comfort. This is mainly related with aesthetic appeal from the point of view of style or fashion. It does not have any active role in functional performance. From the top-level professional sport person to amateurs, all like psychological comfort to some extent along with above three functional comforts.

IV. MOISTURE AND SWEAT MANAGEMENT IN SPORT TEXTILE

The mechanism by which moisture is transported in textiles is similar to the wicking of a liquid by capillary action [4]. Capillary action in a porous material is governed by the

two fundamental properties, such as diameter of the pore and surface energy of the material. The smaller the diameter of pore or greater the surface energy of the material, facilitates in better capillary action. In textile structure, the spaces between the fibres in yarn structure effectively form capillaries. The application of micro-size fibres helps in formation of narrow capillaries resulting effective moisture transport. The surface energy of textile material is governed largely by the chemical composition of the fibre forming polymer in addition of surface texture of the fabric.

Moisture management in textiles during the intense physical activities is the key challenges that need to be addressed to ensure maximum all round comfort to the sportsman [4]. Principally, the comfort characteristic of the clothing is influence by the wetness or drying of the fabric and thermal condition in that particular micro-climate. As a result of this, the sport garments worn next to skin should have good sweat absorption, transmission, and desorption properties. In moisture management, some of the textile manufacturers claim that absorbent fibres, like cotton or viscose is important as they could easily absorb the liquid moisture. While the others say, the fibres for sports application should not absorb moisture and it should allow rapid wicking by capillary action. In this context, the synthetics fibre are preferred over the natural fibres, like cotton, ramie, flax etc. as they do not retain moisture and keep the garment dry and lighter in wet condition. Also wet synthetic fibres are dried faster due to their lower liquid absorbency.

V. WATERPROOF BREATHABLE SPORT TEXTILE

Waterproof breathable fabrics are designed for use in garments that provide protection from the foul environments, like wind, rain, and loss of body heat [4]. Waterproof fabric completely prevents the penetration and absorption of liquid water, while allowing air and moisture vapour to go through it. Therefore, it is important to design such advanced textile structure and finished with suitable chemical so that it will remain breathable without reducing the comfort properties. Waterproof breathable textile can be developed by three technologies, such as (i) high density fabric, (ii) polymeric coating, and (iii) film lamination.

(i) High density fabric: The densely woven waterproof breathable fabrics consist of cotton or synthetic microfilament yarns with high cover factor weave structure. In this regard, finer natural fibre or micro-denier synthetic fibre are most suitable as they can reduce open space either in the yarn or fabric structure. The well-design waterproof breathable fabric known as "VENTILE" was manufactured by using long staple cotton fibres by minimizing the gap between the fibres. Generally, combed yarns with oxford weave are preferred to prevent the penetration of water droplet. When such fabric is wetted in contact of water, the cotton fibres swell transversely reducing the size of the pores in the fabric structure. This helps to develop waterproof fabric and still it is breathable as moisture vapour could easily pass through the inter-fibres and/or inter-yarn spacing due to their smaller in size compared to water droplet. In this process, there is no requirement of water-repellent coating. Similarly, highly dense woven fabrics can also be produced from the micro-denier synthetic filaments yarns with individual filament diameter of less than 10 micron.

(ii) Coated fabrics: The coated fabrics with waterproof breathable functionality are generally produced by coating the one or both sides of the fabric with a polymeric material. Polyurethane is most commonly used in such application. The coatings are of two types: (i) micro-porous membranes (ii) hydrophilic membrane. In micro-porous membrane, the coating contains very fine inter connected channels that are much smaller in size than the finest raindrop, but larger in size than that of water vapour molecules. Hydrophilic membrane is also the similar type of material, however the difference between the micro-porous and hydrophilic membrane is in the former, water vapour passes through the air-permeable channels, whereas in the later water vapour passes by the mechanism of adsorption-diffusion and de-sorption.

(iii) Film laminated: The laminated waterproof fabrics have been made by the application of membranes into textile product. These are thin membrane made from polymeric materials that offer high resistance to water penetration, while allowing water vapour to go through it. The maximum thickness of the membrane is 10 micron. They are mainly, (a) micro-porous membrane of poly-tetrafluoroethylene (PTFE), and poly-vinyldene fluoride PVDF, and (b) hydrophilic membrane is made of poly (ethylene oxide) constitutes.

VI. ANTIMICROBIAL FINISHING OF SPORT TEXTILE

The demand for antimicrobial clothing is surging as the consumers are more aware about their health and hygiene in addition of adverse effect of micro-organisms to human body. Anti-microbial finished textile plays an important role in lowering down the psychological discomfort associated with foul odour in textile due to the microbial growth and skin infections caused by fungi. They also create a power-full barrier against the spread of antibiotic resistant bacteria, which are responsible for hospital-related infection. Antimicrobial textile products are expected to grow in the coming years, as it increases the longevity of the product and give pleasant feel. Antimicrobial textile need to exhibit high degrees of performance in terms of odours neutralization and skin related problems. This is important as during the sport activity significant amount of sweat is produced and temperature is also increased, which is a very much favourable condition for microbial growth. Bacteria and fungi can cause deterioration of ranges of textiles materials, leading to loss of performance, ageing, staining, unpleasant odours and potential skin infections. The antimicrobial textile thus helps in reducing the cross-infection by stopping microbial growth and increases the performance of a sport man. Antimicrobial agents used to treat textiles fall into two categories, known as "static" and "cidal" categorized based on their leaching action [6]. Presently, a large number of antimicrobial agents are available in the market to make the textile antimicrobial, antibacterial and

antifungal. In the last two decades, due to the rapid growth of nano science and technology, various metal nanoparticles have been synthesized and applied in natural as well as synthetic textiles to impart non-durable to durable antimicrobial functionality. Some of the well-explored nanoparticles for textile use are silver (Ag), ZnO, TiO_2, and CuO. Similarly various aromatic and medicinal plants have also been explored for antimicrobial finishing of textiles in an environment-friendly manner. Plant molecules, like chitosan, aloe-vera, neem, tea oil, eucalypotus oil and tulsi leaf extracts showed excellent antimicrobial efficacy on various textile substrates [7-9].

VII. UV PROTECTIVE FINISHING OF TEXTILE

UV protective finishing of textiles is important as it can cause skin ageing, sun burns, weak immune system, sun-tanning, photocarcinogenesis and even, skin cancer. In the past, various chemicals, such as silicate and metal nanoparticles, such as TiO_2 and ZnO have been explored for imparting UV protective finishing on textiles as they are nontoxic, environmentally friendly and low in price. The UV radiation is categorized in three zones based on their wavelength namely, (i) UVC (200-280 nm), mostly absorbed in the ozone layer, (ii) UVB (280-320 nm), penetrates the top layer of skin and causes skin ageing, sunburn etc., and (iii) UVA (320-400 nm), penetrates through the skin and causes skin ageing. Therefore, in UV protective finishing, the textile has to be designed and finished in such a way as to block the transmission of UVA and UVB. The UV protective performance of a textile is defined by the ultraviolet protection factor (UPF). Any textile having the UPF value of ≤ 10 is considered as no protection from UV radiation. On the other hand, if the fabric is having the UPF value of ≥ 50, it is considered to be an excellent UV protective textile. The UPF value of a fabric depends on the fabric properties, such as weave, yarn count, areal density, thickness and chemical parameters, such as the type of dye molecule present, chemistry of fiber, and the type of finish imparted. Erdem *et. al.* investigated the effects of nano-TiO_2 on the UV-protective and structural properties of polypropylene (PP) filaments [10]. The PP/TiO_2 nanoparticles composite were prepared by melt compounding. Filaments were loaded with 0.3, 1, and 3% TiO_2 nanoparticles. The UV-protective properties of the PP filaments were improved after treated with TiO_2 nanoparticles. The wash durable UV protective cotton textile has also been developed using TiO_2 nanoparticles without using any binder or cross-linking agent [11]. The nano-sized ZnO particle has also been explored for similar application by the Kathirvelu *et. al.* [12].

VIII. RECENT DEVELOPMENT POLYMERS FOR SPORTS APPLICATION

(i) Phase change material (pcm)

Phase change material, such as paraffin is used to produce microcapsules. When, the capsules are heated, the paraffin liquidifies and heat energy is stored. Later on, when the environment cools, the paraffin crystallizes/solidifies release the stored heat. The paraffin with various melting points known as phase-change material (PCM) was developed by Triangle Research Development Corp., Research Triangle Park, N.C., for the use in astronauts' gloves as part of the NASA Space Shuttle program. In 1997, Damart, France-based manufacturer was the first company to offer a thermo-regulating jacket made of a fabric containing the capsules for absorbing and releasing the heat. As the paraffin can be formulated with different melting temperature, therefore the warmer paraffin is used for skiing and other cold weather sports, while the cooler paraffin is used for biking gear, mountaineering, and footwear [13].

(ii) Shape memory polymers

A special suit based on a membrane employing shape memory polymers (SMPs) was developed for Swedish sailor. The suit, designed employs the Diaplex smart fabric technology that is completely waterproof, windproof and breathable. This material can remember and retain its shape, or return to its previous form in the change of environment. A garment made from Diaplex is able to sense changes in surrounding environment, evaluate the condition intelligently, and responses accordingly to ensure the high level of comfort. Micro-Brownian motion occurs within the Diaplex membrane, when the temperature goes above the predetermined value and the micro-pores get created that allow water vapour and heat to escape [6].

(iii) Membrane technology

Airvantage system by the W.L. Gore is the first producer of personal thermal climate management system for clothing. The principal of this kind of fabric is creating the air pockets as air is well known poor conductor of heat. Airvantage membrane, specially developed for the construction of permanently airtight and breathable chambers is based on the poly-tetrafluoroethylene technology of Gore Tex. Two laminates are bonded together to make airtight and breathable. And air chambers in this garment are adjusted using a valve. By blowing of air into the chambers significantly improves heat retention (thermal insulation) to provide warmer feel, while releasing the trapped air from the chambers helps in releasing the excess body heat [6].

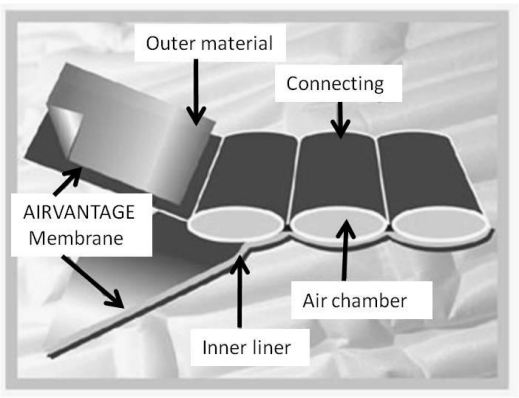

Figure 1: Membrane technology in sports textile application

IX. RECENT DEVELOPMENT FIBRES FOR SPORTS APPLICATION

As discussed above, mostly synthetic fibre based textiles are used in sport application due to their advantages of better moisture management and can be tailor made in fibre shape. Developments in synthetic fibres have opened up enormous avenues for their use in sportswear to meet the specific function [1,4]. In active sportswear single fibre is seldom used. Mostly speciality fibres are used in conjunction with natural fibres and some of the recent developments are mentioned below.

Hygra : Unitika Ltd. has launched Hygra fibre, which is a core-sheath type of filament yarn composed of fibre made of water absorbing polymer and nylon. The water-absorbing polymer has a network structure that can absorbs 35 times its own weight of water and offers quick releasing properties, which a conventional water-absorbing polymer can not do. On the other hand, nylon core provides the required strength and dimensional stability. Hygra also exhibits superior antistatic properties even at low wet conditions. The main apparel applications include sportswear, like athletic wear, skiwear, golf wear etc.

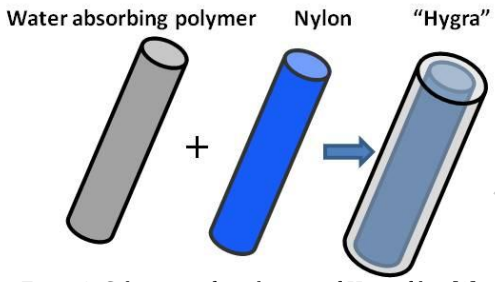

Figure 2: Schematic of mechanism of Hygra fibre [1]

Dryarn : Dryarn is the new fibre from Aquafil. It is a completely recyclable polypropylene microfibre. The fabric made of Dryarn is light in weight and comfortable. In addition, it has a soft handle, high thermoregulatory capacity and also dries quickly. The other advantage is the bacteria can not settle on smooth polypropylene fibre surface that avoids development of unpleasant odour associated with bacterial growth.

Killat N : Killat N from Kanebo Ltd. is a nylon hollow filament. The hollow portion is about 33 percent of the cross section of each filament. It provides good water absorbency and heat retentive property. The yarn is spun as a bi-component filament with a soluble polyester copolymer as a core material and nylon as a sheath material. After spinning of fibre, upon alkali treatment polyester copolymer in the bi-component filament gets dissolved and hollow fibre is produced. This hollow portion helps in capillary action for liquid transport and warm feel due to air pocket.

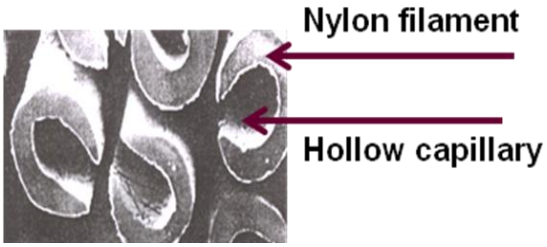

Figure 3: Cross sectional view of Killan N fibre [1]

Triactor: Toyobo Co. Ltd. has developed Triactor, which is a perspiration absorbing/quick drying polyester filament. Polyester is hydrophobic in nature and does not absorb moisture. However, when the cross-section is changed from circular to Y shape, it exhibits faster release of perspiration by capillary action. At the same time, hydrophobic surface and large filament surface area also facilitate in faster drying of perspiration.

X. RECENT DEVELOPMENT FABRIC STRUCTURES FOR SPORT APPLICATION

(i) Soft shells

The products made by company soft-shells are almost suitable for all kinds of leisure activities. These products are air-permeable, light in weight, wind resistance, and stretch fabric constructions resulting very suitable for "next-to skin" application. Four types of Soft-shell fabrics are available namely, (a) Ultralight: woven fabrics with a synthetic outer and cotton inner layer, (b) Efficient: double weave fabrics with synthetic outer and functional inner layer, (c) Warming: synthetic outer and wool inner, and (d) All-in-one: Schoeller WB-400 fabric consists of synthetic outer layer and drivers lining variants sandwiching a functional coating.

(ii) Naiva

Unitika has developed Naiva fabric by combining the Naiva yarn and nylon microfibre. Naiva is an Eval/nylon bi-component filament yarn, where Eval is nothing but a copolymer resin of ethylene vinyl-alcohol. Naiva yarn composed of 55% Eval and 45% nylon. In the Naiva fabrics, there are many nylon micro-loops on the surface, which are formed by high thermal shrinkage property of Naiva yarn. Naiva fabric not only has good moisture permeability, but also it is light in weight and softer in feel. This kind of fabric is very suitable in mountaineering wear and other active sportswear [4].

(iii) Field Sensor

Field Sensor is a very popular high performance fabric from Toray, which is a multilayered structure. It not only absorbs perspiration quickly, but also transports to the outer layer of fabric rapidly by capillary action. It is composed of coarser denier yarn on the inner surface (next to skin) and fine denier hydrophobic polyester yarn in a

mesh construction in the outer surface to ensure quick evaporation of sweat [4].

(iv) Nanotechnology in sport textile

Nano-tex company has several products among those the latest ski-jacket has nano-tex coating to make the two-layer laminates grime resistance as well as wind-proof, water-proof and breathable. It provides better durability of finish than the traditional repellent coating, while allowing the fabrics to retain its soft feel and breathability [6]. It helps to develop superior product quality using a little amount of chemical

CONCLUSION

Performance apparel represents one of the fastest growing sectors of textile and clothing. Market growth is being happened by the emergence of new polymers, fibres, fabrics construction. Among the various end application of textiles, sport textiles are important due to the change in human lifestyles. Recently, people consider sport as a vital exercise in their day to day life to keep them self physically and mentally fit. Demand of active sportswear is increasing among the (i) children, (ii) over 55-age group, and (iii) women, who are involved in aerobics and competitive sports. A well design sport textile should meet the four comfort properties, such as are (i) thermo-physiological comfort, (ii) sensorial/tactile comfort, (iii) mobility, and (iv) psychological comfort. This could be achieved by proper management of moisture vapour and air permeability, while ensuring the required thermal insulation. An engineered sport textile has been developed by utilizing the knowledge of polymer science and textile science. Due to the production of significant amount of sweat during sport activities, the temperature and humidity increases in the micro-climate resulting microbial growth. Therefore, anti-microbial finishing of textile is also essential. To control temperature and permeability of moisture vapour, water proof breathable textile has been developed by (i) high density fabric, (ii) polymeric coating, and (iii) film lamination. Similarly, synthetic fibre has been tailor made by changing the fibre cross-section from circular to Y and C shapes. Single to multi-layer fabric has also been designed by utilizing different fibres in the outer and inner layer of the fabric.

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