CHAPTER- III

METHODOLOGY

The present investigation was carried to study the performance of cotton wool blended knitted khadi fabrics and their consumer utility. Various fiber, yarn and fabric properties were tested to evaluate the impact of blending. The experimental procedure adopted for the present study has been explained under following subsections:

3.1 Collection of raw material

3.2 Instruments used

3.3 Determination of physical properties of fibers

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3.3.3 Single fiber tenacity

3.4 Development of cotton-wool blended yarns

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Collection of fibers
(Cotton (Mech I) and Wool (crossbred wool))
↓
Testing of fiber properties
↓
Blending of cotton and Wool fibers
↓
Oiling
↓
Carding
↓
Spinning on amber charkha
↓
Testing properties of yarn
↓
Knitting on flat bed machine
↓
Determination of fabric properties
↓
Development of prototypes
↓
Pricing and costing of developed prototype
↓
Assessment of developed prototype
3.1 Collection of raw material

The characteristics of raw material affect the performance of final product, hence the selection of fiber is very important. Initially different varieties of cotton and wool fibers were selected to find out most suitable cotton: wool blend combination. Yarns were prepared and properties tested. The result showed that Indian crossbred wool- Rambouillet/local sheep of Jammu and Kashmir and Himachal Pradesh can be blended with cotton Mech I to produce good quality even handspun yarn which can be easily processed on flatbed knitting machine. Therefore, these two fibers were selected for the study. Mech-I cotton obtained from KVIC Pooni plant of Raibareilly and crossbred wool produced in Fatehpur farm of Rajasthan were used in the present study.

3.2 Instruments used

Equipments used in the study have been given in Table 3.1.

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Instrument</th>
<th>Company Name</th>
<th>Purpose</th>
<th>Test method</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Flatbed hand knitting machine</td>
<td>Appex Engineering Work, Ludhiana</td>
<td>Development of knitted fabric</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>Advance Projection Microscope</td>
<td>Radical Projection Microscope, Ambala</td>
<td>Fiber diameter and its variation</td>
<td>ASTMD: 2130-90</td>
</tr>
<tr>
<td>3</td>
<td>Forceps and scale</td>
<td>-</td>
<td>Fiber length and its variation</td>
<td>IS: 1377-1971</td>
</tr>
<tr>
<td>4</td>
<td>Universal testing machine</td>
<td>AMETEC, LLOYD instrument, UK</td>
<td>Tensile strength and elongation of single fiber</td>
<td>IS: 235-1988</td>
</tr>
<tr>
<td>5</td>
<td>Electronic Weighing Balance</td>
<td>Meltler Toledo, USA</td>
<td>Yarn count</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>Meterx Twist Tester</td>
<td>Innolab, New Delhi</td>
<td>Twist per inch of yarn</td>
<td>IS:832-1985</td>
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<tr>
<td>7</td>
<td>Uster Evenness Test</td>
<td>Premier Polytronics</td>
<td>Yarn evenness and</td>
<td>ASTMD:1425</td>
</tr>
<tr>
<td></td>
<td>Instrument Description</td>
<td>Manufacturer/Supplier</td>
<td>Test Parameter</td>
<td>Standard</td>
</tr>
<tr>
<td>---</td>
<td>------------------------------------------------------------</td>
<td>------------------------------------------------------------</td>
<td>-----------------------------------------------------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>8</td>
<td>Universal testing machine</td>
<td>AMETEC, LLOYD instrument, UK</td>
<td>Tensile strength and elongation of yarn</td>
<td>IS:1670-1991</td>
</tr>
<tr>
<td>9</td>
<td>Counting glass and Dissecting needle</td>
<td>-</td>
<td>Wales per inch and course per inch</td>
<td>-</td>
</tr>
<tr>
<td>10</td>
<td>Drape meter</td>
<td>Paramount Instruments Pvt Ltd, Mumbai</td>
<td>Drapability of the knitted fabrics</td>
<td>BS5058</td>
</tr>
<tr>
<td>11</td>
<td>Digital Bursting Strength tester</td>
<td>Tex Care industries, Ghaziabad, UP</td>
<td>Bursting strength of the knitted fabric</td>
<td>IS6489:1979</td>
</tr>
<tr>
<td>12</td>
<td>Sasmira Thermal Conductivity tester</td>
<td>SASMIRA apparatus, Maharashtra</td>
<td>Thermal conductivity of the knitted samples</td>
<td>ASTM D1518-14</td>
</tr>
<tr>
<td>13</td>
<td>SDLFX 3300 Air Permeability Tester</td>
<td>TEXTEST instruments, Switzerland</td>
<td>Air permeability of knitted samples</td>
<td>IS: 11056 -1984</td>
</tr>
<tr>
<td>14</td>
<td>ICI pilling box</td>
<td>Prolific, Noida</td>
<td>Pilling grade of knitted samples</td>
<td>IS:10971-1984</td>
</tr>
<tr>
<td>15</td>
<td>Martindale Abrasion Tester</td>
<td>WIRA Carpet abrasion machine</td>
<td>Abrasion resistance of knitted samples</td>
<td>ISO: 12947-2-1999</td>
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<tr>
<td>16</td>
<td>Instron- 5695</td>
<td>Universal Testing Machine, Chennai</td>
<td>Fabric friction</td>
<td>ASTM D 4632</td>
</tr>
<tr>
<td>17</td>
<td>Sirofast (Fabric Assurance by Simple Testing)</td>
<td>ITEC Innovation lab, model No. 205b</td>
<td>Hand of fabric</td>
<td>-</td>
</tr>
<tr>
<td>18</td>
<td>Eureka crease recovery tester</td>
<td>Eureka Precision Instrument Company, Coimbatore</td>
<td>Crease recovery</td>
<td>IS: 4681-1968</td>
</tr>
</tbody>
</table>
3.3 Determination of physical properties of fibers

Following properties of fibers were determined after conditioning the samples in standard atmospheric conditions of 65±2 % relative humidity and 27±2° C temperature.

3.3.1 Fiber diameter (ASTM: 2130-90)

The determination of mean fiber diameter of wool and cotton was done by “Profile method” which defines fiber diameter in term of the average thickness or width of a two dimensional projected image of a large number of fiber snippets, measured using a projection microscope.

Fibers were selected randomly from the bulk of fiber available and were cut into snippets (0.8-2mm long) using a microtome. The fiber snippets were then mounted on a glass slide in liquid paraffin. The profile images of these short fibers were projected on the screen of projection microscope and diameter of these images was measured by means of graduated scale. The width thus taken is expressed in terms of micrometer (microns).

A continuous frequency distribution of fiber diameter was prepared by classifying the data into class intervals and then average fiber diameter (A.F.D.) was calculated from this frequency distribution of 300 observations.

3.3.2 Fiber length (IS: 1377-1971)

The measurement of fiber length was done in strict accordance with I.S.I specification. Out of the heap of thoroughly mixed and evenly spread loose fibers in square form, 20 pickings each weighing 500 gm were drawn from different portions viz. top, bottom and middle. All the picking so collected constituted the bulk sample.

The bulk sample so drawn was mixed thoroughly by doubling and drawing, spread out evenly and marked out into zones. From central portion of each zone, a small quantity of fibers about 5 gm was drawn. A fiber sample of 0.5 gm approx. was drawn from each of the 5 gm sample and all (0.5 gm samples) were combined together. Each bunch so obtained constituted a test specimen and these bunches taken together formed one test
sample. Three samples were taken for measurement of fiber length manually with the help of scale, a pair of forceps and a tally counter.

Fibers were first removed one at a time and gripped at each end by pointed forceps. The measurement was made by putting the tips of one forcep over the zero line of a scale and gently stretching the fiber until the crimp was just removed, the position of the tips of the second pair of forcep was noted and recorded in the relevant class. The mean fiber length was calculated from 300x 3 observations.

3.3.3 Single fiber tenacity test (IS: 235-1988)

Instron strength tester 5969 model was used to measure the tenacity of fibers. Fiber sample was prepared by proper mixing and doubling. Short fibers were then removed by combing. For single fiber testing, a window of 10mm x10 mm was prepared using black card sheet. The single fiber was selected as test specimen. Fiber specimen was taken and mounted on the window. After that, one end of the fiber window was secured in jaws of one clamp in such a way that the fiber lies along the axis of the machine; other end of fiber window was placed in the jaws of other clamp. Load-elongation behaviour was determined on Instron machine by moving jaw in upwards direction, (holding by another jaw) at a constant speed (rate of cross head speed was 10 mm per minute), at 10 mm gauge length of the clamp. Fiber tenacity in g/tex and elongation percent along with standard deviation and percent coefficient of variation were estimated. A sample of fifty fibers was tested in this way and results were recorded by the computer.

3.4 Development of cotton wool blended yarns

As mentioned earlier, blending of cotton (Mech I) and wool (Indian cross bred wool) fibers was done. A number of blend combinations were prepared according to following configuration:-
Table 3.2: Particulars of handmade yarns

<table>
<thead>
<tr>
<th>Sample Detail</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton</td>
<td>100</td>
</tr>
<tr>
<td>Cotton : Wool</td>
<td>90:10</td>
</tr>
<tr>
<td>Cotton : Wool</td>
<td>80:20</td>
</tr>
<tr>
<td>Cotton : Wool</td>
<td>70:30</td>
</tr>
</tbody>
</table>

3.4.1 Blending of cotton and wool fibers

Cotton and wool fibers were blended in different ratios in cotton system. Cotton and wool fibers were opened thoroughly and blended. After it sandwich blending technique was followed to prepare blend of fibers. In sandwich blending method, successive layers of weighted amount of both the fibers were laid one upon another for uniform results. Cotton and wool fibers were passed through a blow room line of Trutzschler –make using 4 beating point and blended was done in different ratios.

Trutzschler compact blow room line consists of BLENDOMATBO-A, Multi-Function Separator along with waste re-feeding, pre- Cleaner (CL-P), integrated mixer (MX-I with 10 trunks) along with CLEANOMAT Cleaner (CL-C 4), and Foreign part separator. The compact blowroom requires less space and lower energy consumption in transporting the fiber tufts to the next machine (Appendix- 1)

3.4.2 Oiling of material

Oiling of wool and cotton was done to minimize the fiber breakage as well as to reduce fly waste and static electricity during carding. Oil in the material was also needed to improve the moisture retention tendency so that static charge development in further processing is reduced. For the oiling of material mahua oil was used. 3 to4 percent of oil based on the weight of raw material was emulsified in water at 60-70°C and spread on the material in layers by hand. Thereafter the oiled material was run through a mixing picker and allowed to lie overnight to ensure thorough penetration of oil water emulsion. After
oiling of material carding was done on khadi cotton carding machine and different kinds of blends were prepared.

In carding the fibers are separated and then assembled into a loose strand (sliver or tow) at the conclusion of this stage. The cotton comes off of the picking machine in laps, and is then taken to carding machines. The carders line up the fibers nicely to make them easier to spin. The carding machine consists mainly of one big roller with smaller ones surrounding it. All of the rollers are covered in small teeth, and as the cotton progresses further on the teeth get finer (closer together). The cotton leaves the carding machine in the form of a sliver; a large rope of fiber. Carding can refer to these four processes: willowing- loosening the fibers, lapping- removing the dust to create a flat sheet or lap of cotton, carding- combing the tangled lap into a thick rope of 1-2 inch in diameter, a sliver, and drawing- where a drawing frame combines 4 slivers into one- repeated for increased quality. (Appendix-2)

3.4.3 Preparation of yarn on NMC charhka

The roving was further utilized for matching yarn on New Model Charkha (NMC) varying different draft and twist level to achieve desire yarn count.

New Model Charkha is a modified version of Amber charkha used in khadi system for woollen spinning. The input material to the charkha is roving which contains 1000-2000 fibers in their cross section. In order to get optimal spinnability on the spinning system, the numbers of fibers in the yarn cross section must be reduced to about 100. The reduction of fibers in the cross section is effected through drafting. In New model charkha, three rollers single apron drafting system is used. During drafting the fibers are firmly nipped between the bottle of steel fluted roller and the weighted top pressure roller. The pressure is applied by spring weighting system. The roller pairs rotate at an incremental speed resulting stretch (draft) in the material nipped between rollers. The controlled two stage stretching operations (drafting) elongate the feed roving and bring it to the required yarn dimension from the point of view of mass per unit length. (Chattopadhyay, et.al, 2003). (Appendix-3)
Once the drafted product emerges from the nip of the front rollers, it is to be twisted to impart strength to the fiber matrix. Twist is imparted by the combination of ring and traveler. The spindle which holds the package (bobbin) causes the traveller to rotate on a ring. The yarn loop between the front rollers to the bobbin via the traveller causes required force to be imparted on the traveller by the spindle. Every revolution of traveller causes the yarn to be twisted around its own axis. The twisted yarn is simultaneously wound on the package. As the ring moves up and down, the traveller also follows the same and hence the yarn is guided from bottom to top of the bobbin for laying.

3.5 Testing of yarns

Following properties of yarns were tested:

3.5.1 Yarn count

The count of yarn is a number which denotes its fineness. In indirect system of yarn count, the yarn number or count is the number of ‘unit of length’ per ‘unit of weight’. Yarn count was expressed in metric system. Metric count (Nm) is defined as number of hanks of 1000 meter in 1 kg.

To determine the yarn count 3 meter long yarn specimen was taken randomly from test sample. Specimen was weighted on electronic weighing balance. Average of twenty readings was obtained. Yarn count (Nm) was calculated by using given formula.

\[
\text{Yarn Count (Nm)} = \frac{\text{length in meter}}{\text{weight in grams}}
\]

3.5.2 Twist in yarn (IS: 832-1985)

Twist in the yarn was determined by the untwist- retwist method by using Metrex Twist Tester. 10 specimens of 250 mm (10”) length were selected from different parts of the package avoiding any change in the twist of yarn. Movable jaw was positioned at the distance of 250 mm, from non-rotatable jaw. Tensioning device was adjusted to apply a tension. Free ends of test specimen were secured in the jaws without disturbing the twist. The yarn was untwisted by operating the rotating jaw at a speed of at least 60 turns per
minute. Then yarn was re-twisted in the opposite direction until the specimen elongation indicator returns to zero. Number of twist per inch was calculated by the following formula:

\[ tpi = \frac{n}{2l} \]

Where,

\( tpi \) = turns of twist per inch
\( n \) = number of revolutions measured from revolution counter to untwist and retwist the yarn, and
\( l \) = length of test specimen in inch

3.5.3 Single yarn strength and elongation (IS: 1670-1991)

Single yarn strength and elongation was measured using Instron strength tester of Universal Testing Machine, model no LSI-E. This is an electronic instrument used to measure tenacity and elongation percent.

It works on the principle of Constant Rate of Transverse (CRT). Before starting the test, clamps of testing machine were adjusted so that the distance between the nips of the clamps along the specimen axis was 500 mm, rate of transverse of movable jaw was 300mm/min. Constant load of 10 kg was applied. Yarn specimen was taken and its one end was secured in the jaws of one clamp in such way that the twist does not change. Other end was placed in the jaws of other clamp. Machine was started, when the yarn broke, elongation percent and tenacity in g/tex along with standard deviation, and percent coefficients of variation were recorded by computer. Twenty samples were tested in this way and results were obtained.

3.5.4 Yarn Unevenness (ASTM D-1425:1996)

Yarn unevenness was measured on Uster Tester – 5. It is an electronic instrument used to measure yarn unevenness and imperfections at various levels.
Uster Tester – 5 is based on the electronic capacitance tester principle. It has two oscillators having equal frequencies when no material is present in measuring capacitor. When these two frequencies are made to superimpose, the difference in frequency is zero. The presence of material in the capacitor alters the capacitance and hence the frequency of the oscillator. Then there will be a difference between the two frequencies, which varies according to the amount of material present between the capacitor plates. Suitable circuit translates the frequency difference into the signals, which indicates the average irregularity as unevenness percent and coefficient of variation percent.

The sample was conditioned in standard atmospheric conditions. The instrument was switched on. The instrument ran self-test. After the self-test was set, Start button was pressed. The instrument was checked for staple length, fiber fineness and unit speed, “short staple” is selected for fiber length up to 40 mm and “long staple” for fibers above 40mm length. The “test parameter” key was pressed. Sample identification, characteristic values and measuring conditions were fed giving appropriate details. The speed for yarn was kept at 40 meter /minute. The yarn from five bobbins was tested in this way. Results were supplied in the form of print out from the computer attached with the instrument indicating number of imperfections (thin places, thick places and neps) and unevenness percent.

3.5.5 Yarn Hairiness

Yarn hairiness was tested using Uster Tester- 5. This is an electronic instrument used to measure the yarn hairiness, hairiness index and diameter unevenness. It uses the Fresnel Diffraction principle of laser beam to measure these properties. Uster Tester- 5 separates the interference at the right angle to the yarn from the direction of yarn running by means of spatial frequency filtering. Then, it detects the singles in proportion to the thickness and hairiness respectively.

The conventional optional hairiness test is influenced by the variation of yarn thickness due to the diffused reflection by the light. Uster Tester is free from the influence by the yarn thickness due to the spatial frequency filtering which enables Uster Tester to measure
the hairiness index. Hairiness (H) is defined as the total length of all the protruding fibers(hairs) measured in centimeters within one centimeters of yarn.

The power switch was pressed on the interface unit, the compressed air was opened and the air blow was pressed. The key was turned on into the measuring frame and left for approximately 30 minutes to warm up. CPU system and input UT were switched on at the DOS prompt.

The Uster Tester system program started. The laser beam was switched on. Input was fed for test conditions like material speed, and diametric amplitude and hairiness scale. The yarn was led to the measuring lot. F1 key was pressed to start the rollers. F5 key was pressed to start the measurements of hairiness. After completion of test data file was saved. Yarn samples from five bobbins were tested for cotton and cotton: wool blends. Print out indicating the hairiness value (HA), hairiness index (HI) and coefficient of variation percent was obtained from the instrument.

### 3.6 Development of knitted fabric samples

After preparing the yarn, knitted fabric samples were constructed on 10-12 gauge, flat bed hand knitting machine. Double jersey fabric was constructed with the help of latch needles. One knitted sample of 100% cotton and three knitted fabric samples of cotton (Mech I): wool (Indian crossbred wool)were prepared in 90-10%, 80-20% and 70-30% respectively.

### 3.7 Scouring of knitted fabrics

The developed knitted fabrics were first scoured to remove impurities. Natural fibers contain oils, fats and waxes, together with other impurities. Fabrics may contain oil and adventitious dirt collected during manufacturing. The term scouring applies to the removal of these impurities and extraneous materials. For the scouring of knitting fabrics following recipe was used:

\[
\begin{align*}
\text{MLR-} & \quad 1:30 \\
\text{Detergent -} & \quad 2\text{gpl}
\end{align*}
\]
Soda ash - 1gpl
Temperature - 50-60°C
Time - 30 Minutes
pH - 10

After scouring, washing was done 2-3 times with running water (Trotman, 1984)

### 3.8 Determination of physical properties of knitted fabrics

The tests given below were performed after conditioning the samples for 24 hours at 65±5 % relative humidity and 27± 2°C temperature.

#### 3.8.1 Weight per square meter (IS: 1944-1970)

Conditioned test sample of five specimens of 10 cm X 10 cm size (.01 square meters) were cut at random from fabrics and weight was taken on electrical balance. The average of the five readings was taken.

Weight in grams per square meter (g/m²) was calculated according to the following formula:

Weight in grams per square meter (g/m²) = W/A

Where,

W= weight of specimen in grams
A= area of specimen in square meter

#### 3.8.2 Wales per inch and courses per inch

To determine the wales / inch and courses / inch, conditioned knitted fabric was spread on the table and one square inch area was marked. Wales / inch and courses / inch were counted with the help of counting glass and dissecting needle. Five readings were taken at random and their mean was calculated.
3.8.3 Stitch density

Stitch density or loop density was calculated by multiplying the number of courses / cm (cpc) and wales / cm (wpc). (Parmar and Srivastava, 1999)

\[
\text{Stitch density} = \text{Cpc} \times \text{Wpc}
\]

3.8.4 Ks value and loop shape factor

Ks value and loop shape factor were calculated from following formula:

\[
\text{Ks} = \text{Kc} \times \text{Ks}
\]

Where \( \text{Kc} = \text{cpc} \times \text{l} \) (cpc is course per cm)

\[
\text{Kw} = \text{wpc} \times \text{l} \) (wpc is wales per cm)

l is stitch length. To measure stitch length, markings were made on fabric samples at a distance of 50 loops. Each course was carefully removed from the fabric and measured. The measured length was then divided by 50 to get the stitch length.

\[
\text{Stitch length} = \frac{\text{Course length}}{\text{No. of wales}}
\]

Loop shape factor \( R = \frac{\text{Kc}}{\text{Kw}} \) (Postel, R, 1974) and (Munden, D.L., 1959)

3.8.5 Tightness factor

Tightness factor (K) of knitted fabric was determined by the following formula (Padaman, A, and Subramaniam, 2003):

\[
\text{K} = \frac{T}{l}
\]

Where,

\( T = \text{Yarn linear density in Tex} \)

\( l = \text{Stitch length in millimetres} \)

To convert yarn count in Nm into tex following formula \( \text{tex} = \frac{1000}{Nm} \)
3.8.6 Effect of laundering on dimensional stability (IS: 648-1979)

To find out the effect of washing on shrinkage/extension of fabrics, the fabric samples were washed and for washing ISO test no. 1 was used.

The fabric samples were conditioned in a standard testing atmosphere before marking out. Test specimen of 12” × 12” size was taken and laid flat on a smooth surface. After removing all the creases and wrinkles, datum lines were carefully marked with sewing thread on an inside square of 10” × 10”. Then washing treatment was given to the samples. Detergent solution was prepared containing 5g / l soap. Samples were washed in launderometer for a period of 30 minutes at 40°C temperature. After washing, samples were washed in cold water, extra water was extracted and surface was air dried on a flat surface at room temperature. Then the samples were again laid flat on a smooth surface and creases and wrinkles were removed. The distance between the datum lines was measured. The percent shrinkage was calculated from the mean change in between the datum lines.

\[
\text{Percent Shrinkage} = \left( \frac{L_0 - L_1}{L_0} \right) \times 100
\]

Where, \( L_0 \) is the distance between the datum lines before washing and \( L_1 \) is the distance between the datum lines after washing. Course wise and wale wise shrinkage (linear shrinkage) was reported separately. In addition, arial shrinkage was also determined by following formula:

\[
\text{Arial density %} = \frac{A - B}{A} \times 100
\]

Where

\( A = w \times c \) (before washing)

\( B = w \times c \) (after washing)

\( w = \text{length in wale wise direction between datum line} \)

\( c = \text{length in course wise direction between datum line} \)
3.8.7 Skewness (AATCC: 179-1996)

This test method determines change in skewness in woven and knitted fabrics and twist in garments when subjected to repeated automatic laundering procedures commonly used in the home. To find out the skewness change in fabric, three conditioned samples of 38×38 cm were taken. Two 25 cm long pairs of bench marks were marked parallel to the length of the specimen and two 25cm long pairs of bench marks were marked perpendicular to the length of the specimen so that a square formed.

Fabric Marking Method

![Fabric Marking Method Diagram]

Then washing was done in washing machine. Machine was filled with 18 gal water. Water temperature was set at 41ºC. Agitator speed, washing time, spin speed and final spin cycle was selected as 119 rpm, 8 min, 645 rpm and 6 min respectively. AATCC standard
detergent was used for washing. Machine load was maintained 1.8 kg by adding enough ballast (white sheet of 92x92cm size) with test specimen. After washing washed load (test specimen and ballast pieces) was placed in tumble dryer and the temperature was controlled to generate the ≤ 60 °C exhaust temperature. The dryer was operated until the total load was dried. Then the fabric samples were spread on flat surface. After drying the specimen were conditioned at standard atmospheric conditions. After conditioning each test specimen was laid without tension on a flat smooth horizontal surface. Length of the diagonal line AC and diagonal line BD were measured to the nearest millimetre.

Marking specimen for specific calculation

![Diagram showing specimen marking for specific calculation](image)

**Fig- 3.2**

Change in skewness was done by the following formula:

\[
X = 100 \times \frac{2(AC-\text{BD})}{(AC+BD)}
\]
Where,

\[ X = \text{% change in skewness} \]

A positive percent change indicates skewness to the left and a negative percent change indicates skewness to the right.

3.8.8 Crease recovery (IS: 4681-1968)

“Eureka” crease recovery tester was used for measuring crease resistance of 100% cotton and cotton wool blended knitted fabrics.

Ten specimens were cut from the fabric template 2"long×1" wide in both wale and course directions. Each specimen was carefully creased by folding it half, placing it between the plates and adding a weight of two kg. After one minute the weight was removed and the specimen was transferred to the fabric clamp of the instrument and was allowed to recover from crease. The recovery time was one minute. After one minute, as it recovered, the dial of the instrument was rotated to keep the free edge of the specimen in line with knife edge. The recovery angle in degrees was read on the engraved scale. Wale wise and course wise recovery was recorded separately and means value was calculated.

3.8.9 Bursting strength (BS: 4768)

Digital bursting strength tester was used to determine the bursting strength of knitted fabric. This method is based on the principle that specified area of the sample of fabric under test is clamped over an elastic diaphragm by means of a flat annular clamping ring, and an increasing fluid pressure is applied to the underside of the diaphragm until the specimen bursts.

In this method glycerine was used as operating fluid. For the test five specimens of 75mm×75mm size were cut. Each test specimen was clamped on 30mm diameter clamping ring. This clamping ring holds the specimen firmly against the diaphragm at all points. After it fluid pressure was increased smoothly so that the specimen burst within 20±3 seconds. Bursting strength was recorded by computer and test was repeated with other test specimen. The mean bursting strength was reported as Kg/cm².
3.8.10 Abrasion resistance (IS: 12947-2-1999)

Martindale Abrasion Tester was used to check the abrasion resistance of the fabric. In this method a circular specimen, mounted in a specimen holder and subjected to a defined load is rubbed against an abrasive medium (standard fabric) in a translational movement tracing a Lissajous figure, the specimen holder being freely rotatable around its own axis perpendicular to the plane of the specimen. The evaluation of the abrasion resistance of the textile fabric is determined by the inspection at regular interval till 5000 rubs (rubbing cycle).

Before starting the machine at least 3 conditioned specimens of 38 mm diameter were taken from the fabric sample. Standard wool fabric of 140 mm diameter was used as abrading material, 9 kpa abrasion load was applied. Test specimen was placed in the specimen holder with wear side downward. The foam backing was used with the test specimen. For the abrasion test class interval of 1000 rubs (rubbing cycle) was selected. Abrasion tester was started and continued without interruption until the preselected number of rubs was reached. The specimen holder with the mounted specimen was removed carefully from the testing machine. Specimen was weighted on weighing balance. Then specimen with holder was replaced in the machine and next test interval was started. This test and assessment sequence continued till 5000 rubs (rubbing cycle).

The amount of abrasion loss was estimated by weighing the specimen after each 1000 rubs (rubbing cycle). Abrasion loss was derived by the following formula:

\[
\text{Abrasion loss(\%)} = \frac{\text{Initial weight} - \text{weight after 1000 cycles}}{\text{Initial weight}} \times 100
\]

3.8.11 Pilling (IS: 10971-1984)

ICI Pilling box was used to test the pilling of the fabric samples. For this test four specimens each 125mm×125mm were cut from the fabric. A seam allowance of 12 mm was marked on the back of each square. In two of the samples the seam was marked parallel to the wale direction and in other two parallel to the course direction. The samples were than folded face to face and a seam was sewn on the marked line. This gave two
specimens with the seam parallel to the wale and two with the seam parallel to the course. Each specimen was turned inside out. The fabric tubes made were then mounted on rubber tubes. Each of loose ends was taped with PVC tape so that 6mm of the rubber tube was left exposed. All four specimens were tumbled together in a cork-lined box. Tester was allowed to run 18000 revolutions. The specimens were evaluated by comparing it with the standard table:

<table>
<thead>
<tr>
<th>Number of Pills</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-4</td>
<td>5</td>
</tr>
<tr>
<td>5-10</td>
<td>4</td>
</tr>
<tr>
<td>11-20</td>
<td>3</td>
</tr>
<tr>
<td>21-40</td>
<td>2</td>
</tr>
<tr>
<td>41-60</td>
<td>1</td>
</tr>
<tr>
<td>Above 60</td>
<td>0</td>
</tr>
</tbody>
</table>

Table -3.3 Comparison of the pills

3.8.12 Thermal Resistance (ASTM D1518-14)

SASMIRA Thermal Conductivity Tester was used to determine the thermal insulation value. Sample of 15 cm diameter was placed over hot plate. A gap of 5mm was kept between hot plate and sample. The temperature of guard plate was maintained at 50°C and that of hot plate at 45°C. The drop in temperature in °C was recorded in sample at different intervals, i.e. 15, 30, 45 and 60 min. The measurements were carried out at room temperature (27±2°C), maintaining the hot plate temperature at 37°C to simulate human body temperature. The temperature gradient was calculated for knitted sample and Clo value was determined by using standard calibrated graph in m²s°C-cal. (Shakyawar et al., 2007). Three readings were taken for each sample. Thermal insulation value percentage was calculated using the following relationship:

\[
\text{Thermal Insulation Value (%)} = \frac{\text{Clo value of fabric} - \text{Clo value of bare plate}}{\text{Clo value of fabric}}
\]
3.8.13 Air permeability (IS: 11056-1984)

Air permeability of knitted fabric was measured by using SDL Air Permeability Tester. The method is based on the measurement of the rate of flow of air through a given area of fabric at a given pressure drop across the fabric. For the purpose of this standard, air permeability shall mean the volume (cm³) of air passing through one square cm of fabric per second at a pressure difference of 1 cm head of water.

For the test conditioned test specimen was taken and mounted between the clamps with sufficient tension by eliminating wrinkles. The suction fan was started to force air through the fabric and the rate of flow of air was adjusted till pressure drop of one centimeter water head across the fabric was indicated. Test was repeated at ten different places and result was recorded directly by computer.

3.8.14 Wettability

The ability of a fabric to absorb water, especially by a wicking or capillary action, may be observed by timing the rate at which water climbs up a narrow strip of fabric or suspended vertically with its lower end dipping into the water. (Booth, 1976)

Sample of size 10 X 1 inch was taken and suspended vertically with its lower end of 1 inch dipped into water. Height of climb was observed after 10 minutes. Rate of wetting was calculated by given formula-

$$\text{Rate of wetting (inches/min)} = \frac{\text{Height of climb after 10 minutes}}{10}$$

3.8.15 Fabric handle

Fabric handle was objectively assessed by SiroFAST. SiroFAST is a set of instruments and test methods for measuring mechanical and dimensional properties of fabric that can be used to predict performance in garment manufacture and the appearance of the garments in wear. It was developed in Australia by the CSIRO Division of Wool Technology to meet industry's need for a simple, reliable method of predicting fabric performance. (Boos, De, A., 2005)
Schematic diagram of deformations important in garment manufacture

Fig-3.3

SiroFAST consists of three instruments and a test method:

SiroFAST-1 is a compression meter that measures the fabric thickness.

SiroFAST 2 is a bending meter that measures the fabric bending length.

SiroFAST-3 is an extension meter that measures fabric extensibility.

SiroFAST-4 is a test procedure for measuring dimensional properties of fabric

Table – 3.4 Properties describing resistance to deformation

<table>
<thead>
<tr>
<th>Deformation</th>
<th>Property</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile</td>
<td>Extensibility</td>
<td>Extension of a fabric required under a redefined load.</td>
</tr>
<tr>
<td>Bending</td>
<td>Bending Rigidity</td>
<td>Couple required to bend unit width of a fabric to unit curvature</td>
</tr>
<tr>
<td>Shear</td>
<td>Shear Rigidity</td>
<td>Shear load required to deform unit width of fabric to unit stain</td>
</tr>
</tbody>
</table>
A schematic diagram of the instruments

Fig- 3.4 SiroFAST-1 compression meter

3.8.15.1 SiroFAST-1 Compression meter

The SiroFAST-I Compression meter measures thickness of fabric which is defined as the difference in accurately measures fabric thickness measure that the two loads, and is of 2g-cm² and 100 g-cm². The surface layer is calculated from these measurements. The measurements are normally made on the (conditioned) fabric and then repeated after the fabric as been relaxed in steam. From these measurements the released thickness and released surface layer thickness are obtained. Comparison of the original surface thickness and the released surface thickness can be used to assess the stability of the finish on the fabric under the conditions of garment manufacture, such as pressing and steaming.
3.8.15.2 SiroFAST-2 Bending meter

This measures fabric bending length using the cantilever bending principle, as per British Standard Method (BS: 3356 (1961)). Bending rigidity is a measure of the stiffness of a fabric and is related to handling in garment making. It uses a photocell to detect the leading edge of the sample. It eliminates the operator error and SiroFAST 2 bending meter more reliable and simpler to use than alternative instruments.

3.8.15.3 SiroFAST-3 Extensibility meter

The SiroFAST-3 extensibility meter measures the extensibility of a fabric under three different loads (5, 20 and 100 W eing of width). The loads are chosen to simulate the level of deformation the fabric is likely to undergo during garment manufacture. SiroFAST-3 is
also used to measure the bias extensibility of the fabric (a 145° to the warp direction) under a low load (5g-cm width). Bias extensibility is not used directly but instead is used to calculate shear rigidity. Shear rigidity is one of the principle determinants of the ease, which is a measure of the ease with which a fabric can be deformed into a three-dimensional shape.

Formability is derived from measurements made using SiroFAST-3 in combination with data from SiroFAST-2

Formability = Bending Rigidity X ((Extension (20g/cm) - Extension (5g/cm))

![Diagram of dimensional stability]

**Fig- 3.7 SiroFAST-4 Dimensional stability**

### 3.8.15.4 SiroFAST-4 Dimensional stability test

SiroFAST-4 is a test method for measuring the hygral expansion and relaxation shrinkage of fabric. SiroFAST-4 is a modification of the conventional "wet-dry" test and can be completed in less than two hours; another advantage of SiroFAST-4 is that the fabric does not require conditioning. With SiroFAST-4 the fabric is dried in a convection oven at 105°C and its dry dimensions measured. The fabric is then relaxed by wetting in water and its wet dimensions measured. Lastly, the fabric is dried again at 105°C and its final dry dimensions are measured.

**Sampling for SiroFAST tests**

SiroFAST-1, 2, 3 test samples are 150 mm X 50 mm.
SiroFAST - 1 Compression - 5 replicates

SiroFAST – 2 Bending – 3 warp and 3 weft replicates

SiroFAST- 3 Extension - 3 warp, 3 weft, and 6 bias replicates (3 left-bias and 3 right-bias)

SiroFAST-4 requires a separate sample (300 X 300 mm).

The Instron model 2810-005 coefficient of friction measures the static and kinetic coefficient of friction of plastic film and sheet. It includes a 200 g square metal sled wrapped with a 1/8 in (3.2 mm) thick foam pad and a rectangular-shaped metal table with a defined surface finish. A pulley is located at one end of the table that allows the sled, when attached to the crosshead via a nylon or metal tow line, to be pulled horizontally along the plate. The test sample can be attached to the sled, the plate, or both. The Coefficient of Friction Fixture is mounted in the testing system load frame using Instron’s standard Type D base grip adapter. The pull cord attaches to the upper load cell using an Instron Type C couple.

**Principle of Operation**
The coefficient of friction test fixture consists of a fixed horizontal table and a moveable sled. Both the table and sled can be covered with the test material. A tow line attaches the sled to a low-force load cell with a pulley that guides the tow line during the test. The fixture is mounted to the base of the instrument and, as the crosshead/ load cell moves, the sled is pulled across the horizontal table. Data is recorded from the load cell during the test and analyzed to determine both static and kinetic friction. The static friction is derived from the first maximum peak (force) on the load curve and kinetic friction is derived from the average force between two pre-defined points. The coefficient of friction is defined as the recorded force divided by the mass of the sled.

3.8.17 Subjective evaluation of hand of fabric

Fabric samples were evaluated for their hand and touch and feel method. For this purpose twenty experts from the fields of textiles were selected purposively to evaluate the fabric samples independently. The hand was evaluated on five point rating scale which was very
soft, soft, medium, harsh and very harsh. The collected data were then processed and analyzed on the basis of weighted mean score (w.m.s)

\[
W.M.S. = xx +yy +zz - \text{Total number of respondents}
\]

Where,

\[
X,y,z= \text{Attributes}
\]

\[
X,y,z= \text{Number of respondents}
\]

3.8.18 Drape (BS: 5058)

For determining % drape coefficient of fabric, a drape meter was constructed.

Drape meter measures three dimensional fabric deformations due to gravity. The experimental method generally involves hanging fabric specimens of 15 cm radius over supporting disc of 9 cm radius. Unsupported area drapes down under its own weight. Drape is measured as drape co-efficient which theoretical various 0 and 100. Circular fabric specimens of 30cm diameter were placed on hard board disc and used for making shadows of draped specimens.

Hardboard disc was raised close to the top disc (diameter 15 cm). Specimen was placed in such a way that centre of the specimen coincided with centre rod. The second disc was placed over the fabric so as to hold down the fabric clamp thus allowing the specimen to drape under its own weight. With the help of narrow light, a shadow of the draped specimen was obtained on the circular paper placed on hardboard disc. The outline of the shadow was drawn on the tracing paper. Shadow area was cut out with scissors and weighted on analytical balance. Weight per unit area of paper used was also determined. The following % drape coefficient of fabric was calculated from the following formula-

\[
\% \text{ Drape coefficient} = \frac{A_s - A_d}{A_D - A_d} \times 100
\]

Where,
As = area of draped specimen

Ad = area of supporting disk

AD = area of specimen

\[ As = \frac{W}{W} \]

Where

w = weight per unit area of paper

W = weight of shadow area of draped pattern

3.9 Product development

Prototypes of ladies garment were developed which included top, sweater and jacket. Designing of top, jackets and sweater was done in the following steps:

3.9.1 Collection of designs

Various illustrations of knitted tops, jackets and sweaters were collected from various sources. These sources were:-

- Books
- Fashion magazines
- Internet
- TV

Books and Fashion magazines available in Central and Department library, Institute of Design of Banasthali University and library of Central Sheep and Wool Research Institute, Avikanagar were referred to find out the illustration of knitwear garments.

3.9.2 Development of design sheets

Different designs for ladies tops, sweaters and jackets were developed for teenagers keeping in mind their preferences. These were developed by making modification into
existing design and with new design ideas. Latest trend in fashion was also taken into consideration while designing. Total 18 designs were prepared (6 designs for each type i.e. ladies top, sweaters and jackets). 3 designs for each type of garment were planned by adding colours / designs in knitted fabric (fabric dyeing) while in other 3 designs, coloured yarns were incorporated at the stage of fabric manufacturing (yarn dyeing) in each garment category. Designs were sketched on a white sheet. To get favorable results, various desired details and features were used on design sheets. Colours of autumn winter, 2015- blue, pink, purple, orange and grey were selected according to forecasted colour scheme given by Pinterest. (http://www.pinterest.com-pin-190066046748581617)

3.9.3 Evaluation of developed designs-

Developed design were evaluated by respondents comprising 100 students of class XI and XII, Kendriya Vidyalaya (Avikanagar, Malpura).

The design sheets were displayed to the respondents and evaluated on the basis of - Colour combination, Aesthetic appeal, Uniqueness in design. Three point rating scale was used as given below:-

<table>
<thead>
<tr>
<th>Rating No.</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Excellent</td>
</tr>
<tr>
<td>2</td>
<td>Good</td>
</tr>
<tr>
<td>1</td>
<td>Fair</td>
</tr>
</tbody>
</table>

Table 3.5: Rating scale
Weighted mean score was calculated for each criterion. Total weighted mean score of each design was calculated by adding score of each criterion. Designs were ranked on the basis of total weighted mean score obtained by each design.

Out of 18 designs 2 designs each for ladies tops, sweaters and jackets were selected on the basis of rank. Thus total six designs were selected for prototype preparation.

3.9.4 Development of selected designs into prototype

Garments were manufactured from blended cotton: wool knitted khadi fabrics (2 garments from each blend ratio that is 90 C: 10W, 80C:20W and 70C: 30W respectively). Yarns and fabrics were dyed as per the design by cross dyeing method using direct and acid dyes before construction of garment. Fabric/yarn was first dyed with direct dye and then acid dye. Recipe used for dyeing with direct and acid dyes are mentioned below-

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Chemical</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sodium chloride</td>
<td>10g/l</td>
</tr>
<tr>
<td>2</td>
<td>Sodium carbonate</td>
<td>3g/l</td>
</tr>
<tr>
<td>3</td>
<td>MLR</td>
<td>1:40</td>
</tr>
</tbody>
</table>

The fabric was pre-soaked in water. Amount of dye was calculated and dye paste was prepared with lissapol. Dye paste was added at 40°C into dye bath and stirred properly. The pre-soaked material was added into dye bath. The temperature was raised to 80°C within 10-15 minute. The fabric was removed from dye bath and sodium chloride and alkali were added. The fabric was re-entered into the dye bath. Dyeing was done at boiling temperature for 10-15 minute. The fabric was removed from dye bath and washed with plain water. (Trotman, 1984)
Table 3.7: Recipe for acid dyes

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Chemical</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MLR</td>
<td>1:40</td>
</tr>
<tr>
<td>2</td>
<td>Sodium sulphate</td>
<td>5%</td>
</tr>
</tbody>
</table>

Amount of dye was calculated and divided into two equal parts for two installments. Similarly the amount of sodium sulphate required was calculated and divided into two equal parts for two installments. Dye paste was prepared with ezee and acid dye. First installment of dye paste was added at 40°C in the dye bath and stirred properly. Sodium sulphate was added into beaker. The pre-soaked material was put into dye bath. The temperature was maintained at 40 – 60°C for 30 min. After that second installment of dye paste was added into dye bath. Dyeing was continued for 45 – 60 min. After it the fabric was removed from dye bath and washed with plain water. (Trotman, 1984)

3.9.5 Assessment of developed prototype

A panel of 50 respondents was selected to judge and evaluate constructed tops, sweaters and jackets. All respondents were selected from Department of Home Science because they have knowledge of designing and latest fashion trends.

Tops, sweaters and jackets were draped on dummies and shown to judges to analyse the developed tops, sweaters and jackets in knitted khadi.

4 criteria were decided for evaluation of tops, sweaters and jackets i.e. Colour combination, Aesthetic appeal, Uniqueness in design and cost. Acceptability of the designed khadi ladies tops, sweaters and jackets was evaluated.

3.10 Pricing and costing of the developed prototype

For price determination, material cost (includes fabric cost, thread cost, needle cost and accessory cost), drafting and stitching cost was also included and 20% extra cost was added as profit margin. Fabric cost included cost of fiber, yarn manufacturing cost and fabric knitting cost.
3.11 Statistical analysis of data

The statistical techniques used in this investigation are as follows:

Mean: Mean has been used in this investigation to get the average value of a set of raw scores:

\[
\text{Mean} = A \pm \sum \frac{fd}{n} \cdot i
\]

Where,

A = assumed mean

f = frequency from assumed mean

d = deviation from assumed mean

\[\sum fd\] = sum of frequency deviation

n = number of observations

i = group intervals

Standard Deviation

This has been used to know about the spread of data around mean on different variables of the study

Calculation of the SD from the distribution data was done using formula:

\[
\text{SD} = \sqrt{\frac{\sum fd^2}{n} - \left(\frac{\sum fd}{n}\right)^2}
\]

Where,
f = frequency in each class interval

d = deviation from assumed mean

n = number of observations

i = group intervals

**Coefficient of Variation (C.V.)**

This statistics is the measure of dispersion of values around its mean value i.e. to reflects the variability of the scores.

The coefficient of variance (CV %) was derived from the standard deviation and the mean as follows:

\[
CV\% = \frac{S.D.}{Mean} \times 100
\]

**Coefficient of correlation**

This has been used to see that to what extent two variables or things are relation and to what extent variation in one variable go with variations in the other. The coefficient of correlation was calculated for the different properties of fibers, yarns and also for the different properties of experimental knitted fabrics.

**ANOVA**

ANOVA was used to find out whether there is significant difference between the properties of different blend ratios.

**t-Ratio**

This has been used to know how far the two means representing the value of the two concerned variables differ significantly.

SPSS and Microsoft excel were used for all statistical procedures.