CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Comfort may be defined as a pleasant state of psychological, physiological and physical harmony between a human being and the environment. All the three aspects are equally important, since people feel uncomfortable if any one of them is absent. Comfort is not a property but a condition of mind. The human mind responds with various degrees of satisfaction to the ever changing environment. This perception includes the effect of clothing between body and environment. A number of properties of fibres, yarns, fabrics and garments are significantly related to comfort and must be taken into account in producing apparel items.

Fabric properties depend on fibre properties, yarn structure, fabric structure and the mechanical and chemical finishing treatments given to the fabric. Of the various fibre properties, fibre type, fineness, cross sectional shape, crimp, length and surface properties are extremely important. Yarn structure governs the yarn properties produced from a fibre with a given set of fibre properties. Type of yarn like filament yarn, textured yarn and spun yarn produced on different spinning systems, twist level, unevenness and hairiness of yarns have a significant influence on comfort and other properties of fabrics. Fabric structure includes yarn linear densities, sett, weave, crimp levels and can influence such critical fabric properties like thickness, cover, bulk density, mechanical and surface behaviour which have direct relation with fabric comfort opine Mehta and Narrasimham (1987).

Wetting is important for textile processing and performance. The comfort of clothing made from cellulosic fibers is closely associated with moisture
absorbency opines Wong et al., (2001). The term wetting is usually used to describe the displacement of solid air interface with solid liquid interface. Wetting behaviour is commonly characterized by the value of the contact angle within the liquid. The absorption of water (or of any other liquid) by a textile is largely determined by two parameters. The first is the surface energy of the fibre materials, and second is the capillary effects of the yarn suggest Mahltig and Textor (2008). A droplet of wetting liquid spontaneously wicks into the yarn due to the capillary forces associated with the given structure and geometry of the void spaces between the filaments remarks Chen et al., (2001). According to Harnett and Mehta (1984) ‘wettability’ is the initial behaviour of a fabric, yarn or fibre when brought into contact with a liquid. It also describes the interaction between the liquid and the substrate prior to the wicking process.

A spontaneous transport of a liquid driven into a porous system by capillary forces is termed wicking because they are caused by wetting; wicking is the result of spontaneous wetting in a capillary system. Wetting and wicking are two related processes. A liquid that does not wet fibres cannot wick and wicking can only occur when fibres assembled with capillary spaces between them are wetted by a liquid. Fibre wettability is therefore a prerequisite for wicking states Kissa (1996).

Wicking transports the moisture away from the skin, using the capillarity transport mechanism. The ability of the fabric to wick depends on the surface properties of the constituent fibres and their total surface area. All regenerated cellulosic fibers have the same chemical composition, but they differ in density, molecular mass, polymerization degree, molecular arrangement and the degree of crystallization. This will have a significant effect on the absorption properties and the mechanical properties (www.mindfully.org).

Sorption refers to the action of either absorption or adsorption. As such it is the effect of gases or liquids being incorporated into a material of a different state
and adhering to the surface of another molecule. In crystalline region, the fiber molecules are closely packed together in a regular pattern. Thus it will not be easy for water molecules to penetrate into a crystalline region, and, for absorption to take place, the active groups would have to be freed by the breaking of cross-links.

Capillarity can be defined as the microscopic motion or flow of a liquid under the influence of its own surface and interfacial forces in the narrow tubes, cracks and voids. The surface tension is based on the intermolecular forces of cohesion and adhesion. When the forces of adhesion between the tube and the tube walls are greater than the forces of cohesion between the molecules of the liquid, then capillary motion occurs quote Sharabaty et al., (2008). It is a phenomenon in which the surface of a liquid is observed to be elevated or depressed where it comes into contact with a fabric (www.answers.encyclopedia.com).

Various parameters, such as fibre structure, morphology, molecular weight and its distribution, fibre strength, fineness, crystallinity and orientation influence wicking of fibres. Regenerated cellulosic fibres are hydrophilic in nature with better feel and similar higher moisture absorbency leading to good comfort in wear.

A flow involving more than a single phase is classified as multiphase or nonhomogeneous such as liquid flows in porous fibre media. The dynamics of such flow are dominated by surface tensions, porous media anisotrophy and nonhomogenity, fibre volume fraction, and fibre wetting behaviour. The uncertain structural conditions in fibrous media, including the susceptibility to even small loads, as well as the tortuous connectivity of their open pores and poorly defined boundaries, result in complex local nonhomogeneous flows and interfacial evolution remarks Hentschel (1994). This complexity in many case becomes prohibitive for the development of analytical theories describing these phenomena.
The wetting and wicking of fibre mass constitute a class of flows that have critical scientific and practical significance on which technologies such as fibre lubricating and processing fibre-reinforced composite manufacturing and fibre web bonding and dyeing are based. Wetting and wicking behaviour of many consumer products such as baby diapers, female hygiene products and sport and other protective garments are critical in determining their commercial success suggest Lucas et al., (2004).

1.2 LUCAS - WASHBURN THEORY

For both scientific and practical purposes, the so-called wicking (or absorbency) rate is of great interest. The European Disposables and Nonwovens Association (EDANA) and The International Nonwovens and Disposables Association (INDA) recommended tests to measure the vertical speed at which the liquid is moving upward in a fabric as capillarity of the test material. The vertical rate of absorption is measured from the edges of the test specimen strips suspended in a given liquid source. The resultant report of the test contains a record of capillary rising heights after the time of 10, 30 and 60sec (and even 300 sec, if required). Gupta (1997) defined the absorbency rate as the quantity that is characterized based on a modification of the Lucas – Washburn and then he modified it to apply to a flat, thin circular fabric on which liquid diffuses radially outward.

Miller and Friedman (1992) introduced a technique for monitoring absorption rates for materials under compression. Their Liquid/Air Displacement Analyzer (LADA) measures the rate of absorption by recording changes of the liquid weight when liquid is sucked into a flat textile specimen connected to a liquid source.
A more scientific definition of the wicking rate is based on the Lucas-Washburn theory. This simple theory deals with the rate at which a liquid is drawn into a circular tube via capillary action. Such a capillary is a grossly simplified model of a pore in a real fibrous medium with a highly complex structure opines Berg (1989). Theory is actually a special form of the Hagen-Poiseuille law state Landau and Lifshitz (1988) for laminar viscous flows. According to this law, the volume dV of a Newtonian liquid with viscosity µ that wets through a tube of radius r and length h during dt is given by the relation

\[
\frac{dV}{dt} = \pi r^4 \frac{p_1 - p_2}{8h\mu}
\tag{1.1}
\]

where \( p_1 - p_2 \) is the pressure difference between the tube ends. The pressure difference here is generated by the capillarity force and the gravitation. The contact angle of the liquid against the tube wall is denoted as \( \theta \), and the parameters \( \beta \) is the angle between the tube axis and the vertical direction. The capillary pressure \( p_1 \) has the value

\[
p_1 = 2\gamma \cos \theta / r
\tag{1.2}
\]

While hydrostatic pressure \( p_2 \) is

\[
p_2 = h \zeta g \cos \beta,
\tag{1.3}
\]

where \( \gamma \) denotes the liquid surface tension, \( \zeta \) is liquid density, \( g \) is the gravitational acceleration, and \( h \), in this case, is the distance travelled by the liquid measured from the reservoir along the tube axis. This distance obviously is the function of time, \( h = h(t) \), for a given system. When we substitute the quantities \( p_1, p_2, \) and \( h(t) \) into equation (1.1), expressing the liquid volume in the capillary \( V \) as \( \pi r^2 h \), we obtain the following Lucas–Washburn equation:

\[
\frac{dV}{dt} = r \gamma \cos \theta / 4\mu h - r^2 \zeta g \cos \beta / 8\mu
\tag{1.4}
\]
For a given system, parameters such as \( r, \gamma, \theta, \zeta, g, \) and \( \beta \) remain constant. We can then reduce the Lucas-Washburn equation (1.4) by introducing two constants,

\[
K' = r \gamma \cos \theta / 4 \mu \quad \text{and} \quad L' = r \zeta g \cos \beta / 8 \mu
\]

into a simplified version,

\[
\frac{dh}{dt} = \frac{K'}{h} - L'
\]

The above relation is a nonlinear ordinary differential equation that is solvable only after ignoring the parameter \( L' \); this has a physical interpretation when either the liquid penetration is horizontal \((\beta = 90^\circ)\), or \( r \) is small, or the rising liquid height \( h \) is low that \( K'/h \gg L' \) or \( L' \to 0 \), and the effects of the gravitational field are negligible and the acceleration \( g \) vanishes. The Lucas–Washburn equation (1.6) could thus be solved with ease:

\[
h = \sqrt{2K't}.
\]

The result satisfies the initial condition \( h = 0 \) for \( t = 0 \).

Now we turn our attention back to Gupta’s approach to the wicking rate remark Zhong et al., (2002), where a fluid from a point source in the centre of a substrate spreads radially outward, instead of the ascending liquid front in a fibrous substrate partially dipped into a liquid as illustrated.

It is now useful to transfer the Lucas–Washburn equation into a modified version by replacing the distance \( h \) with liquid mass uptake \( m \). Such a transition is described in detail by Ford (1993) and Hsieh (1995). This manipulation does not influence the fundamental shape of equation (1.7) because the relationship between \( h \) and \( m \) is linear for a circular tube of fixed cross section. Furthermore, for the radial spreading, liquid mass is \( m_r = \pi h^2 T \zeta V_L \) and the ascending liquid
front \( m_A = w h T \, \zeta \, V_L \), where \( T \) is the thickness of the substrate and \( V_L \) is the liquid volume fraction inside the substrate of width \( w \).

For the radial spreading in a flat textile specimen, we can then write using equation (1.7)

\[
Q = \frac{m_R}{t} = 2\pi K'T \, \zeta \, V_L \tag{1.8}
\]

where \( Q \) is the liquid wicking (absorbency) rate used by Gupta (1997), which is independent of time during the spreading process.

Let us now substitute liquid mass uptake \( m_A \) into the original Lucas–Washburn equation (1.6), with the result as follows:

\[
d\frac{m_A}{dt} = \frac{K}{m_A} - L \tag{1.9}
\]

The new constants \( K \) and \( L \) are

\[
K = (w T \, \zeta \, V_L)^2 K', \quad L = w T \, \zeta \, V_L L' \tag{1.10}
\]

It is obvious that the constant \( K \) in the modified Lucas–Washburn equation (1.9) is proportional to the wicking (absorbency) rate \( Q \) that is defined in (1.8) and from (1.8) and (1.10), it follows that \( Q = 2\pi/ w^2 \, T \, \zeta \, V_L \times K \). Hence, the parameter \( K \) can be used as a measure of the spreading wicking rate \( Q \) in the experiments when a fabric is hung vertically into a liquid. The values of \( K \) and \( L \) can be derived from the slope and intercept of the \( d \, m_A/dt \) versus \( l/ m_A \), as mentioned in Miller and Jansen (1982).

On the other hand, equations (1.6) and (1.9) can be solved in terms of functions \( t(h) \) or \( t(m_A) \) without dropping the gravity term \( g \), suggest Lucas and Soukopova (1999). For the liquid mass uptake Lucas-Washburn equation (1.9), one obtains for the ascending liquid front the relation

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\[ t(m_A) = -\frac{m_A}{K} - \frac{K}{L^2} \ln \left(1 - \frac{L}{K} m_A \right) \]  \hspace{1cm} (1.11)

Conversely, however, we are unable to acquire the inverse solution, \( m_A(t) \), using the common functions.

The Lucas–Washburn approach presents an approximate tool to investigate the wicking and wetting behaviour of textiles despite their complicated, noncircular, non uniform and nonparallel structure of the pore spaces.

In the field of liquid sorption in a porous area, Washburn (1921) has expressed the following equation:

\[ H = C t^{0.5} \]  \hspace{1cm} (1.12)
where \( H \) is the wicking height (m); \( C \), the capillary liquid transport constant. The above equation shows that the capillary force causes the progress of liquid through a capillary channel. This capillary force depends upon the radius of capillary channel and the contact angle between liquid and capillary channel as well as rheological properties of the liquid.

Ring spinning is an old technology, first patented in 1828. Nevertheless, it is still the most popular spinning technology. The spinning is carried out on spinning frames, each of which may contain up to 500 spindles. Ring spinning machine further attenuates the material coming in from the roving process by roller drafting until the required draft is obtained. Simultaneously, the yarns are twisted to gain strength. This process requires two types of labour: spinners who set up the roving supply (out of the roving process); and doffers, who remove the filled bobbins from the spinning frame and replace them with empty ones.
Twist is primarily introduced into a staple yarn in order to hold the constituent fibres together, thus giving strength to the yarn. As twist is increased where the strength of the yarn reaches a maximum value, after which the strength is reduced as the twist is increased still further.

The problem of moisture transport through yarns is crucial for many applications like bed sheets and towels. During the last five years, a number of papers were published on wicking of yarns obviously to study the potential of various spinning technologies from which they have been produced. Wicking behaviour of yarns was studied by Nyoni and Brook (2006) to highlight their use in many applications. Wicking is easy to measure and very simple equipment is needed. Mazloompour et al., (2007) have used the electrical resistance method to study the rate of horizontal wicking of different fluids into untreated and finished cotton fabrics. Fangueiro et al., (2010) have studied the wicking behaviour and drying capability of functional knitted fabrics. Many wicking experiments were carried out on various types of yarn with vigour to obtain valuable information on comfort properties of fabrics. Das et al., (2011) have developed mathematical model recently to predict vertical wicking behaviour in yarn and fabrics.

The high wickability of the ring yarn is believed to result from the small, uniformly distributed and inter connected pores and channels, which facilitate fast liquid transport. When liquid is taken up in a yarn, apparently two aspects can be distinguished, namely (i) the amount of liquid absorbed per unit of surface of mass; and (ii) the velocity with which wicking takes place suggest Subramaniam et al., (2007). A single droplet of liquid placed on a yarn forms a reservoir of limited capacity. As wicking proceeds and this reservoir becomes progressively depleted at some point cease to express accurately the rate of wicking. The yarn wicking performance was significantly affected by the tension applied and the
twist inserted. The heterogeneity of pore size, shape and orientation affect the penetration of the liquid into the yarn structure remark Nyoni and Brook (2006).

In a very recent paper on wicking performance of cotton acrylic yarns and knitted fabrics, Ozturk et al., (2011) have discussed the wicking performance of single jersey fabrics produced with Ne 20 and Ne 30 rotor yarns. The fibre compositions were 100% acrylic, 50/50 cotton acrylic, 85/15 cotton acrylic, and 100% cotton. Results showed that wicking height of the yarns tended to increase with the increase of the acrylic ratio. Also the wicking height of Ne 20 was generally higher than those of Ne30 yarns due to coarseness in yarns with lesser counts. The influence of yarn wicking on fabric wicking in the course direction tended to be higher than its influence on fabric wicking in the wale direction.

1.3 MOTIVATION

No data are provided so far on the wickability of the fibres which is supposed to affect the wickability on yarns and fabrics and this work addresses this area for the first time. The effects of yarn count, twist, blend and tension on wickability of the viscose and their blends have been systematically studied in order to provide useful data. Wickability has considerable impact on comfort aspect of the fabric and based on this, apparel fabrics can be designed for summer and winter seasons especially for the work personnel in the industry and outdoor fabrics namely sportswear who do hard work and perspire easily. The information on wickability will have considerable utility in providing the best uniform materials to the staff for better efficiency. The work presented here is closely related to previous work but the effect of finishes on wicking behaviour in different directions of grain like warp, weft and bias in various mediums like water kept at temperature 80°C, acid perspiration, distilled water and alkaline ph have not been undertaken. Also the effect of weave structures and sett utilising some new parameters on the wickability of cotton fabrics has been examined.
Among the various textile fibres, wool and silk are protein fibres and are also considered as luxury materials. Today China and India are the major production centres of silk. Silk was used as a suture material from the time immemorial and recently there is a surge in the consumption of various types of silk. It is a well known fact that there are considerable differences in the properties of these silks and only little literature is available. Most of the studies have been directed towards the stress–strain characteristics of silk and degumming losses. But the literature on degumming losses of these two types of silks following degumming is scant. If sericin is not properly removed, it will affect the dyeability of the material and also make the material harsh.

The action of light on protein fibres results in loss of tensile strength of the fibres, change in the dyeing properties, handle and yellowing of the fibres. During the exposure, the fibres undergo photo-oxidation and photo-sensitized degradation. The source of radiation and the duration of exposure, the surrounding atmosphere, humidity, nature of the fibre substance, light absorption characteristics of the dyes and chemicals present on the fibre during the exposure, temperature, etc. influence the degradation of the fibre taking place during the exposure. Very little information is available in literature regarding the fading and photodegradation behaviour of mulberry and tasar silk. So the present study deals with the changes in tensile strength, dye uptake and wickability of mulberry and tasar silks after photodegradation which has not been examined so far.

It is observed that heretofore studies silk fabrics have not been investigated for wickability and this aspect is considered in depth in the current study. Although mulberry and tasar silk constitute major types of silks produced in India, it is disappointing to note that the amount of research work that has been carried out is insignificant. Only some products have been developed using tasar silk and scientific data on their handle and comfort properties are non existent. The
motivation of this work is to explore these areas and contribute to the scientific advancement of the subject. With the introduction of the various novel methods of investigating the properties of textile materials, it is imperative that these methods should be applied to these materials in order to improve our understanding of various properties. The goal of the present study is to provide valuable information on the wickability of mulberry and tasar silks which will throw considerable light on their comfort characteristics.

1.4 THEESIS OBJECTIVES

The objectives of the study are,

1. To investigate the wicking behaviour of man made cellulosic fibres such as viscose, modal, tencel and bamboo fibres.
2. To study the wicking behaviour of viscose staple yarns differing in linear densities.
3. To study the wicking behaviour of viscose staple yarns differing in twist levels and tensions.
4. To study the wickability of polyester viscose yarns differing in blend composition, counts and twist levels.
5. To examine the effect of weave structures and sett and various finishes on wickability of cotton fabrics.
6. To study the changes in tensile strength, dye uptake and wicking behaviour of mulberry and tasar silk fabrics after photodegradation.
7. To examine the properties of fibres, yarns with different linear densities, and twist levels and cotton fabrics produced with different structures and pick densities and mulberry and tasar silk fabrics.
1.5 ORGANISATION OF THE THESIS

The thesis is divided into 11 chapters.

- Chapter 2 contains an extensive review of literature.
- Chapter 3 deals with details of materials and methods used in the current research work.
- Chapter 4 deals with the development of wicking tester for fibres, yarns and fabrics.
- Chapter 5 deals the wicking behaviour of manmade cellulosic fibres such as viscose, modal, tencel and bamboo fibres.
- Chapter 6 discusses the wicking behaviour of viscose staple yarns differing in linear densities.
- Chapter 7 looks at the wicking behaviour of viscose staple yarns differing in twist levels and tensions.
- Chapter 8 deals the effects of blend composition, linear density, and twist on wickability of polyester viscose yarns.
- Included in Chapter 9 are the effect of weave structures and sett and various finishes on wickability of cotton fabrics.
- Chapter 10 deals the study of changes in tensile strength, dye uptake and wickability of mulberry and tasar silk fabrics after photodegradation.
- A general summary and conclusion obtained from the present research work with future recommendations is included in Chapter 11.