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Comfort Properties of Textiles: A Review of Some Breakthroughs in Recent Research

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Abstract

The article critically reviews the recent research trends related to comfort characteristics of fabrics. The comfort properties of fabrics are of sensorial and non sensorial nature. Many researches have focussed on these aspects. Comparative studies on cotton and cotton/polyester blend fabrics woven in various designs have shown that cotton fabrics exhibit better comfort properties than their blend counterpart. Active sports wear is one area where comfort is crucial. In this regard the comfort properties of different bi layered knitted structures made from outer layer comprising of tencel yarn and inner layer of acrylic/microfiber polyester. Such an investigation is intended to largely help the researchers who are analysing the comfort characteristics of layered knitted fabrics for sports wear. Utilization of recycled polyester in the knit apparel industry is ever increasing but the characterization of knit apparel made from recycled polyester yarns is limited to mechanical and moisture management properties.

Hence the thermal comfort properties of single jersey knit fabrics made from recycled polyester and cotton blended yarns have been investigated. A special design clothing based on sombrero effect by inclined wedge providing shadow on the base material has been proposed and investigated analytically to improve the thermos physiological comfort under dry and hot environment. Such an investigation offers a new design concept to engineer the clothing surface to reduce heat load under dry hot radiation and the mathematical model forms a basic framework for analytical modelling the heat mass transfer in such systems.

Keywords: Fabric comfort; Electro physical properties; Properties; Thermal behavior; Recycled; Polyester; Microclimate; Subjective assessment

Introduction

Intensive growth of world population indicates the need of making clothing fabrics that comply with the requirements of a large number of consumers. It is not enough for clothing fabrics to have only a good painting, colorful solution and durability. The fabrics should also have good comfort properties. According to the literature1, there are two aspects of clothing comfort, viz sensorial and non-sensorial. Sensorial properties such as fabric handle, compression properties, electro-physical properties and frictional properties describe the performance of a fabric on skin contact. Non-sensorial comfort is not only comprised thermal and moisture transmission but also includes air permeability, water repellency and water resistance. From the survey of literature, it is evident that a large number of studies are devoted to determining both sensorial and non-sensorial properties of fabrics [1-9].

In textiles due to continuous changing preference, product diversification becomes one of the crucial issues for a visible economic activity. The evolution of synthetic fibres, which have many advantages over cotton in certain aspects like durability and elasticity, has revolutionized the textile production [10]. As a result of this change in raw material utilization, combined with an enormous increase in energy and chemical demand, the world is now facing an ecological crisis. Further, the ever decreasing petroleum reserves all over the globe have compelled the textile manufacturers to look for alternate sources for raw materials, which are friendly to environment and biodegradable. Polyester and cotton account for 40% and 35% of global clothing industry respectively. Polyester is a petroleum-based synthetic fibre and relies on the utilization of non-renewable resources.

The stringent environmental requirements coupled with people's increased awareness on environmental friendly practices have facilitated the development and utilization of eco-friendly practices. Recycling of materials is considered to be eco-friendly and post- consumer polyethylene terepthalate (PET) bottles are recycled using mechanical and chemical processes [11-15]. Deserts constitute nearly 7% of the land area of the globe and hot dry deserts and semi-deserts are living place of nearly 6% of global population. The typical air temperature ranges there between 35 °C and 55 °C and relative humidity of air remains less than 40%; often becomes 4 - 10%. The heat flux of solar radiation during noon can become 750W/m2 or even more. The clothing used in these extreme climates must give sufficient protection from direct exposure to sun and provide thermo-physical comfort to the wearer who is generally exposed to dangerous intense solar radiation and high air temperature during the day.

It is well known that the nomadic population in sub-tropical desert regions use special style of clothing but a scientific investigation of the various design factors of clothing for such application is not reported often. Human body has a typical core temperature of 37 °C, and the skin has a typical temperature of 33 °C - 34 °C under normal condition [16]. In active sports, the performance of sportswear is identical with its comfort characteristics. The important quality decisive factor that affects performance, efficiency and well-being of sportswear is the wear comfort [17]. Any physical activity will produce different levels of the need to release excessive heat and maintain a stable body temperature [18-19].

Relating Fabric Quality to Comfort Properties

Although the electrical properties of woven fabrics have been studied for a long period of time, this topic still leaves many opportunities for various researches, especially when it covers the comfort of clothing fabrics. Since textile materials are in continuous contact with consumer bodies during their use, it would be necessary to investigate an appearance of static electricity which creates unfavorable effects like increased dirt, cleaning problems and increased tendency of materials to form the rolled-up ends of fibres on their surface. Created static electricity in textile material may also lead to sticking to textile fabrics for the consumer bodies or other textile materials, creating an unpleasant sensation when wearing these clothes [20].

These unfavorable effects are especially pronounced in synthetic textile fabrics with extremely high electric resistances, and low values of relative dielectric permeability [21-26]. For these reasons, the tendency of textile materials to produce static electricity might be considered the most important single criterion of comfort. The sensory aspect of textile comfort, like handle of clothing material, is getting more priority in the quality evaluation of fabric [27,28]. One of the most important indicators of fabric handle is softness which can be judged through the change of fabric thickness under the influence of compression load. Magnitude of compression load generated in the textile material and how it is distributed on the skin influence human perception of fabric softness and fabric comfort quality.

In addition to the above, air permeability is also considered as an important comfort property of the fabric. It determines the ability of air to flow through a given area of the fabric [29,30]. Air flow through textiles is mainly affected by the pore characteristics of fabrics. If there is no possibility of air flow through the pores of the fabric or the flow is difficult, very soon it will cause feeling of discomfort. For this reason, air permeability might be considered as a feature of fabric which has a great contribution in overall clothing comfort. Due to the well-known tendency of textile materials to produce static electricity, which causes unpleasant sensation on the skin, an attempt has been made to study the quality of clothing woven fabrics primarily through their electro-physical properties, such as volume resistivity, effective relative dielectric permeability [31].

In order to get a complete picture of the comfort quality of investigated fabrics, compression properties such as compressibility, compressive resilience, and air permeability have been studied. Values of monitored characteristics were used for establishing the level of quality of clothing woven fabrics with regard to their comfort properties by the application of ranking method. Findings of the study show that the cotton fabrics are characterized by lower values of the volume resistivity as compared to fabrics that have been produced from cotton/PES fibre blends. Also, it is found that the volume resistivity increases with the decrease in humidity that can be ascribed to decrease in the moisture content of the textile samples.

The effective relative dielectric permeability increases with the increase in relative humidity, hence woven fabrics with the highest moisture contents generally have the highest values of effective relative dielectric permeability. The results show that the air permeability depends on the porosity of fabrics with very high coefficient of linear correlation (0.9807) between the air permeability and the porosity. Concerning compression properties, cotton fabrics exhibit better compressibility, but worse compressive resilience compared to cotton/PES fabrics. Besides, it has been noticed that all investigated comfort properties of woven fabrics are determined by the raw material composition, type of weave as well as fabrics surface condition.

Application of ranking method indicates the fact that the cotton woven fabric in satin weave has the best comfort properties and cotton/PES woven fabric in twill 3/1 weave has the poorest. Also, the group of cotton fabrics has better characteristics of comfort in regard to the group of cotton/PES blend fabrics. Studying the relationship between fabric structure and clothing comfort as well as variation in parameters of fabric structure enables to obtain a woven material as per the demand of textile market in terms of required comfort properties.

Comfort Properties of Dyed Cotton/Mildewed Blended Rotor Yarn Fabrics

One such hitherto less investigated lingo cellulosic fiber is the seed fiber obtained from Pergularia daimio, naturally growing drought and pest resistance tree of Indian origin, well known for its medicinal values [31,32]. The plant Pergularia Dalmia belongs to the family of Asclepiadaceous and genus of Pergularia and comes under the milkweed fibres. The milkweed flowers are grown as milkweed pod which contains the seed attached with the fibre or floss which is filled with tiny hollow tube-like structures that act as insulators [33-37]. Like cotton, it is a single cell fibre, but unlike cotton, it is free from convolutions and has low cellulose content [38,39]. Due to its very smooth surface, spinning of 100% milkweed fibre is difficult. Because of its short length, milkweed floss has been blended with cotton and processed to develop yarns in ring and rotor spinning systems [40,41].

The studies conducted on spinning of milkweed fibre blends showed that spinning of pure milkweed fibres is not practically

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possible due to the inherent characteristics of the fibre and could be able to spin with other fibres after suitable chemical modification of fibres. Further, the properties of milkweed blended yarns are found to be inferior to 100% cotton yarn [42-44]. This study explores the dyeability of cotton/milkweed rotor yarn fabrics with reactive and natural dyes and comfort properties of cotton/milkweed blended yarn fabrics [45].

Comfort Properties of Blend Weft Knit Fabrics

Mechanical recycling is basically a melt extrusion process and chemical recycling aims at the reduction of plastic polymers into various levels like oligomers or monomers by reaction with certain chemical agents. Blending of various fibres is a familiar practice in the textile industry. Blending aims at enhancement of the properties of resultant fibre mix and optimizes the cost of raw materials [46].

Polyester/Cotton (P/C) fibre blending displays higher durability and easy care properties than 100% cotton [47]. Of late, recycled fibres are supplemented with the addition of virgin polyester fibres and/or cotton in order to achieve enhanced properties, aesthetics and functional values [48,49]. Researchers have successfully studied the blending of recycled PET flakes with virgin PET chips [50-55]. Recycled polyester blended yarns were successfully produced by ring, rotor and friction spinning [56-61]. Knit fabrics are commonly preferred in sportswear, casualwear and innerwear due to their outstanding comfort properties, extensible loop structure, light weight, warmth, wrinkle resistance and easycare properties [62]. Plain knitting amounts to 90% of all knitted fabric consumption globally [23,63]. Growing awareness on eco-friendly practices has expanded the production of knitted goods with the inclusion of recycled fibres and their blends [24,64].

Comfort is typically defined as "the absence of displeasure or discomfort", or "a neutral state compared to the more active state of pleasure [25,65]". Clothing comfort can be classified into four categories, namely psychological, thermo-physiological, sensorial (tactile) and garment fit comfort [26,66]. Psychological comfort relates to the sensory perceptions and fashion trends, thermo-physiological comfort is governed by movement of air, moisture and heat through the fabric, sensorial (tactile) comfort depends upon fabric surface and mechanical properties and garment fit comfort depends on the fit (loose/normal/tight) of the garment on the body. Of these four types of comfort, thermal comfort has drawn the attention of numerous researchers due to significance of maintenance of thermal balance at various atmospheric conditions Literature suggests that thermal comfort depends on a wide variety of parameters such as fibre properties, yarn properties, fabric properties, finishing (mechanical and chemical) treatments and clothing conditions [27-40,67-70]. Thermal comfort can be best understood by the measurement of thermal conductivity, thermal resistance, air permeability and relative water-vapor permeability.

Utilization of recycled polyester in the knit apparel is ever increasing but the characterization of knit apparel made from recycled polyester blended yarns is limited to mechanical and moisture management properties. Choi and Kim [41] have characterized the mechanically recycled PET, chemically recycled PET, PET-nylon 6 blend and virgin PET knitted fabrics and found that tensile, compressional and pilling properties of both mechanically and chemically recycled PET knitted fabrics were similar to that of virgin knitted fabrics and wick ability of mechanically recycled PET knitted fabric was better than other recycled PET knitted fabrics and recycled PET–nylon6 blend knitted fabric possess good moisture regain, moisture permeability, smoothest appearance and coolest feeling [71].

The primary objective of the present study is to investigate the thermal comfort properties of single jersey knit fabrics made from recycled polyester and cotton blended yarns. To fulfill this objective, effect of recycled polyester fibre content, linear density and loop length on thermal comfort properties has been studied. It is found that the recycled polyester blend ratio, loop length, linear density have significant influence on single jersey fabric's thermal comfort properties. It is observed that with the increase in recycled polyester ratio, fabric becomes thinner, lighter and more porous with higher thermal conductivity, air permeability, relative water-vapor permeability and lesser thermal resistance.

Similarly, increase in linear density results in thicker, heavier and less porous fabric with higher thermal conductivity, lesser air permeability and thermal resistance and high relative water-vapor permeability at medium linear densities [72]. Loose structure results in thinner, lighter and more porous fabric with higher thermal resistance, air permeability and relative water-vapor permeability and lesser thermal conductivity. Optimum blend ratio, linear density and knit structure can be suitably designed to meet the thermal comfort requirements of various ends uses.

Innovative Design Concept for Providing Comfort in Hot Arid Climate

The tolerance of the thermo-physiological system in case of human is narrow and therefore care must be taken to respect such narrow tolerance and maintain thermo- physiological comfort by ensuring an optimum heat flow across the skin. An ordinary human being can be considered to be in a thermo-physiologically comfortable state when the average outward (or cooling) heat flux across his skin from body core to environment is around 90-120 W/m2. This net heat flux is generally a function of the metabolic condition, environment condition along with the design and properties of the clothing. The body generally loses heat due to pure heat convection transfer and sweat evaporation associated with free convection (when air temperature is lower than the skin temperature), or due to forced convection, when a human walk with common velocity (3 - 4km/h), which is around 1m/s.

The radiation loss from the body is largely compensated by the incident scattered radiation from surrounding and the net balance depends on the temperature of the surrounding. The

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heat gained by the body is primarily due to the metabolic heat generated inside, the convective heat transfer from air to skin when air temperature is higher than skin and radiation incident on skin, particularly direct radiation from hot sources such as Sun. Clothing must act as an engineered system which can impart the net heat balance towards the direction necessary so as to maintain a comfortable heat flow as mentioned above. The role of various design parameters of clothing on the thermal comfort and protection provided by clothing ensemble has been the topic of scientific research for a reasonable time. For example, the effects of apertures, air gaps and reflective layers have been studied experimentally [2-7]. Manikins are generally used for such purpose. A number of empirical models for clothing comfort has been proposed as well. Only a few of them have discussed the role of radiation and hot climate on the overall heat-mass transfer through clothing. Shkolnik et al [8]. reported their studies on the effect of different dress styles and coolers on the net heat transferred through the clothing to skin surface under real conditions in a desert.

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