CHAPTER -2

REVIEW OF LITERATURE

The literature review is a critical step in the research process. It helps to direct ones thinking and moves one toward developing a specific research question to be answered. Primary objective of reviewing literature is to understand previous work that has been done in the subject and to chalk out a research endeavor with a focus on the unexplored aspects of the problems.

Literature related to study has been presented under following subheads:-

2.1 Khadi

2.2 Structure and properties of wool fiber

2.3 Indian cross bred wool

2.4 Properties of cotton fiber

2.5 Indian cotton

2.6 Blending

2.7 Cotton and wool blends

2.8 Characteristic of single jersey/ double jersey fabric

2.1 Khadi

1. Khadi is Indian handspun and hand woven cloth, raw material may be cotton, silk and wool which is spun into threads on a spinning wheel called charkha. It is versatile fabric, cool in summer and warm in the winter. It has good moisture absorbency, and a rugged texture with a unique look and feel. Khadi is a cloth produced by the interlacement of hand spun yarn, which gives maximum comfort to the weave. Khadi is natural and unique fabric. The rustic no machine looks of the fabric in cloth is sophisticated and bohemian. The marketability of khadi will only increase when people start wearing khadi and get addicted from it. (http://rajkhadi.rajasthan.gov.in/index.aspx.)
The birth of khadi took place in the eventful year of the freedom struggle with a vision to recreate an economically sufficient crafts based society, by using a textile for this purpose was linked with renewal of hand spinning and hand weaving industries with the establishment of Sabarmati ashram in Ahmedabad in 1915. (The Hindu, 1999)

According to Dogra, “the popularity of khadi has increased in recent time. “The ever increasing presence of khadi has some reason. A look at the past reveals the way khadi was promoted by Ghandiji. This was to promote village economy to stop the exodus from village to cities. Khadi was promoted extensively to make them economically more self-sufficient”.

In 1989 “the first high fashion khadi show was presented in Mumbai by the Khadi and Village Industries Commission (KVIC) where nearly 85 khadi garments were created by Devika Bhojwani, in an exciting array of eastern and western attire. She also launched the Swadesi label in 1985 which was distributed through nearly 5000 Khadi Gramodyog Bhandars and Emporia”.

In 1990, designer Ritu Kumar presented “her first Khadi collection at Crafts Museum, eight collections were presented of which khadi was a very significant one. Since then the Tree of Life show has been presented several times for charity and caused a stir with its creations. In 1997, again, Ritu Kumar presented the Tree of Life shown this time in London where the British were amazed with her khadi collections. Being a sign of freedom, Khadi today holds a fashion status and has become a part of every wardrobe when it comes to selecting fabric with a discerning eye”, informs Ritu Kumar.

Her exhibition titled Elegance in Khadi and Khubsoorat Khadi with eight designer collections presented ethnic wear in varied forms along with western garments.

Another person who has been working regularly on khadi is Kamal Wadkar, “he is the well know promoter of traditional crafts. For decades khadi has been associated with rural wear. Although many would say it is just the right fabric for the Indian climate due to its loose weave and cool texture. She has been associated with the Gujarat Handicrafts Board (Gurjari) and the Mumbai Khadi Sangh. Her exhibitions in Mumbai for KVIC (Khadi
Village Industries Commission) have netted nearly Rs.12.5 million. Kamal, presented nearly 4500 garments in 150 styles in different colors weaves and embellishment with prices ranging from Rs.460-750.”

But since Khadi is woven by hand in villages it is often difficult to provide large quantities of the fabric at short notice, handmade quality of the fabric with its inherent defects that is the beauty of Khadi and that is what the buyer wants at times. It is not a poor man’s fabric although it provides employment to the poor man. It is a very up-market fabric largely accepted by high class.

http://www.indiaprofile.com/fashion/khadi.htm

Nona Walia, reports that in Paris, “a boutique named Rue Debelleyeme, attracts a large number of people. It does not sell fancy silk, cashmere or designer clothes that the fashion capital of Europe is known for, it sales an exotic range of khadi kurtas, tunics and trousers that have become a rage for Parisians as well as tourists who visit the city. Neilson says, "My ultimate dream is to use lot of color and chikan embroidery on khadi, with modern techniques”.

Fashion designer Christina Kim’s shop Dosa, in Los Angeles, USA,” sells high-end khadi clothes. Indian fashion designer Gaurang Shah, gave a new spin to khadi at his show at Berlin Fashion Week”.

Neilson from Khadi & Co, Paris, reported about the fabric’s current 'haute' status, “the great beauty of hand-spun khadi is its unique flexibility which keeps you warm in winter and fresh and cool in summer.” Tourists from all over the world, especially Japan and Italy, love their kurtas.

Though khadi was appreciated for being eco-friendly and sustainable, it was criticized for its coarse texture and limited design range. Shah, who personally loves the fabric “added a twist by giving khadi a modern makeover, he used 80 to 100 counts of thread per inch to make the fabric more malleable (traditionally khadi uses 60 counts of thread per inch). His
collection of khadi had colorful floral patterns on a cream base and displayed skirts, flowy dresses and jumpsuits”.

Kim, “whose clients include Jennifer Aniston and Michelle Obama, has been listed as one of the most influential names in the world of sustainable fashion by Time magazine. The aim is not to make just fashion products, she also expresses individuality. I want khadi to become a way of being and feeling. The fact that her products are becoming popular in Los Angeles and New York shows that khadi's appeal has become more international”.

The craze of khadi is not limited to clothes. In London, Conran shop of Abraham & Thakore's “khadi cushions have a unique charm they sell plain, undyed fine khadi cushions without any ornamentation, and there is a huge demand for handmade khadi products”. (nona.walia@timesgroup.com)

Mishra and Jain (2012 ) has reported that “sheen of Khadi is faded now, needs revitalization by an effective dose to be given by Government of India, Khadi and Village Industries Commission (KVIC), Khadi Industries (KI) and non-Governmental Organizations (NGOs). Concerted efforts are needed by them in favor of Research and Design (R&D) work, training to artisans, market – survey to note who wants what. A very good infrastructure, financial as well as political support, borrowing high-tech to complete internationally, giving an impressive exposure to quality Khadi, through mass-media in a bid to make our young generation of 21st century socially aware and awakened is the need of the hour today. Khadi is our national pride should now be recognized as ‘National Fabric’ ‘National Flag’, ‘National Dress’, ‘Symbol of National Economy’ and what not more, as dreamt by Mahatma Gandhi, our Father of the Nation. We do not lack manpower, natural resources, finances or infrastructure in our country however, we lack only will power. If it is brought on the way we can definitely bring our India once again on glittering globe ahead of Japan, Indonesia, Switzerland, Singapore, Malaysia and China”.

The case, "Reviving Khadi in India" provides an overview of the importance of Khadi during the freedom movement, the problems it faced in the post-independence era and the
reasons for its declining share in the overall production of KVIC. The case specifically deals with the strategies adopted by KVIC to improve the sales of the fabric and its efforts to popularize Khadi as fashion fabric. The case gives insights into the restructuring activities undertaken by KVIC in order to face the challenges of globalization. KVIC's prospects to fully exploit the potential of the fabric holds have also been explored”.(http://www.icmrindia.org/casestudies/catalogue/Business%20Strategy1/BSTR055.htm)

2.2 Structure and properties of wool fiber

Animal fibers are largely those which cover mammals such as sheep, goats and rabbits, but also include cocoon of the silk-worm as well as feather from poultry. Globally natural Fibers contribute about 48% to the fiber basket with 38% from cotton, 8% from bast and allied fibers and 2% from wool and silk fibers. India is a vast country with 44describe sheep breeds spread over a wide range of environmental conditions.

Wool is the fiber from the fleece of the domesticated sheep. It is a natural, protein, multicellular, stable fiber (Gohl and Vilensky, 1987)

“Wool is consumed mainly in suiting and knitted garments for men’s wears while for women’s wear, shawl, coating and dress material are major products. In addition, one of the important end use of non-apparel wool is in hand knotted, tufted and woven carpets. Woolen industry in India is small in size as compared to cotton and synthetic fiber based industry, wool and woolen activities in rural areas are having important position. The woolen industry including carpet sector contributes about Rs. 5000 crore in export earnings. Moreover, the industry provides employment and source of sustenance to about one million people mostly belonging to low income group. In addition the expansion of the industry particularly the Khadi, handloom and carpet segments will create more job opportunities in future”. In India, about 456 lakh kg sheep wool of 22-60 micron is produced which is mainly utilized in carpet, blanket, felt, suiting and shirting etc. (Karim and Shakyawar, 1985)
Morphological features:

The fibers of animal origin are natural and have special characteristics. These are different types of cells constituting the different parts of these fibers are called cuticle, cortex and medulla etc. These scale structure is of different geometrical designs and some fibers can be identified from those geometrical designs and some fibers can be identified from those geometrical patterns. Generally the scales have the dimensions of width, height fiber surface and angle with respect to fiber axis. These dimensions may differ from fiber to fiber. The cross-sections of the fiber vary from circular to highly irregular shape in fine to very coarse fibers. (Parthasarthy, 1998)

Physical structure of wool

The wool fiber is crimped, fine to thick, regular fiber. As the diameter of the wool fiber increases the crimp per unit length decreases. (http://textilebd-yarn.blogspot.in/2012/02/macro-and-micro-structure-of-wool-fiber.html)

- **Length**: (1.5 to 15) - (3.8 to 38)
- **Diameter**: Fine 14um, coarse 45um,
- **Length width ratio**: 2500:1 for the fine and shorter, 7500:1 for course and longer
- **Color**: Off white and light cream.
- **Crimp**: Fine wool 10 crimp/cm, coarse wool 4 crimp/cm

**Fig- 2.1 Morphological structure of wool fiber**
Jefferson, (2005) reported that “individual hairs may be as long as 91cm (36 inches) but some are not more than 41cm (16 inches). Thus fibers of hairs and wool are not continuous and must be spun into yarn if they are not to be woven or knitted into textile fabrics or they must be made into felt. Any hair fiber can legally be marketed as wool or bear the common English name of the animal from it was gathered for example camel's hair”.

Gohl and Vilensky (1987) stated that “the tenacity of wool is 1.0-1.7 grams per denier. The strength is an important parameter, which influences the processing and durability of the product. The coarse wool has more strength than fine wool. Medullation in coarse wool fiber significantly influences the stress - strain characteristics of wool fibers”.

**Chemical structure and property**

Jefferson (2005) stated that “all animal fibers are complex proteins. They are resistant to most organic acids and to certain powerful mineral acids and to certain powerful mineral acids such as sulphuric acid (H₂SO₄). However, protein fibers are damaged by mild alkalies (basic substances) and may be dissolved by strong alkalies such as sodium hydroxide (NaOH). They can also be damaged by chlorine-based bleaches and undiluted liquid hypo chloride bleach will dissolve wool or silk. The principle component of hair, wool and fur is the protein keratin”.

Behera and Shakyawar (1998) mentioned that “wool is a natural fibers growing out of the follicles in the skin of sheep. The wool fiber consists mostly of complex mixture of protein called Keratin. There are many other fibers i.e. rabbit hair, camel hair, cashmere etc which has similar structure and chemical properties of wool. Wool fiber enjoys a unique place in the fiber market in spite of stiff competition from manmade fibers. i.e. acrylic, nylon, polypropylene etc, because of its warmth, handle, resilience and other desirable properties”.
2.3 Indian cross bred wool

Table 2.1: Classification of Indian wool according to gross dimension

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Class</th>
<th>Fiber diameter (micron)</th>
<th>Breeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fine</td>
<td>&lt;28</td>
<td>Hissardale cross-bred wool, Kashmir valley wool, Kashmir valley-Russian merino, Bharat merino, Avivastra and Gaddi Synthetic wool</td>
</tr>
<tr>
<td>2</td>
<td>Medium</td>
<td>28-38</td>
<td>Chokla, Rampur bushair, gaddi, naali wool</td>
</tr>
<tr>
<td>3</td>
<td>Coarse-medium</td>
<td>34-40</td>
<td>Marwari, jaisalmeri, magra, pugal wool</td>
</tr>
<tr>
<td>4</td>
<td>Coarse</td>
<td>40-50</td>
<td>Malpura, sonadi, patanwadi, hassanwool</td>
</tr>
<tr>
<td>5</td>
<td>Very coarse</td>
<td>50-80</td>
<td>Mirjapuri, jalauni, shahabadi wool</td>
</tr>
<tr>
<td>6</td>
<td>Hairy</td>
<td>&gt;80</td>
<td>Nellore, ramnad</td>
</tr>
</tbody>
</table>

2.4 Properties of cotton fibre:

Cotton is a natural cellulosic fiber obtained from seed of cotton plant. Cotton has medium strength, it is a good conductor of heat, and it is very absorbent but does not dry very quickly. It is very comfortable, although laundry is easy, it needs great care. Cotton lacks very appreciable resilience and it is relatively inelastic. For these reasons it wrinkles and creases readily, also lacks luster.

It is classified as a natural, cellulose, seed, mono-cellular, staple fiber. Under a microscope, a cotton fiber appears as a very fine, regular fiber. Cotton fiber looks like a twisted ribbon or a collapsed and twisted tube. It ranges in length from about 10 mm to 65 mm, depending upon the quality of the fiber. Cotton is a very fine fiber with little variation in fiber diameter; compared with wool for instance, its fiber diameter is not considered as critical a fiber dimension as its length. The fiber length to breadth ratio of
cotton ranges from about 6000:1 for the longest and best types, to about 350:1 for the shortest and coarsest cotton types. The greater this ratio, the more readily can the cotton fibers be spun into yarn. Cotton fibers vary in color from near white to light tan. (http://allabouttextiles.blogspot.in/2008/01/cotton-structure-and-properties.html)

The cotton polymer is a linear, cellulose polymer. (Gohl and Vilensky, 1987)

Fiber length is one of the most important parameter in cotton selection. A comparison of all the world cotton reveals that fiber length varies from $\frac{3}{4}$" to $1 \frac{3}{4}$" or even 2", two types of length i.e. 2.5% and 50% span length. 2.5% span length is the distance 2.5% of the fibers extend from the clamp where they are caught at random along their length. 50% span length is a distance 50% of the fibers caught at random extend from the clamp along their lengths.

It can be assumed that the fiber of under 4-5 mm will be lost in processing, fiber up to about 12-15 mm do not contribute to strength but only fullness of yarn, and only those fibers above these length produce the other positive characteristics in yarn. Fiber length variation will cause the problems at every stages of processing.

In Blow Room, the feed roller and the beaters have to be set at the appropriate level for maximum opening with minimum damage to fibers and deterioration in yarn quality.

In Carding, as the setting between the feed plate and the licker-in and other setting are dependent on fiber length and its variability.

When fibers varying widely in length are drafted, too many fibers may lie uncontrolled in the drafting zone leading to the formation of high amplitude drafting waves.
Kadole and Kidile (2012) analyzed “impacts of spinning processing on fiber and found that if the machinery used is at par with the prescribed norms, the cotton fiber suffers no mechanical damage in the blow-room stage. The card is the heart of spinning mill demonstrates the immense significance of carding in the spinning operation. It has been established that the nepds removal efficiency of card can considerably influenced by the condition of card clothing. Cotton is the king of textile fiber the warmth, comfort and feel offered by cotton cannot be matched by any of the synthetic fiber. Among the characteristic of cotton fiber length, strength, micronaire and elongation is of utmost importance to the spinner. Fiber length has excellent correlation with yarn breaking extension and correlation with yarn evenness, imperfection and hairiness. Raw cotton fiber, irrespective of quality, contains impurities. The blow-room which is the first stage of cotton processing, performs the important functions of opening and cleaning. It is a common perception in the industry that cotton fiber can be damaged or broken during the blow-room processing. Proportion of short fibers is increases by over 10 % if the blow-room line contains one more cleaning machine than necessary. The fiber length degradation resulting from breakage during lint cleaning is less severe in cotton greater individual fiber strength. The potential of cotton fiber to form nepds during lint cleaning is inversely related to maturity and directly related to non- lint content”.

| Table no- 2.2: Standards of cotton for 2.5% span length values |
|-----------------|-----------------|
| Extra-long staple | 32.5 & above |
| Long staple | 27.5 to 32.0 |
| Medium long staple | 25.0 to 27.0 |
| Medium staple | 20.5 to 24.5 |
| Short staple | 20.0 and below |
The strength of cotton fibers is attributed to the good alignment of its long polymers (that is its polymer system is about 70 per cent crystalline), the countless, regular, hydrogen bond formations between adjacent polymers, and the spiraling fibrils in the primary and secondary cell walls. It is one of the few fibers which gains strength when wet. It is thought this occurs because of a temporary improvement in polymer alignment in the amorphous regions of the polymer system. The cotton fiber is relatively inelastic because of its crystalline polymer system, and for this reason cotton textiles wrinkle and crease readily. Only under considerable strain will cotton polymers give and slide past one another.

“The general crispness of dry cotton textile materials may be attributed to the rapidity with which the fibers can absorb moisture from the skin of the fingers. This rapid absorption imparts a sensation of dryness which, in association with the fibers inelasticity or stiffness, creates the sensation of crispness. The hygroscopic nature ordinarily prevents cotton textile materials from developing static electricity”. (Rivett et al, 1996; Taylor, 1988)

2.5 Indian cotton

Tables 2.3-2.5 provide summarized data on the” fibre attributes of some of the Indian Cottons in different staple groups

(a) 20mm – 25mm

(b) 26.0mm – 30mm

(c) 31mm to 36mm

in comparison to some of the foreign growths of the same staple grade”. (Sreenivasan & Venkatakrishnan, 2007)
Table 2.3: Fibre attributes of Cottons in the Staple group 20 mm – 25.0 mm

<table>
<thead>
<tr>
<th>Variety</th>
<th>2.5% S.L.(mm)</th>
<th>Mic. Value</th>
<th>Tenacity(g/tex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jayadhar</td>
<td>22.7-23.7</td>
<td>5.1-5.4</td>
<td>14.7-17.5</td>
</tr>
<tr>
<td>CD.327</td>
<td>18.5-21.8</td>
<td>5.5-7.8</td>
<td>13.7-16.4</td>
</tr>
<tr>
<td>LD.491</td>
<td>18.4-21.4</td>
<td>6.8-7.7</td>
<td>15.1-16.6</td>
</tr>
<tr>
<td>NHH.44</td>
<td>22.5-28.2</td>
<td>2.7-5.3</td>
<td>16.3-22.7</td>
</tr>
<tr>
<td>RS.2013</td>
<td>23.7</td>
<td>7.4</td>
<td>20.4-21.9</td>
</tr>
<tr>
<td>RST.9</td>
<td>23.5-27.1</td>
<td>3.5-5.6</td>
<td>18.0-22.7</td>
</tr>
<tr>
<td>V.797</td>
<td>22.6-25.4</td>
<td>4.1-5.5</td>
<td>15.5-15.7</td>
</tr>
<tr>
<td>Y.1</td>
<td>23.2-25.8</td>
<td>3.9-5.4</td>
<td>19.8-23.6</td>
</tr>
</tbody>
</table>

Table 2.4: Fibre attributes of Cottons in the Staple group 26 mm – 30 mm

<table>
<thead>
<tr>
<th>Variety</th>
<th>2.5% S.L.(mm)</th>
<th>Mic. Value</th>
<th>Tenacity(g/tex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AKH.468</td>
<td>27.8-29.1</td>
<td>3.5-3.7</td>
<td>22.1-23.5</td>
</tr>
<tr>
<td>Ankur 651</td>
<td>25.9-30.8</td>
<td>3.4-5.1</td>
<td>19.5-23.5</td>
</tr>
<tr>
<td>DHH.11</td>
<td>26.4-28.9</td>
<td>3.7-4.2</td>
<td>19.2-24.3</td>
</tr>
<tr>
<td>LHH.144</td>
<td>26.3-29.8</td>
<td>3.4-4.7</td>
<td>20.6-25.6</td>
</tr>
<tr>
<td>LK.861</td>
<td>26.5-29.4</td>
<td>3.7-4.8</td>
<td>19.1-22.6</td>
</tr>
<tr>
<td>MCU.5</td>
<td>27.6-33.1</td>
<td>3.0-4.1</td>
<td>20.2-26.4</td>
</tr>
<tr>
<td>MECH.1</td>
<td>26.4-32.5</td>
<td>3.0-4.5</td>
<td>19.5-25.5</td>
</tr>
</tbody>
</table>
Table 2.5: Fibre attributes of cottons in Staple group 31 – 36 mm

<table>
<thead>
<tr>
<th>Variety</th>
<th>2.5% S.L.(mm)</th>
<th>Mic. Value</th>
<th>Tenacity(g/tex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bunny</td>
<td>27.2-35.7</td>
<td>3.0-4.7</td>
<td>20.2—28.1</td>
</tr>
<tr>
<td>DCH.32</td>
<td>30.1-37.9</td>
<td>2.6-3.9</td>
<td>23.4-29.6</td>
</tr>
<tr>
<td>Surabhi</td>
<td>31.3-34.2</td>
<td>3.3-4.6</td>
<td>21.5-27.1</td>
</tr>
<tr>
<td>Navbharat Kranti</td>
<td>34.0-36.2</td>
<td>3.7-4.1</td>
<td>23.5-27.2</td>
</tr>
<tr>
<td>Suvin</td>
<td>38.8-39.4</td>
<td>3.5-3.6</td>
<td>32.7-35.4</td>
</tr>
</tbody>
</table>

Mech I is “cultivated in state of Maharashtra, Andhra Pradesh and Madhyapradesh. Quality of yield per year is about 1.7 million bales of each of 170 kg. It is sown in the month of June/july and the crop is ready for picking by November- January. Fiber properties of mech I cotton are, its length is 27-29mm, fiber fineness of 3.5 to 4.9 mm having a bundle strength of 85 to 96 lbs/sq. inch and 21 to 23g/tex”. (http://www.nanoagrofoods.com/mech-I-29-mm.html)

2.6 Blending

According to Patni (2003) “blending is done to achieve some of the following objectives:

- To partially compensate short comings of one fiber by other fiber and thereby improve average mixing quality.
Blending also makes the fabric manufacturing process economical. Blending could also be used for reducing the mixing cost, for example, fiber like wool is blended with cotton for producing specific yarns, with reduced raw material cost.

Veldsman and Taylor (1978),” is a process a 75/25-wool/cotton blend seems to have been purely arbitrary, in starting the minimum amount of cotton necessary to blend with wool to ensure satisfactory processing on the short staple system trials were carried out to establish this point. They found that all lambs wool lot proved to be difficult when processing through the blow room since licking around the calendar rollers was excessive”.

Influence of ultra fine wool fiber curvature and blending with cashmere on attributes of knitwear by McGregor (2005) “both blend ratio and wool type affected the attributes of tops, roving, yarn and knitted fabric. The differences in raw wool attributes of low crimp ultrafine wool, compared with standard high crimp ultrafine wool, were translated into numerous different knitted fabric physical properties. It was demonstrated that most of the properties of knitted fabrics were crimp dependent. The blending of cashmere with wool resulted in a reduction of the mean fiber curvature of the blend compared with the unblended wool, with a resultant change in physical properties of the textile materials. The present work demonstrated that the physical properties of pure low crimp ultrafine wool fabrics were closer to the properties of pure cashmere knitted fabrics than were knitted fabrics made from pure standard ultrafine wool. Increasing the content of cashmere in a wool/cashmere blended knitted fabric generally resulted in a change in the measured fabric attribute in the direction of pure cashmere fabric”.

Bel and Louis (1985 ) “spun yarn of wool/ coton and wool/polyester blends by different methods. The scoured wool stock used in this study was mechanically cleaned and shortened by a carding cleaner machine developed at the SRRC. Wool/cotton and
wool/polyester blends of 50/50 ratio were successfully processed into different types of spun yarns. The spinning methods were ring, ring yarn with nylon filament wrap, ring yarn with nylon filament core, Sirospun, Sirospun with nylon filament wrap, Sirospun with nylon filament core, Coverspun, Coverspun with nylon core, worsted, and friction (DREF-3) spinning. It was concluded that the Coverspun technique produces the highest quality yarn, followed by ring, worsted, and friction spinning”.

2.7 Cotton and wool blends

Studies on processing of wool-cotton blends on cotton spinning system were conducted by many researchers. A project was carried out by Anonymous on “realization of knitted fabrics and woven fabrics from blends of cotton and wool noils. Noils are sound but short fibers eliminated during wool combing. By comparison with cotton, wool is a costly raw material. For this reason, it is worth processing the highest possible percentage of wool fibers, thus also the noils, to produce high quality end products. The starting point of this project consists mainly in the results obtained in a previous CRAFT project dealing with the realization of wool blend fabrics from cotton and carbonized wool noils. In that project a soft carbonizing process for wool noils and a process for realizing a blend with cotton was set up. Successful industrial trials demonstrated that existing woolen spinning machinery could be used to spin 50:50 blend of cotton and wool noils, with the addition of 10% longer wool fibers and different fabric samples have been produced satisfactorily. The dyeing and finishing processes however were not studied extensively. The innovation in the present project is to extend the process to the realization of an intimate blend on the cotton spinning system, allowing thus a wider outcome on the market by including the hosiery sector and to develop finishing processes applicable directly on the yarn blend (cotton and wool having different requirements concerning the pH of treatment), necessary to achieve competitive prices and quick response. As some of the properties can only be evaluated on the knitted or woven fabric itself, like softness, hand shrinkage, local defects, abrasion and pilling strength, the industrial trials will go from the raw material up to the finished product. The proposed study allows to join two natural fibers, wool and
cotton, whose complementary properties will be used to profit for the creation of new articles for sportswear and for the hosiery industry, attractive by their comfort and a good quality / price. The valorization of wool noils through their use in blends with cotton will give them added value. This will contribute to a better use of natural resources and to the protection of the environment, the blends being constituted exclusively from natural fibers, the resulting yarns will give entirely biodegradable products that could be eco labelled according to the selected dyeing process”.

Lupton and Khan (1984) studied “performance of wool blend fabrics composed of yarns spun on the cotton system. Two grades (62s and 80s) of 50.8mm (maximum fiber length, 2 inches) cut – top wool were intimately mixed with cotton and with polyester fibers at varying blend levels. Subsequently, 13 yarns (6.9 tex, 16/1Nc) were ring-spun using the short staple system of mechanical processing and standard crepe fabrics were manufactured from each. Generally, increasing the wool content of a fabric decreased its tensile properties: wool/polyester blends exhibited higher tensile properties than cotton/wool blends of a similar wool content, in this narrow range, the grade of wool used in a specific blend did not significantly alter the tensile properties, durable press ratings or pilling properties. Cotton/wool fabrics containing 80s wool, however, shrank significantly more than their counterparts containing 62s wool. As the wool content of both blends increased, abrasion resistance decreased”.

Aldrich (1976) has investigated “the processing performance of 67/33 cotton/wool blends on cotton system. He reported that blow room blend of open top of raw cotton generally produced best quality yarn. The combed type yarn was slightly stronger than the strongest carded type yarn but was far superior in the yarn irregularity and nep content and was less hairy then any carded type yarns. He also reported that the type of wool had a relatively small influence on the overall characteristics of the fabric”.

Spencer & Taylor (1979) reported that “relatively short scoured wool with moderately heavy vegetable fault can be processed successfully when blended with cotton in 75/25 and 50/50 on standard cotton machinery using tandem card”.

37
Chattopadhyay (2003) reported that “crossbred wool named Avivastra having 21 micron diameter can be successfully blended with cotton up to 40% using cotton spinning system to produce yarn of 20s (Ne) or 30Nm. However, it could be blended up to 30% on rotor spinning system. They also reported that as the proportion of wool in the blend increased, various tensile properties and evenness in the blended yarn were found to deteriorate for all the yarns in both ring and rotor spinning system”.

Several studies were conducted on wool-cotton blends and showed that blends of wool and mechanically opened cotton can be successfully carded; gilled and combed on worsted system. CSIRO (Harry and Robinson, 1977) has shown “the practicality of processing wool-rich blends when both wool and cotton are from combed stock”. Schmidt & Turpie (1976) “processed different grade of cotton lint on double swift continental worsted card to establish the suitability of these grades best level of lubrication and influence of card production rate. The hand blended lots of 50/50 wool-cotton were successfully processed into tops on the worsted system. The use of already carded cotton in these blends resulted in improvement in sliver quality at significantly higher card production rates”.

Another study was carried out by Turpie and Marseland, (1977) on worsted spinning system. They reported that “roving prepared from combed 55/45 wool/cotton blends and an uncombed 67/33 cotton/wool (prepared up to draw frame stage on cotton system) could be successfully spun on worsted spinning system”.

Lupton (1980) reported that “the quantity of neps in wool-cotton blends tend to decrease as the proportion of cotton in the blends decreased. When wool is used on short staple system, combed fiber is normally the input for the cotton spinner, fiber length undoubtedly the greatest difficulty he faces selecting works for satisfactory processing, the fiber suppose must have a length distribution with not more than 5% of fiber exceeding 65mm”. Caddel et al “developed six pima cotton/wool yarns of 80/20, 70/30, and 60/40”. (https://rirdc.infoservices.com.au/downloads/11-150)
Palmieri (1986) stated that “wool/cotton blend fabrics or cool wool are not expected to replace all wool apparel, but rather to extend the use of wool into apparel in a nontraditional niche such as summer suit. In Indian climate conditions, during pre and post winter seasons, use of cotton/wool (cots wool) blended fabric is very popular for apparel purpose. In cots wool fabric, wool fiber provides warmth property due to its scaly surface, as air entrapped in the scales acts as an insulator”.

Stone et al (1985) opined “production of cotton/wool blend these fabrics to provide completely washable products in appropriate fabric densities requires total engineering beginning with the wool and cotton fiber selection, the wool preparation, cutting, blending, yarn manufacturing, fabric construction, dyeing and finishing. Studies conducted by Cotton Incorporated determined that an 80/20 cotton/wool blend was the best overall to achieve a washable product without the use of chlorinated wool. Both cut and stretch broken wool in grades 56's, 64's, and 70's were evaluated. Draw blending and intimate blending provided different fabric properties, yet both proved satisfactory in spinning, knitting, weaving, dyeing, and finishing. Since cotton is normally processed under alkaline conditions, while wool is normally processed under acidic conditions, preparation and dyeing of blends of these fibers involved unique processing considerations. Techniques for preparing, bleaching, and dyeing to achieve heathers, cross dyes and union shades have been developed that cause minimum wool degradation. Finishing techniques for this blend have been evaluated and formulations found which provide true performance products that are fully washable with easy care and low shrinkage properties”.

“Cotswool is very light weight, having soft feel suitable for women’s underwear and also light weight outer jersey. Wool cotton blends for apparel fabrics combine comfort with exceptional aesthetic apparel. The cotton/cashmere blends are used for light weight sweaters. The wool/cotton blend is superior in durability to all wool fabrics but there is loss in other desirable characteristics, such as handle, drape, pleat retention and crease recovery. Development of union fabrics using short fine wool yarn and cotton yarn as an alternative value addition for short fine wool was done in this study. Two types of wool-
cotton union fabric were produced using two different counts of wool yarns spun from short fine wool as weft and colored cotton yarns as warp. The woolen part of the fabrics was cross dyed using 1:2 metal complex dyes to uniform shade followed by finishing with cationic softener. The performances of finished union fabrics were compared with the 100% wool control fabric to find their suitability as blanket for tropical winter season. The stiffness, linearity of compression (LC), resilience of compression (RC) and resistance of the grey fabrics were improved by about 30% and 40% respectively, due to better dyeing and finishing. The union fabrics showed 40% - 50%, reduced felting compared to 100% wool control fabric”.

2.8 Characteristic of single/double jersey fabric

Knitting is a way of interlocking a series of loops that creates hand and machine knitted fabric. The loops are interlocked using a needle to hold the existing loop while a new loop is formed in front of the old loop. Knitting differs from weaving in that a single piece of yarn can be used to create fabric. The fabric consists of horizontal rows known as courses and vertical column of loops known as wales. Knitted fabric has useful properties that make it suitable for a range of garments including tights, gloves, underwear and other close fitting garments. The loop structure of knitted fabric stretches and moulds to fit body shapes. (Johnson, 2006)

The word knitting was evolved from the Saxon word ‘Cnyttan’ which has its origin from the Sanskrit word ‘Nahyati’. The art of hand-knitting was known and practiced sometime before 256A.D. Earliest type of knitting was known as Arabic knitting, which was carried on by the nomadic tribes of North Africa. Hand-knitting was most likely introduced into Europe by the Arabs. Knitting is a process of manufacturing a fabric by the intermeshing of loops of yarns. When a loop is drawn through another loop, a ‘stitch’ is formed.

(Ajgaonkar, 1998)

Stitches may be formed in a horizontal or in a vertical direction. The two main forms of knitting technology are: - warp knitting and weft knitting. Weft knitting is a method of
forming a fabric by knitting means in which the loops takes place in a circular or flat form on a course wise basis.

Fibers used in knitting:-

Yarns used for knitting belong to either of the two main groups of fibers viz., i) Natural fibers and ii) Man made fibers. Natural fibers are obtained either from vegetable, animal or mineral whereas man made fibers may be divide in regenerated cellulosic fibers and synthetic man made fibers. (Ajgaonkar, 1998)

Knitting is the most common method of interlooping and is the second only to a weaving as a method of manufacturing textile products. It is estimated that over 7 million tons of knitted goods are produced annually throughout the world. Although the unique has capability of knitting to manufacture shaped and form fitting articles has been utilized for centuries, modern technology has enabled knitted constructions in shaped and unshaped fabric form to expand into a wide range a apparel, domestic and industrial end uses.

Weft knitting is the more diverse, widely spread and larger of the two sectors, and accounts for approximately one quarter of the total yardage of apparel fabric compared with about one sixth for warp knitting. Weft knitting machines, particularly of the garment length type, are attractive to small manufacturers because of their versatility, relatively low capital costs, small floor space requirements, quick pattern and machine changing facilities, and the potential for short production runs and low stock holding requirements of yarn and fabric. All weft knitted fabric is liable to unrove, or ladder, from the course knitted last, unless special “locking courses” are knitted, or unless it is specially seamed or finished. (Spencer, 1989)

**Weft knitting:**

Weft knitting is a method of forming a fabric by knitting means in which the loops are made in horizontal way from a single yarn and intermeshing of loops takes place in a circular or flat form on a course-wise basis. In this method, one or more yarns are being fed one at a time, to a multiplicity of knitting needles, placed in either lateral or circular fashion. (Ajgaonkar, 1998)
Filling or weft knitting in simplified terms, involves the use of a continuous single yarn rather than sets of yarns at right angles as found in weaving. The term weft is used to identify filling knitting processes; this term is taken from hand weaving techniques, where it is used synonymously with filling to refer to the horizontal or crosswise direction of a fabric. Some weft-knitted fabric is made on flat-bed machines. (Joseph, 1986)

**Flat-bed knitting:**

Straight bed or V-bed knitting machines are mainly used for woolens and acrylic fiber yarns in India. Though a linear type of fabrics is manufactured with a variety of surface effects, the basic principle is that of weft knitting. (Ajgaonkar, 1998)

On these machines the thread moves from one side to other and forms a series of loops, which are pulled through the loops previously formed. The needles move as the machine is operated so that they pick up the thread and form each new loop. (Joseph, 1986)

The typical flat machine has two stationary beds of tricks in which the latch needles and other elements slide during the knitting action and from which their butts project and are controlled as they pass through the tracks formed by the angular cams of a bi-directional cam system attached to the underside of a carriage which with its selected yarn carriers, traverses in a reciprocating manner across the machine width.

As with all knitting machines, there is a separate cam system for each needle bed, the two systems are linked together by a bow or bridge which passes across from one needle bed to the other. (Spencer, 1989)

Hong Hu et.al (2011) described that “flat knitting is a widely used fabric manufacturing technology. Compared with warp knitting and circular knitting, flat knitting is characterized by its higher process flexibility and greater fabric structure variety. In this work, flat knitting technology was exploited to fabricate auxetic fabrics which laterally expand when stretched. Three kinds of geometrical structures, i.e. foldable structure, rotating rectangle and reentrant hexagon, were employed as basic reference structures for the development of these kinds of auxetic fabrics. The weft knitting processes based on these structures were specially developed and auxetic fabrics were fabricated using the
computerized flat knitting machines. The Poisson’s ratio-strain curves of the developed fabrics were plotted and compared with those calculated using existing models to demonstrate the variation trends of Poisson’s ratio with the axial strain. The results reveal that except the folded fabric formed with the face loops and reverse loops in a rectangular arrangement, of which the auxetic effect firstly increases and then decreases with the axial strain, the auxetic effects of all other fabrics decrease with an increase of the axial strain. The work also shows that auxetic fabrics can be realized based on knitted structures and that flat knitting technology can provide a simple, but highly effective way of fabricating auxetic fabrics from conventional yarns”.

Four primary structures- plain, rib, interlock, and purl are the base structures from which all weft knitted structures are derived. Each is composed of a different combination of face and reverse meshed stitches knitted on a particular arrangement of needle beds. Plain is produced by the needles knitting as a single set, drawing the loops away from the technical back and towards the technical face side of the fabric. Plain is the base structure of ladies hosiery, fully fashioned knitwear and single-jersey fabrics. Its technical face is smooth, with the side limbs of the needle loops having the appearance of columns of Vs in the wales, these are useful as design units when knitting with different colored yarns. On the technical back the heads of needle loops and the bases of sinker loops form columns of interlocking semi-circles whose appearance is sometimes emphasized by knitting alternate courses in different colored yarns. (Spencer, 1989)

Fletcher et.al (1952) described the “geometry of six plain and six rib circular-knit cotton fabrics with three different finishes. Data on both gray and finished fabrics for stitch length, diameter of yarn, and wale and course spacing’s were used in evaluating the equations derived by Peirce for length of yarn in one stitch and for weight per unit area. Measured stitch length agreed with that calculated from Peirce's formula, \( l = 2p + w + 5.94d \), when a specific volume of 1.1 was as summed for the yarn. When the measured value for the yarn diameter was used, the stitch length was given by \( l = 2p + w + 4.56d \). Weight of the fabrics calculated by Peirce's formula showed good agreement with that obtained by weighing a known area.
In laundering tests, it was found that the shrinkage of the yarn was negligible, usually less than 1% in the finished fabrics. Curves relating the wale and course spacings of the unlaundered gray fabrics conformed to no orderly pattern. The gray material shrank in length and stretched excessively in width. Wale spacings plotted vs. course spacings in the laundered gray and finished fabrics followed parabolic curves. The finished fabrics in which wale and course spacings approximated the parabolic relationship of the laundered fabrics changed the least in the length and width dimensions. These were the tighter-knit fabrics of two of the finishes. On the other hand, the fabrics having the greatest knitting stiffness shrank the most in area”.

The problem of unpredictable shrinkage of cotton knitted fabrics and garments faced by the industry has been investigated by Roy et al (2011) by “knitting single jersey cotton fabrics using the similar yarn and knitting parameters as used in the industry and finishing them. Through linear regression analysis, the variable factors, which affect the shrinkage and should be included in the domain of the quality control system, have been identified and predictive equations and established. Although, the variable factors, namely linear density, twist factor, machine gauge and stitch length, influence the shrinkage to a variable degree, stitch length is the dominating factor. If shrinkage can be controlled, fabric weight is predicted with high accuracy”.

Ahmed et al (1994) reported “importance of tightness factor in assessing cotton knitted fabrics. Two Indian cottons, 170 CO2 and Hybrid 4 were selected for the study. The chief fibre properties, ie, 2.5% span length, fibre fineness, bundle strength and maturity were determined. Results conclude that dimensional properties constants of plain knitted fabrics are dependent on the linear density of yarn used for knitting. Linear relationships with highly positively correlations were observed between tightness factor and each of the various properties like fabric thickness, aerial density, loop shape factor, drape coefficient and t/l ratio. Air-permeability tends to decrease linearly with increase in TF and further decreases after wetting and relaxation. Most of the dimensional properties of knitted fabrics show substantially high values after wet relaxation compared to dry relaxation, but the tightness factor has a marginal increase mainly in coarse counts”.


Kurbak, A. (2009) described “the 1×1 rib knitted fabric is mostly used for collar, cuff, waistband, etc. of outer wear knitted garments and it is also very popular nowadays for using as performs of knitted composite structures. A geometrical model to predict the dimensional properties of conventionally knitted 1×1 rib fabrics is created”.

Ramkumar et al (2000) “examined the influence of structural variables on the frictional properties of 1x1 rib- knitted cotton fabrics. The results indicate that both the loop length and the yarn linear density influence the fabric-on-fabric frictional properties. The variation in the structure of knitted fabrics is reflected in the frictional properties as defined by the new frictional constant. A statistical relationship is established between the frictional constant and the variables that exert some influence such as the loop length and the yarn linear density”.

Raje et.al (1994) studied “influence of fibre and yarn properties on knitted cotton fabrics. Eighteen cotton varieties belonging to different species and hybrids were spun to 20s count on a ring frame and the yarns knitted into single jersey fabrics. The fibre, yarn and fabric properties were determined by standard procedures. Analysis of results shows that there exists a good negative correlation between micronaire value of cotton and air-permeability of knitted fabrics. Also, it was observed that bursting strength of the fabrics is influenced by lea CSP and yarn irregularity. The relationship between friction and the tactile properties of woven and knitted fabrics was investigated. Coefficients of friction for the fabrics were measured using two devices: a previously developed Textile friction analyser and Kawabata evaluation system FB4. The tactile properties of the fabrics were evaluated by a panel, which assessed the roughness and the prickle of the textile surfaces in two different blind subjective tests. Correlation between fabric friction and subjectively perceived touch properties was found for knitted, but not for woven fabrics. In order to find out if additional parameters could have influenced the obtained relationship, textile properties such as bending, compression, basis weight, hairiness and fabric thickness were invested. Result reveals that there is a relationship between friction and touch properties of fabrics were bending, thickness and compressibility. On the other hand, the friction results showed a lack of commonality between to be a negative correlation between the two apparatus. It was attributed to the different testing conditions such as applied load,
sliding speed, contact area and material surfaces and illustrated the dependence of fabric friction properties on testing variables”.

Ramchandran. et.al (2010) described “the effect of thermal behaviour, such as thermal insulation, thermal conductivity and thermal diffusion, of single jersey, rib and interlock knitted fabrics made out of ring and compact-spun yarns. The physical characteristics, such as fabric aerial density, air permeability, tightness factor and fabric thickness, have been studied and their relationship with thermal behavior using multivariate ANOVA has been analyzed. The experimental results showed that the thermal conductivity, thermal diffusion and thermal resistance of the knitted fabrics depend on the fabric properties such as thickness, tightness factor, aerial density and air permeability. It is found that the compact spun yarn knitted fabrics (Sussen Elite and Corn4) show higher thermal insulation behavior in all the knitted structures in comparison to ring-spun yarn knitted fabrics”.

46