CHAPTER - 4

RESULTS AND DISCUSSION

The aim of this project was to develop a Data based mathematical model for comfort of suiting fabrics which can compare two fabric samples for their mechanical as well as thermal comfort. Fabric data related to structural, mechanical and thermal properties of Polyester Viscose blended suiting fabrics commercially produced from a wide range of yarn counts and weaves are chosen for this study. It eliminates the chances of any unrealistic data that might have been produced in fabric samples prepared in the laboratories.

Kawabata's Evaluation system for fabric (KESF) developed by Prof.Suo Kawabata is used to evaluate fabrics for Hand Values (HV's) and Total hand value (THV). The system developed in this project also compares two fabric samples in similar terms of mechanical as well as thermal comfort factors and also over all comfort value. But the system has two important features which make it different from KESF.

1. This system does not incorporate any subjective grading by judges. It is totally an objective method of evaluation of fabric comfort. Comfort factors are obtained from regression analysis with the fabric properties selected based on their correlation coefficients. Thus it is free from the main draw back of KESF system which is based on subjective grading by Japanese judges and is unsuitable outside Japan.
2. In this method simple instruments and techniques available in most textile testing laboratories in India are used for evaluation of yarn and fabric properties rather than costly instruments used by KESF system for fabric.

Results of this work are discussed in three parts:

I. Properties of yarn which influence fabric comfort properties.

II. Fabric properties contributing to mechanical and thermal comfort.

III. Comfort analysis and development of software **FabCOM - Fabric Comfort by Objective Measurement.**

4.1 Yarn Properties contributing to comfort properties of suiting fabric.

Suiting fabrics selected in this study (see table 1, page 94) have been produced from two ply 65/35 P/V blends yarn in the count range from 2/15 Ne (78.77 tex) to 2/60 Ne (19.75 tex). Analysis of various yarn properties gives useful relationships with yarn count. Yarn properties tested in section 3.2 are summerised in different counts In Table 27.

Table 27. Properties of constituent yarns used in the fabric samples.

Yarn code	Count Ne Tex	Twist per inches TPI	Hairiness s3- value	Flexural Rigidity(m) gm-cm^{2}x10^{-4}	Tensile modulus @5%extension(Ey) gms/denier x10^{-3}
$Y_{2/15}$	2/15	11.74	966	67.88	20.85
$Y_{2/18}$	2/18	12.08	554	66.89	20.71
$Y_{2/20}$	2/20	13.38	404	53.57	23.21
$Y_{2/24}$	2/24	13.09	322	44.17	23.05
$Y_{2/30}$	2/30	15.53	169	41.39	24.56
$Y_{2/40}$	2/40	17.14	131	40.30	25.93
$Y_{2/60}$	2/60	19.75	50	20.29	27.87

$Y_{2/15}$ – is the 2-ply yarn having 15 Ne count.

Besides other spinning parameters such as spinning system, fibre properties and chemical finishes, yarn twist plays important role in deciding its properties.

Ply twist in Yarn varies as power function of yarn count (Ne). Yarn twist increases the circularity and packing density of yarn, and also regulates the yarn hairiness and bending properties.

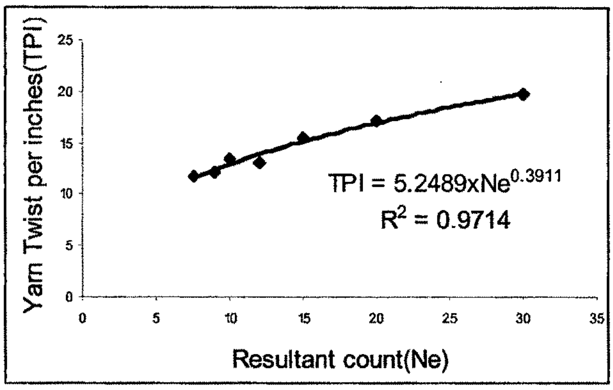


Fig.48. TPI increases in finer yarns.

Yarn hairiness affects the fabric compression and surface properties and also fabric cover. Air permeability which decides thermal property of cloth depends on fabric cover. Yarn hairiness depends on fibre fineness and its bending property, spinning system and yarn twist. In fig 49 the yarn hairiness measured in terms of s3-value (average number of hairs of less than 3 mm length) decreases in finer yarns. Finer yarns contains longer, finer fibres gives compact yarns with less hairiness.

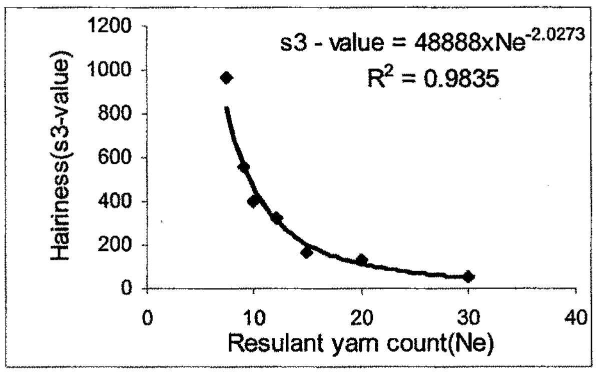


Fig.49. Hairiness decreases in finer yarns

Flexural rigidity as a measure of its bending resistance plays important role in fabric forming and

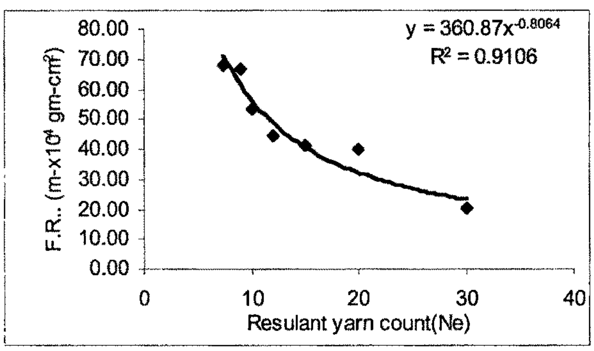


Fig.50. Finer yarns offer less bending rigidity

the crimp balance in the fabric.Yarn flexural rigidity is affected by the fibre bending and surface properties (shearing effect of fibres during yarn deformation), yarn structure and yarn fineness.

Yarn tensile modulus Ey in grams per denier at 5 % extension as a measure of yarn extensibility affects fabric extensibility and shear deformation.

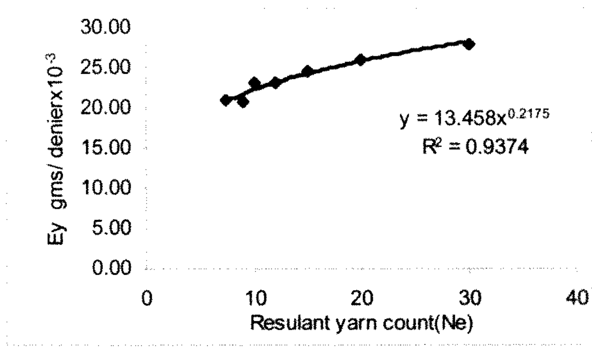


Fig.51. Extensibility decreases in finer yarns

The regression equations obtained above relating yarn properties with yarn count (Ne) can be used as guideline for prediction of the yarn properties for the PV blended yarns. For other blends and spinning conditions similar equations can be obtained to predict yarn properties.

4.2 Fabric properties contributing to mechanical and thermal comfort.

4.2.1 Fabric constructional parameters:

Yarn tensile and bending properties along with fabric weave (effect of yarn interlacement) and fabric sett (i.e. epi and ppi), determine fabric construction. Fabric dimensional parameters such as fabric thickness and aerial density influence its mechanical properties related to compression, bending and shear properties. Thermal properties are greatly influenced by fabric thickness and fabric cover factor.

Fabric sett :

Weave factor as discussed in section 2.2.1.2 affects fabric sett. Plain weave has least value of the weave factor as compared to 2/1 twill and 2/2 twill which has highest value. Thus plain weave gives least value of fabric sett, 2/1 twill gives higher fabric sett and 2/2 twill produces still higher sett. With increase in fabric sett cloth cover increases which influence fabric thermal property.

Table 28. Fabric constructional parameters:

Fabric Code	Weave	Weave factor	Fabric sett EPI	PPI	Intersections per sq. inch	Crimp % Warp	weft	Cloth cover	Weight in gms per sq. meter	Fabric Thickness @ 10 gm per sq.cm	@ 50 gm per sq. cm
		M	n1	n2	I	c1	c2	kc	W	t_{10}	t_{50}
A1	Plain	1	42.4	36.0	1526	5.2	14.6	21.36	273	0.556	0.528
A2	Plain	1	51.0	41.0	2091	7.5	11.8	22.37	265	0.498	0.478
A3	Plain	1	50.0	40.0	2000	5.0	12.2	22.06	253	0.485	0.460
A4	Plain	1	52.0	40.0	2080	4.6	12.1	21.66	234	0.439	0.417
A5	Plain	1	62.0	51.8	3212	5.6	14.7	21.74	194	0.383	0.348
A6	Plain	1	95.6	40.8	3900	11.4	2.7	25.93	235	0.452	0.422
A7	Plain	1	66.2	53.4	3535	5.4	13.6	22.46	210	0.391	0.354
A8	Plain	1	75.6	63.2	4778	5.4	12.6	24.13	180	0.324	0.297
A9	Plain	1	64.0	53.6	3430	2.2	15.4	20.17	152	0.325	0.291
A10	Plain	1	117.2	67.8	7946	10.5	3.3	27.00	219	0.358	0.334
A11	Plain	1	87.6	70.8	6202	2.9	16.2	21.54	140	0.281	0.247
B1	Plain	1	50.0	40.8	2040	5.3	13.8	21.73	243	0.487	0.460
B2	Plain	1	50.0	42.0	2100	3.3	15.6	21.59	239	0.477	0.447
B3	Plain	1	49.8	48.6	2420	3.8	15.0	21.89	234	0.459	0.430
B4	Plain	1	54.8	46.6	2554	7.0	15.2	21.91	228	0.432	0.401
B5	Plain	1	52.4	62.6	3280	1.3	21.7	22.28	219	0.424	0.389
C1	Plain	1	66.0	55.2	3643	8.4	11.6	22.62	212	0.397	0.361
C2	plain	1	85.5	56.5	4831	15.2	5.3	25.16	248	0.437	0.404
C3	2/1twill	1.5	88.4	62.4	2452	8.8	9.2	25.80	261	0.455	0.422
C4	2/2twill	2	79.4	72.2	1433	6.2	14.3	25.49	269	0.460	0.423
D1	2/1 twill	1.5	49.2	57.6	1260	5.5	11.7	21.53	267	0.438	0.411
D2	2/1 twill	1.5	87.0	67.0	2591	8.0	9.3	25.88	261	0.444	0.414
D3	2/1 twill	1.5	77.0	58.0	1985	6.3	13.2	24.22	233	0.422	0.393
D4	2/1 twill	1.5	121.7	66.3	3587	9.4	6.5	27.63	256	0.453	0.426

Fabric Tightness :

The number of intersections of threads per sq. inch of cloth as a measure of yarn interactions is maximum for plain weave and least for 2/2 twill or Satin weave. Twill or satin weaves produce denser fabric sett but the larger floats results in poor yarn interactions. Thus plain weave gives tight structure and stiffer fabric as compared to twill weaves.

Cloth cover:

It is the measure of area covered by the constituent yarns out of the total projected area. Denser fabric sett gives higher cloth cover. Coarser yarns with less twist and more hairiness further increase the cloth cover. Calendaring and other mechanical finishes are given to flatten the fabric and hence increase the cloth cover. Finer yarn being less hairy if woven into denser sett gives thin papery feel to the fabric. Thus cloth cover is an important fabric constructional parameter affecting fabric performance.

Yarn crimp:

The excess length of crimped yarn in the fabric determines the low stress fabric mechanical properties. At the weaving stage crimp in the fabric depends on the yarn balance β given by the ratio of weft diameter to the warp diameter, tension on warp and weft, bending property given by yarn flexural rigidity of warp and weft, fabric sett i.e. epi and ppi etc. Though

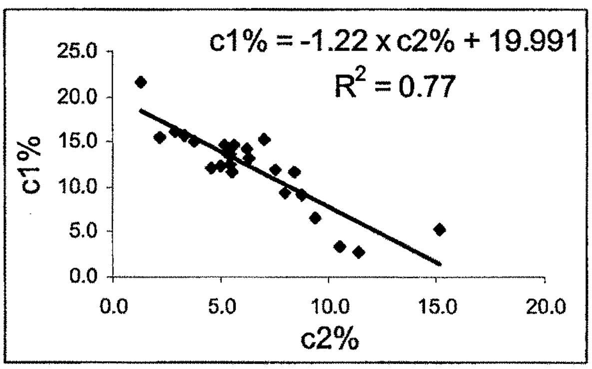


Fig.52. Crimp balance in finished cloth

yarn crimp is further set at the finishing stage on stenter, final crimp balance in the finished fabric is governed by the linear eq. $c2\% = -1.135\, x\, c1\% + 19.64;\ \ R^2 = 0.72.$

Thus crimp in one set of yarn is balanced by the crimp in transverse threads.

Fabric thickness:

Theoretically the sum of warp and weft diameters gives third dimension to the fabric perpendicular to plane of the cloth called thickness. Thus count of yarn predominantly decides the fabric thickness. Weave interlacement affecting fabric tightness also affects fabric thickness. Twill weaves gives higher thickness than plain woven fabric. Yarn hairiness and its bulk density further affect fabric thickness. Calendaring process in finishing makes fabric flatter. Thicker fabric entraps more air within it to provide thermal insulation in cold weather. Increase in fabric thickness increases fabric stiffness which results in reduction of the true fabric/skin area of contact. The air pockets between fabric and skin reduces the rate of cooling from fabric and provides warmth.

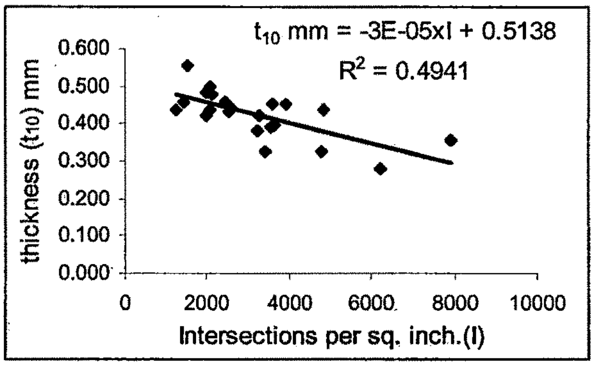


Fig.53 Effect of weave intersections on thickness

Fabric weight (GSM):

Yarn count, fabric sett and yarn crimps are primarily accounted for the fabric weight calculation. Heavier fabric gives better drape and thus graceful appearance. But fabrics produced from coarser count are heavier and also

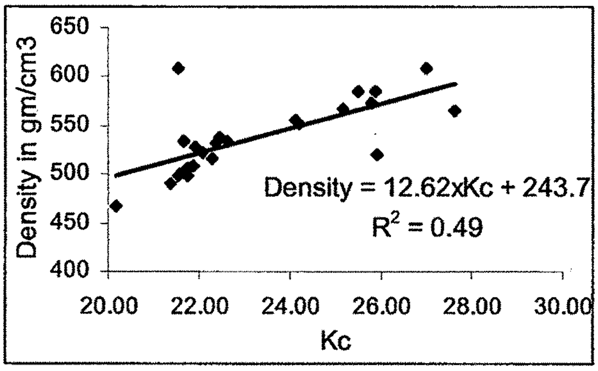


Fig. 54..Denser sett increases fabric density

thicker which may not be comfortable. So fabric weight is divided by thickness to get fabric density. Density increases with fabric cover.

Thus finer count with denser sett (epi and ppi) increases fabric cover to give graceful fall and fuller appearance of the garments which is opposite to the thin papery feel.

4.2.2 Fabric mechanical properties:

It is evident from the preceding sections that yarn properties and fabric construction demonstrate most of the fabric properties. In section 3.3 various mechanical properties obtained through simple testing of fabric. Fabric mechanical comfort parameters are obtained from these fabric properties are tabulated in table 18. Mechanical comfort of fabric is judged through five mechanical deformation of cloth under stress viz. tensile, bending, compression, shear and surface smoothness.

i) Tensile property:

Fabric extensibility is desired while the fabric is stretched during body movement such as movement of arms and legs,

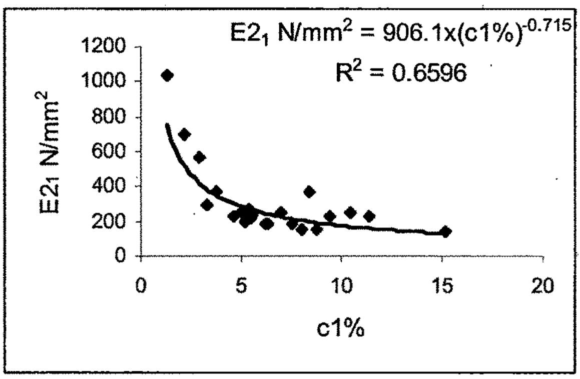


Fig.55. Low crimp gives rigid cloth

bending of torso during sitting etc. Fabric modulus in N/mm^2 at 2 % extension (E_2) in two principal directions as a measure of fabric extensibility is found to decrease with increase in crimp percentage. Lower warp crimps as compared to weft crimps in most of the fabric samples give higher modulus in warp direction and thus lower extensibility. Extensibility decreases as the number of interlacement of the weave decreases from plain, to 2/2 twill weaves as flat portion between the interlacement in twill and matt weave do not contribute to fabric extensibility.

ii) Fabric bending property:

Flexural rigidity value for the fabrics samples has been obtained from fabric weight and bending length in sect 3.4. Thus it gives fabric stiffness in bending as has been appreciated by fingers while fabric is grasped. Heavier fabrics appear stiffer to fingers.

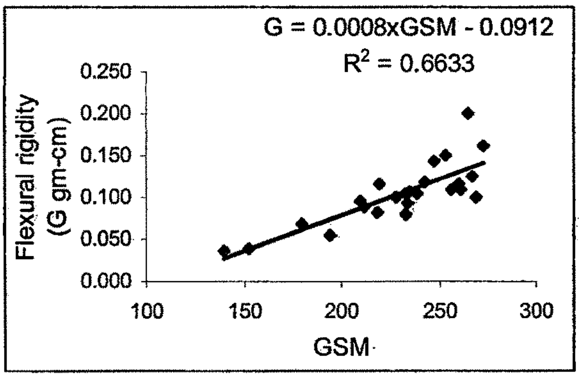


Fig.56. Heavier fabrics are stiffer.

Plain weave fabric bends less due to more number of interlacements per unit area and appears stiffer. Fabric thickness also plays important role in bending. So bending modulus is calculated from flexural rigidity and

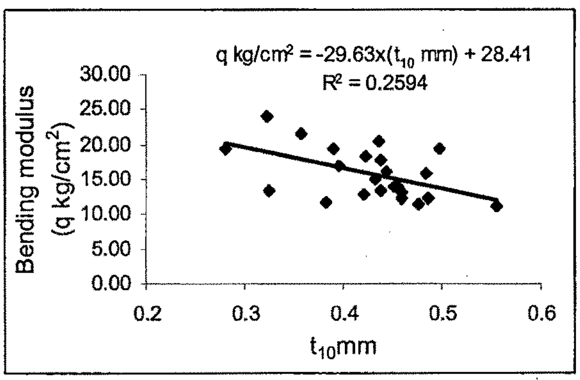


Fig.57. Thin fabrics give papery feel.

fabric thickness to take into account fabric thickness. It determines the draping quality of the fabric. Lower value of q gives fuller feel, opposite to thin papery feel.

iii) Shear deformation of cloth:

When applied load is in bias direction to both warp and weft, fabric shear deformation causes threads sliding. This changes the angle between warp and weft threads. At critical angle when no sliding of threads are possible, compressive stress buckles fabric or wrinkle appears. Fabric extension in bias direction at which wrinkle starts expressed as Eb % is a measure of fabric shear deformation. The buckling of a specimen during shearing is affected by thickness and weave interlacements and hence the fabric stiffness. Plain weave fabric has the highest shear rigidity because of more yarn to yarn interlacing with smaller float. Higher sett leaves less space for sliding which causes fabric to buckle at lower % extension. Fabric is poor in shear

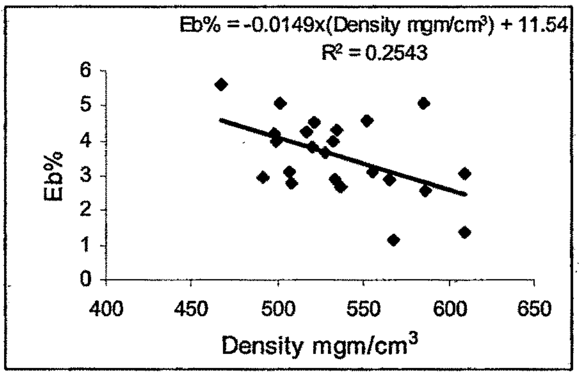


Fig.58 Denser sett gives poor shearing

iv) Fabric compression property:

Fibre blend and yarn twist decide the bulk density of yarn. Yarn hairiness, weave and sett affect fabric compression property. Fabric thickness measured at two different pressures is used to calculate fabric softness parameters such as surface hardness and compression modulus. These properties indicate the softness of fabric as appreciated by pressing between fingers.

v) Fabric surface smoothness:

It is a surface character. Fibre and yarn surface properties govern fabric smoothness. For a fibre type and yarn structure increasing threads per inch, the fabric surface becomes smoother. Coarser yarn increases fabric surface roughness due to increased crown height or crimp amplitude. The effect of weave can not be ignored. Plain fabrics with a regular interlacement give flat, smooth surface in comparison to twill fabrics with lower regularity and thus higher surface roughness. Fabric sett decided by yarn count and weave also decide the smoothness. Fabric surface smoothness is measured using sled covered with rubber to simulate human skin. The frictional amplitude of the

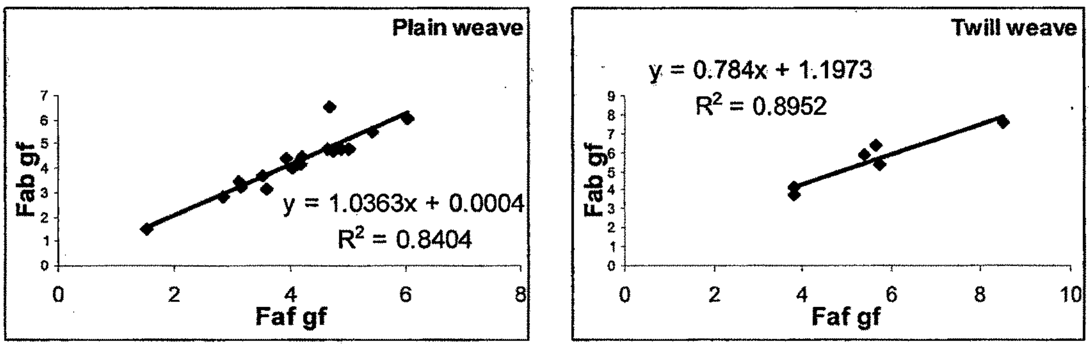


Fig.59 Plain cloth poses same surface smoothness of face and back while for twill it differs.

stick-slip motion of load-displacement curve represents the smoothness. The plain weave fabric have similar surface smoothness on face as well as the back side as shown in fig.59. the graph passes through origin with slope 1. In case of irregular weaves such as irregular twill smoothness differs on either sides.

4.2.3 Cloth thermal comfort properties:

Important facets of fabric thermal comfort include:

1. Movement of air through fabric: Air permeability is a measure of air movement. It decreases with increase in cloth cover. Twill weave with larger floats and less intersections of threads gives higher air permeability than plain weave. Air permeability influences thermal comfort. It removes vapour from the body and reducing sweating. Bad smell escape from body giving freshness.

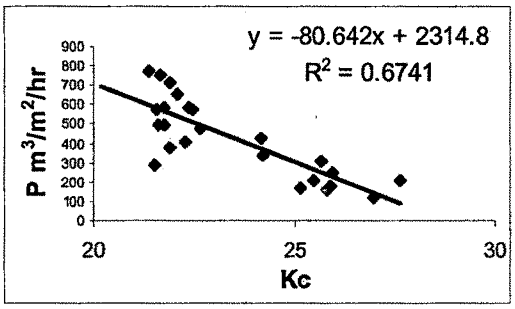


Fig.60 Open fabric assists permeability.

2. Dry heat transfer to and fro the body

Thermal resistance which is opposite of the thermal conductance, is affected by fabric thickness. Fabric thermal resistance increases with thickness. Fabrics with regular, flat and smooth surface give a cooler feel. Fabrics with twill weave have increased thickness and irregular surface, hence has the highest value of thermal resistance, whereas plain fabrics with lower thickness and smoother surface have in general the lowest value of this parameter.

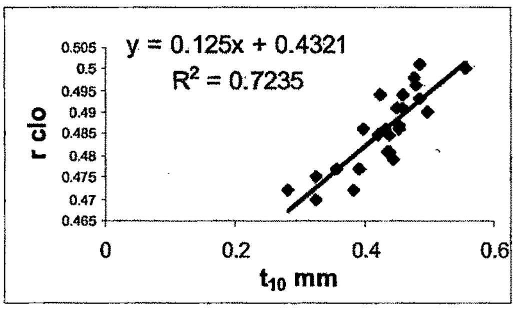


Fig. 61 Thicker fabrics provide insulation

3. Moisture evaporation from skin:

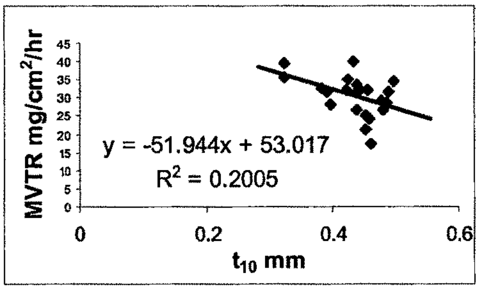


Fig.62 Thicker fabric has poor MVTR

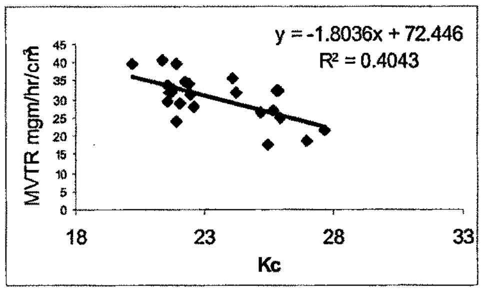


Fig.63 open structure increases MVTR.

Convective heat from body escapes due to vapour transfer. Vapor transfer is affected by the pore size decided by the structure of fabric. It decreases with increased cloth cover. Increase in thickness decreases the water vapor transmission.

4. Sweat absorption by cloth:

Sweat from the body must be carried away through the fabric on its surface for evaporation. This keeps the body dry and also cools the body temp. due to latent heat of evaporation. Capillaries in the fabric provide channel to carry the water.

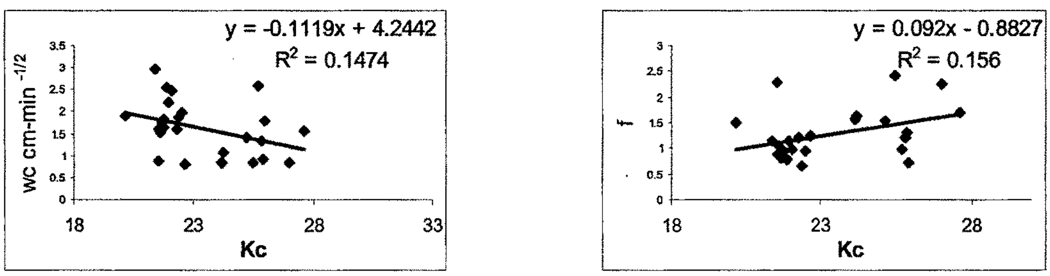


Fig.64. Wicking is faster in open fabric with low Kc decreasing the water it holds near the skin.

wc- wicking coefficient value indicate rate of wicking which depends on capillary size and is affected by the fabric sett.

f - fluid filling fraction is the measure of the amount of water fabric can hold.

wc value decreases with increase is cloth cover. In PV fabric denser sett closes the capillaries with increase in fabric sett. This is due to yarn hairiness which hamper free flow of water in the capillaries. Thus sweat wicks faster in open fabric with low Kc. The sweat is spread and gets evaporated faster. This decreases low value of f- fluid filling fraction. This provides thermal comfort as the sweat is carried away from the fabric keeping body dry and cool.

4.3 Comfort Factor analysis and development of software

From the above discussion it is evident that various mechanical as well as thermal parameters well explain the comfort feeling of clothing. In this section various comfort factors obtained in section 3.4 pertaining to human comfort feeling are described.

4.3.1 Mechanical comfort factors:

In section 3.4.1, five mechanical comfort factors based on their correlation coefficients with fabric low stress mechanical and surface properties are obtained to describe the fabrics' mechanical comfort in subjective terms similar to those used by KESF. Multiple Linear Regression give empirical equations for prediction of these Mechanical comfort factors from fabric properties:

1. **Hardness Factor:**

This factor is obtained from fabric bending and compression properties. Flexural rigidity of cloth G in gm-cm is the measure of stiffness appreciated by fingers while surface hardness H in mgm per cu. cm and compression modulus q in gm per sq.cm obtained from the fabric thickness at two different pressures indicates fabric hardness while pressed between finger tips. Positive correlation coefficient of this factor with Flexural rigidity value (G), surface hardness (H) and compression modulus (q) shows that fabric becomes stiffer in bending and compression with increase in value of this factor. Thus this factor is termed Hardness Factor. Its value ranges from 0.16 – 0.49 for the PV suiting fabrics evaluated. Lower value of this factor indicates soft compressible fabric and fabric feels hard to bend or press by fingers as its value increases.

2. **Extensibility factor:**

This factor has negative correlation with fabric tensile modulus in warp direction which naturally gives a positive value of correlation coefficient with weft way fabric tensile modulus. As discussed In section 4.2.2 the warp and weft way extensibility varies inversely. Increase in warp crimp gives rise to low tensile modulus in warp direction and hence higher extensibility. Density affected by fabric sett affect the extensibility. Higher density increases fabric tightness and hence lower value of crimp. Fabric tensile modulus at 2% extension increases which decreases the value for this factor. The factor is given nomenclature of Extensibility factor.

Extensibility factor varies from 411 - 607 for PV suiting fabrics. Lower value indicates poor stretchability.

3. Surface Smoothness Factor:

Third factor of mechanical comfort analysis has fairly good negative correlation with frictional amplitude of stick-slip curve. Higher amplitude of the stick-slip curve indicates rough surface. This shows fabric smoothness increases with the increase in value of this factor. Thus it is termed smoothness factor. Smoothness factor decreases with increase in fabric density. This is due to the fact that dense fabric sett (epi and ppi) which produces rough surface as compared open weave structure.

Smoothness value ranges from (-18) to (-9) for PV suiting. Higher value (-9) gives smoother fabric.

4. Fullness factor:

The factor has good positive correlation coefficient with the bending modulus of cloth. As explained earlier in section 4.2.2 bending modulus refers to fuller appearance. Thus this factor is termed fullness factor. Fullness factor increases with increase in fabric density given by positive correlation. It has negative correlation with compression modulus. Compression modulus has higher value for hard incompressible fabric which is opposite to fullness. Thus fabric fullness can be evaluated by the fullness factor.

Numerically fabric fullness varies from 17 to 33 for PV suiting fabrics. Lower value gives thin papery feel as compared to fuller handle for higher value of this factor.

5. Shear Stiffness factor:

This factor has good negative correlation with Eb% i.e. increase in value of Eb% causes the value for this factor to decrease. Eb % is the bias fabric extension at critical shear angle. Higher value indicates that fabric is less rigid under shear and it conforms to any shape. This is also referred as Shear formability. Thus this factor is termed shear rigidity factor. This factor also shows good positive correlation with fabric density which increases with fabric sett. High sett fabric has less space for yarn to slide during fabric shear and hence show poor shearing given by high value of shear Stiffness factor.

Shear rigidity factor varies from (- 6) to (+7). Lower value of this factor indicates higher fabric extension at critical shear angle. This is preferred as during shear deformation at the bends of the garments such as knee and shoulder, it gives wrinkle free appearance.

Fabric over all mechanical comfort value is obtained from the multiple linear regression of WD_{0M} value in table 21 with these five above mentioned comfort factors. It resembles to Kawabata's Total hand Value (THV). It value ranges from 9.77 to 14.04. Thus two fabrics with similar Mechanical comfort value exhibit similar comfort character.

4.3.2 Thermal comfort factors:

Analysis of thermal comfort in section 3.4.2 identifies three Fabric Thermal comfort factors.

1. Impermeability factor:

This factor shows good negative correlation with the air permeability value as well as moisture vapour transfer rate. Fabric which allows air to pass will provide free passage to water vapour as well. Negative correlation of this factor indicates that air and moisture transfer rate decreases with increases in this factor. Thus this factor is termed Impermeability factor. It value ranges from (- 55.68) to (-19.32) for PV suiting fabrics. Value (-55) gives good permeability of air and water as compared to (-19).

2) Insulation factor:

This factor having 0.91 correlation coefficient with fabric Clo value is termed Insulation factor. Negative correlation with the fluid filling fraction justifies that the insulation value decreases in wet fabric. A positive value of correlation with wicking coefficient is due to water spreading fast over the fabric surface reduces water held by fabric which reduces thermal conductivity of fabric.

Insulation factor ranges from 0.45 to 0.51. Lower value refers to poor insulation and thus good heat transfer through fabric which is preferred for summer suiting.

3) Wicking factor:

This factor is positively correlated to the wicking coefficient and negatively related to the fluid filling fraction. It is a measure of wicking performance hence named wicking factor. The high correlation with MVTR shows the fabric wicks faster if it possesses good moisture permeability. As described in section 2.2.2.4 wicking angle is less than 90 degree which assist wicking.

Its value ranges from (- 0.74 to + 2.91). Higher value of 2.91 indicates good wicking property for PV suiting fabrics.

WDT0

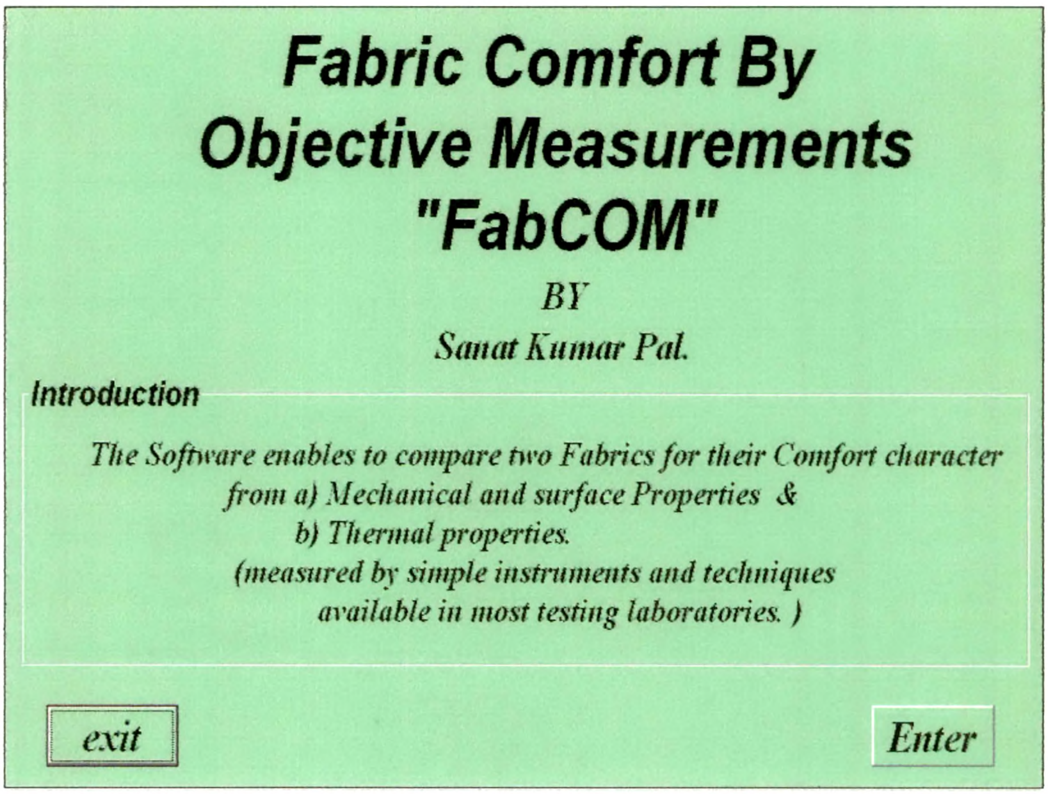
In table 25, WD_{0T} value for the PV suiting fabrics are calculated as a measure of over all thermal comfort. It is termed as Thermal comfort Value which is governed by the three thermal comforts. Thermal comfort values for PV suiting fabrics range from 0.82 to 2.00. It compares two fabrics for over all thermal performance.

4.3.3 FabCOM - Fabric Comfort by Objective Measurement.

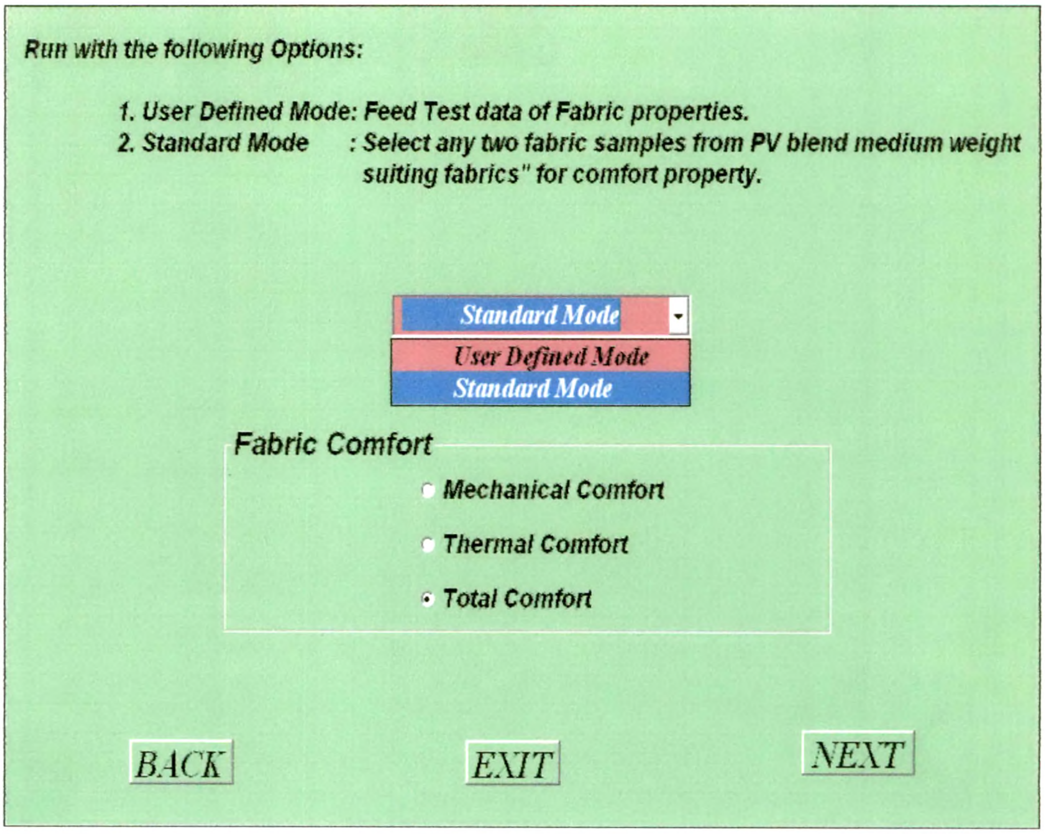
The five mechanical and three thermal comfort factors identified to objectively describe the fabric comfort are structured in forms of computer software using Visual Basic programming language. This makes analysis of handle fairly simple. Fabric properties obtained through testing described in section 3.3 are used as input data. It calculates comfort parameters using formulae described in section 3.4 and obtain mechanical and thermal comfort factors with the regression equations (see appendix I & II) . Fabrics are ranked on a scale of 0 to 1 for comparing two fabric samples.

Features of the software along with Forms of Visual Basic Programming are described below.

Form 1: It is an introduction form.



Form 2 : It is an option form.



User can opt for 1) User defined mode which enables to feed data manually.

2) standard mode uses data from standard library.

Also option is also available for evaluation of

1) Mechanical comfort

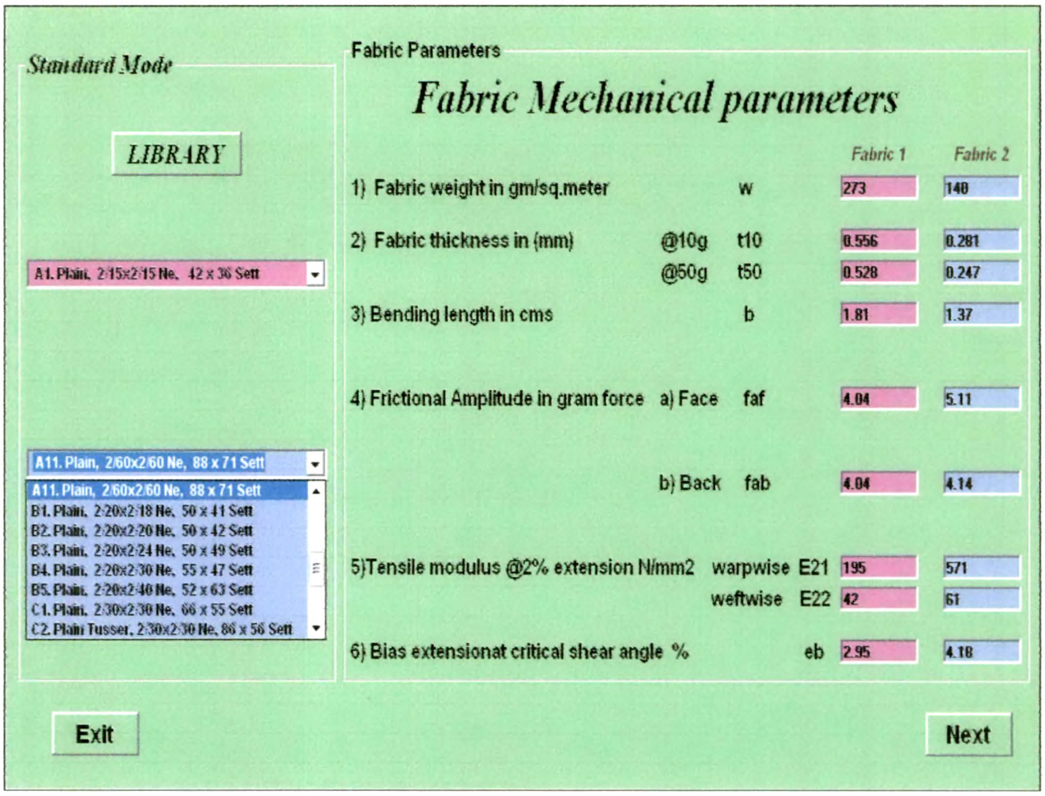
2) Thermal comfort or

3) Total comfort i.e. both mechanical and thermal comfort.

Once these options are chosen all the subsequent forms will work in sequence to evaluate the two samples and define their comfort feeling in ranks for various comfort factors.

A) Mechanical comfort analysis:

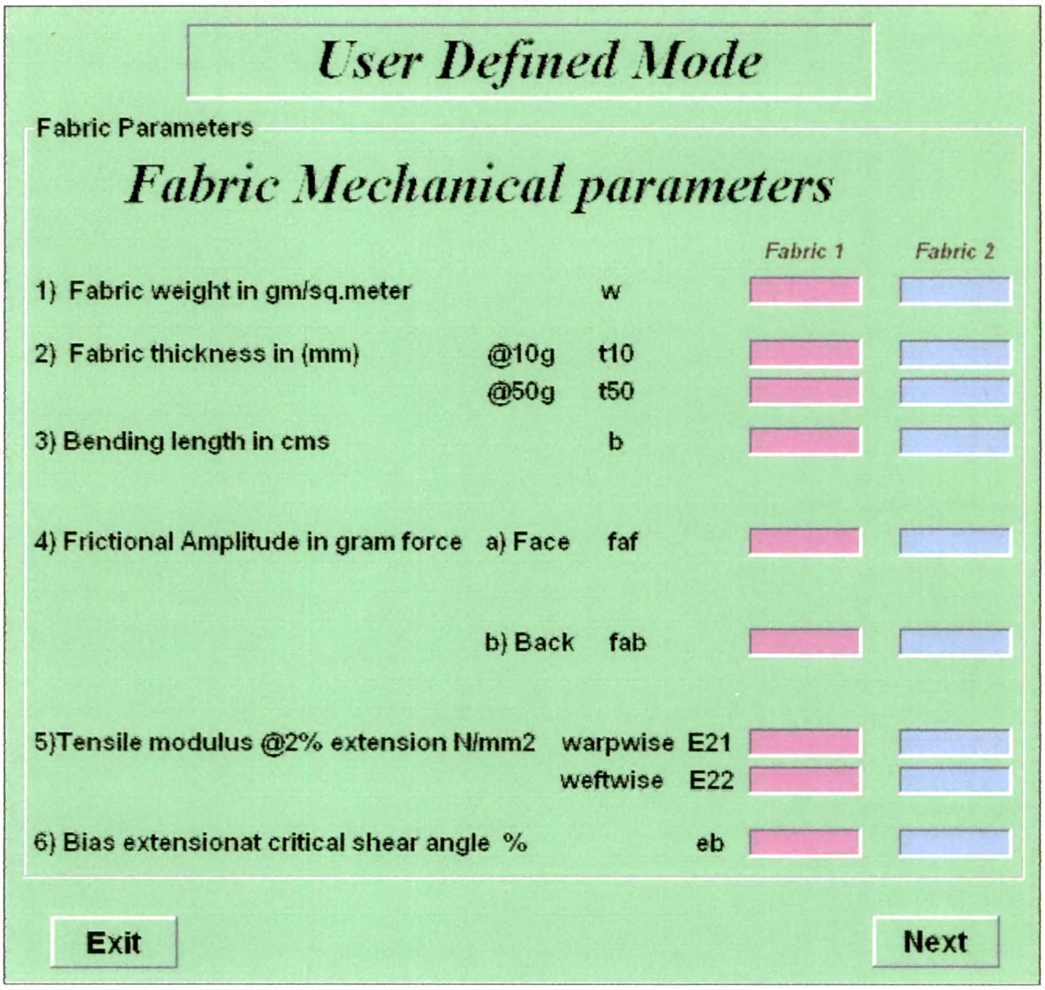
Form: 3a. (Option I standard mode).



It contains information of fabric properties of any two fabric samples selected from the standard library by the drop down menu. The fabric properties stored in the library will be loaded in the respective windows. The form displays the properties of A1 and A11, both plain weave fabrics but A1 has coarse yarns while as A11 has finer yarns.

Form 3b: (Option II User defined mode).

This is a blank form without any library for standard data. The user can feed manually various fabric properties from six tests of any two samples which are required to be compared for their comfort characteristic.



User Defined Mode

Fabric Parameters

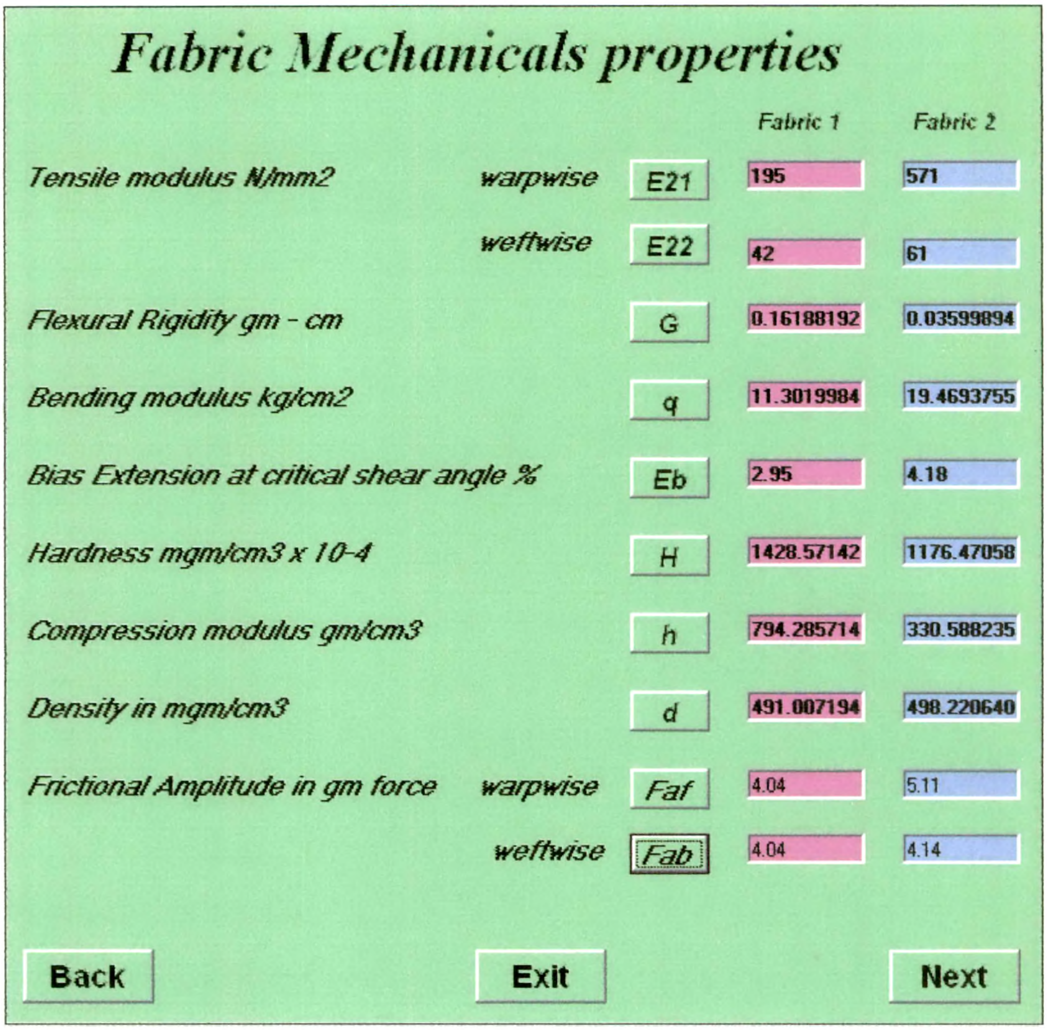
Fabric Mechanical parameters

			Fabric 1	Fabric 2
1) Fabric weight in gm/sq.meter		w		
2) Fabric thickness in (mm)	@10g	t10		
	@50g	t50		
3) Bending length in cms		b		
4) Frictional Amplitude in gram force	a) Face	faf		
	b) Back	fab		
5)Tensile modulus @2% extension N/mm2	warpwise	E21		
	weftwise	E22		
6) Bias extensionat critical shear angle %		eb		

Exit Next

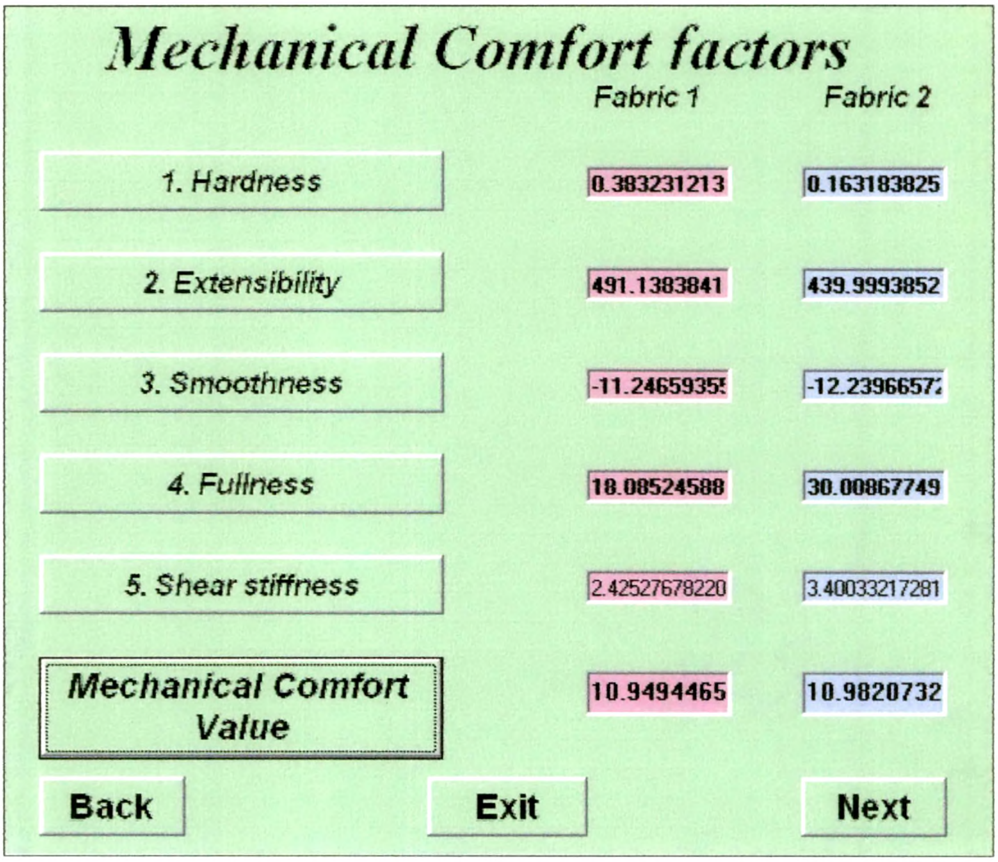
Form 4. It calculates the fabric mechanical comfort parameters from data in the

Form 3.



Calculations in this form are based on formulae in section 3.4.1 for the required fabric mechanical parameters. These are considered essential parameters governing fabric mechanical comfort forming standard matrix M in table 18.

Form 5. It calculates five Mechanical comfort factors and over all fabric comfort value discussed in section 3.4.1.



Comfort factors in this form are based on the following regression equations obtained in appendix I.

Hardness $= 1.09 \times (G\ gm\text{-}cm) + 7.25E\text{-}05 \times (H\ mgm/cm^3 \times 10^4)$

$+ 1.39 \times 10^{-4} \times (h\ gm/cm^2) - 0.0073;$

Extensibility $= 0.35 \times (E2_2\ N/mm^2) - 0.16 \times (E2_1\ N/mm^2) + 0.61 \times (\rho\ mgm/cm^3) + 207;$

Smoothness $= - 0.018 \times (\rho\ mgm/cm^3) - 0.74 \times (Fa_f\ gf) - 0.78 \times (Fa_b\ gf) + 3.59;$

Fullness $= 0.89 \times (q\ kg/cm^2) + 0.017 \times (\rho\ mgm/cm^3) - 0.0098 \times (h\ gm/cm^2) + 7.67;$

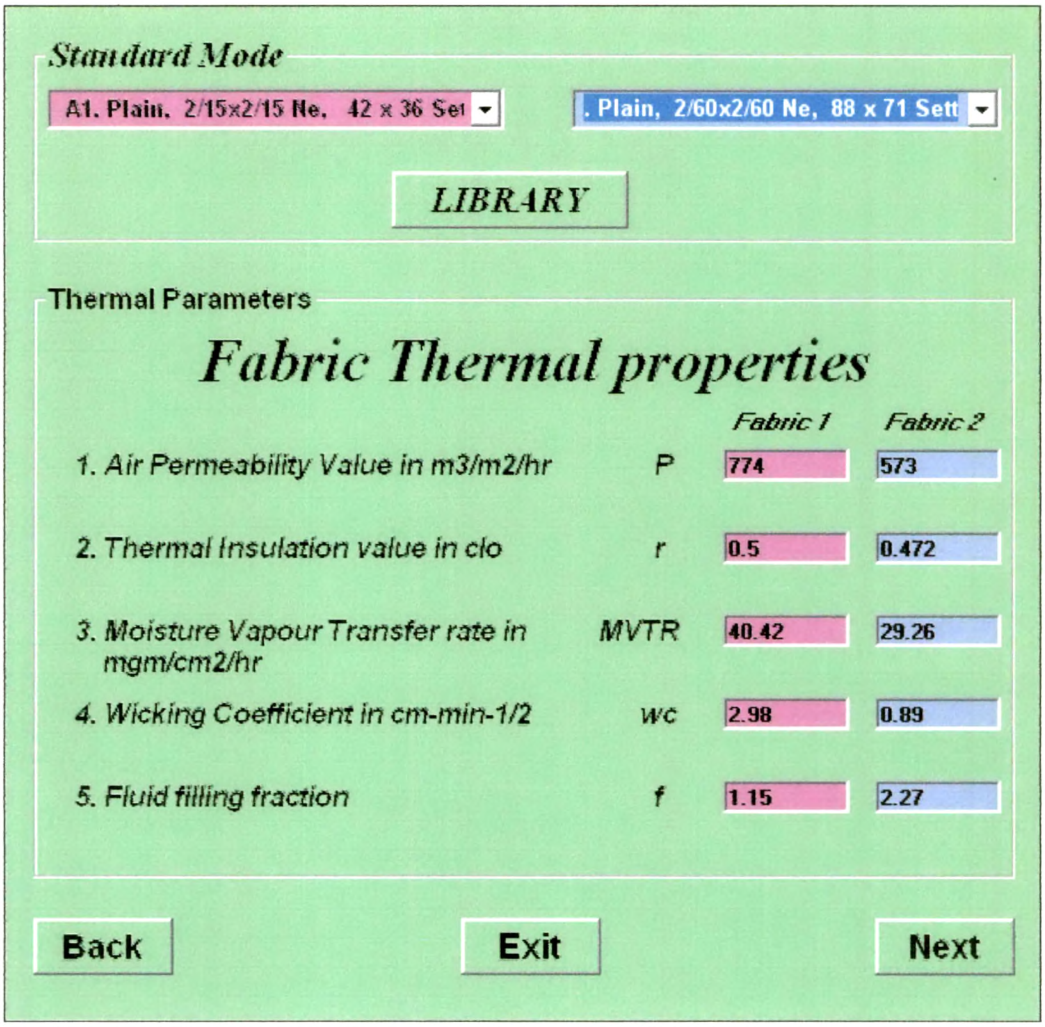
Shear stiffness $= 0.27 \times (q\ kg/cm^2) - 1.01 \times (Eb\ \%) + 2.34;$

Mechanical comfort value = 3.06 X Hardness + 0.019 X Extensibility

- 0.12 X smoothness + 0.137 X Fullness - 0.06 X shear stiffness – 3.48 ;

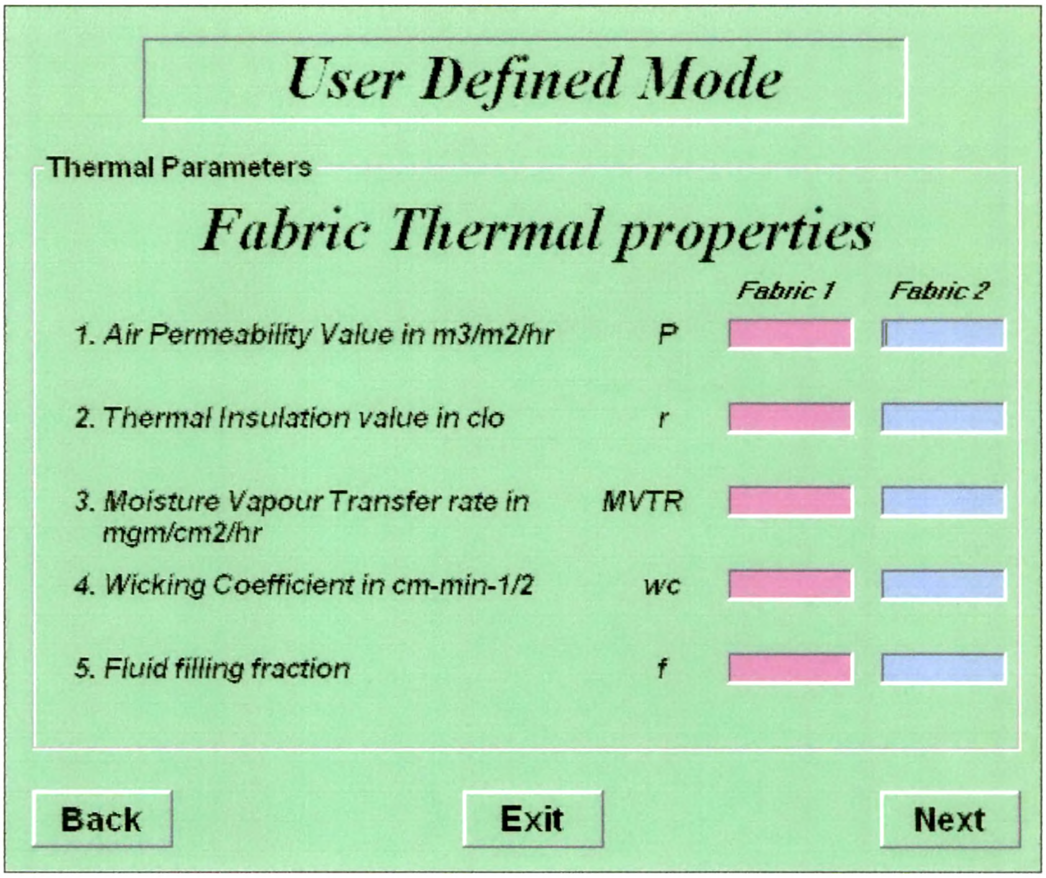
B) Thermal comfort Analysis:

Form 6a: It carries fabric thermal properties. (Option I Standard mode)



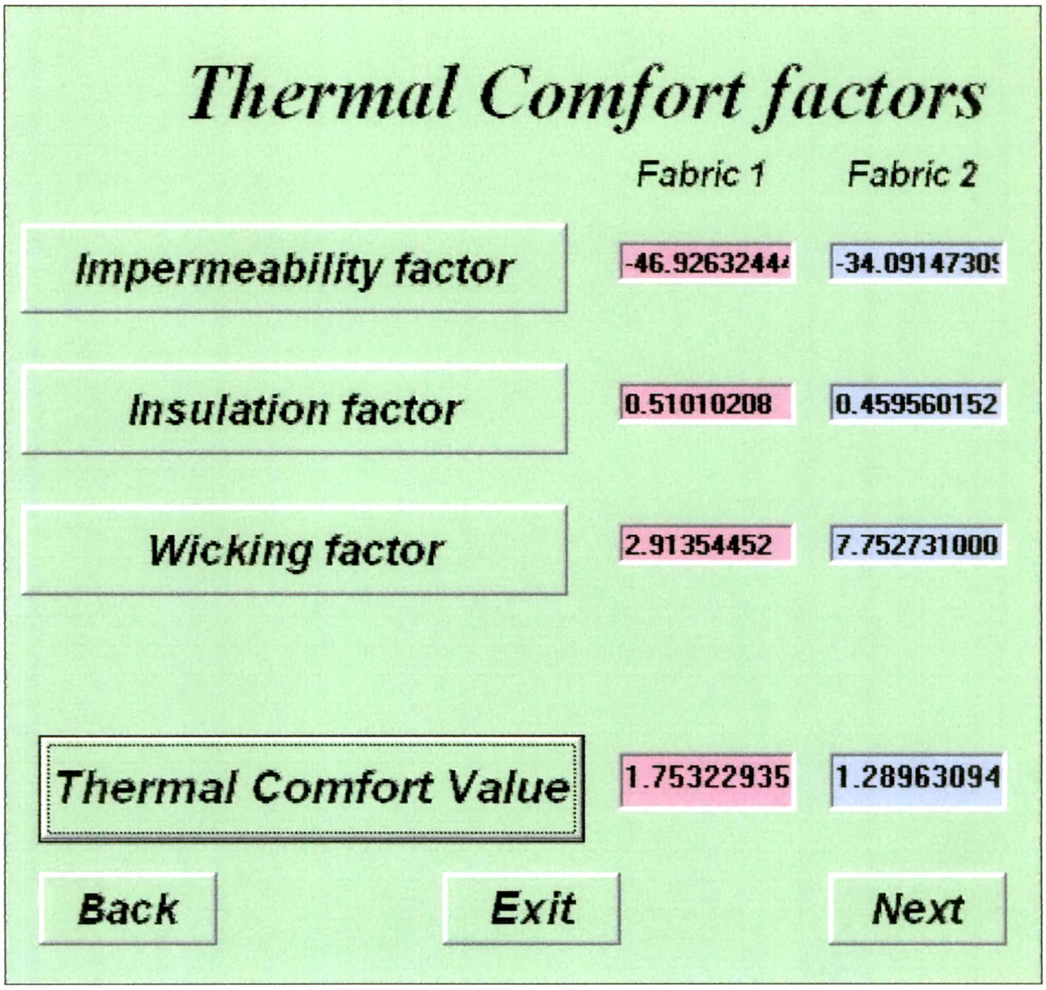
Fabric thermal properties of two samples already selected in form 3a will be loaded in this form. If user is not opting for mechanical comfort but only thermal comfort is required then fabric sample are to be selected from the standard library by the drop down menu.

Form 6b: (Option II User defined mode).



This is a blank form without any library for standard data. The user can feed manually various fabric thermal properties from four tests (described in section 3.2) for any two samples which are required to be compared for their thermal comfort characteristic.

Form 7: It calculates thermal comfort factors.



Calculations in this form are based on the regression equations of the multiple regression analysis enclosed in appendix II.

Impermeability factor = - 0.049 - 0.0085 X (P $m^3m^{-2}hr^{-1}$) - 0.99 X (MVTR $mg/cm^2/hr$);

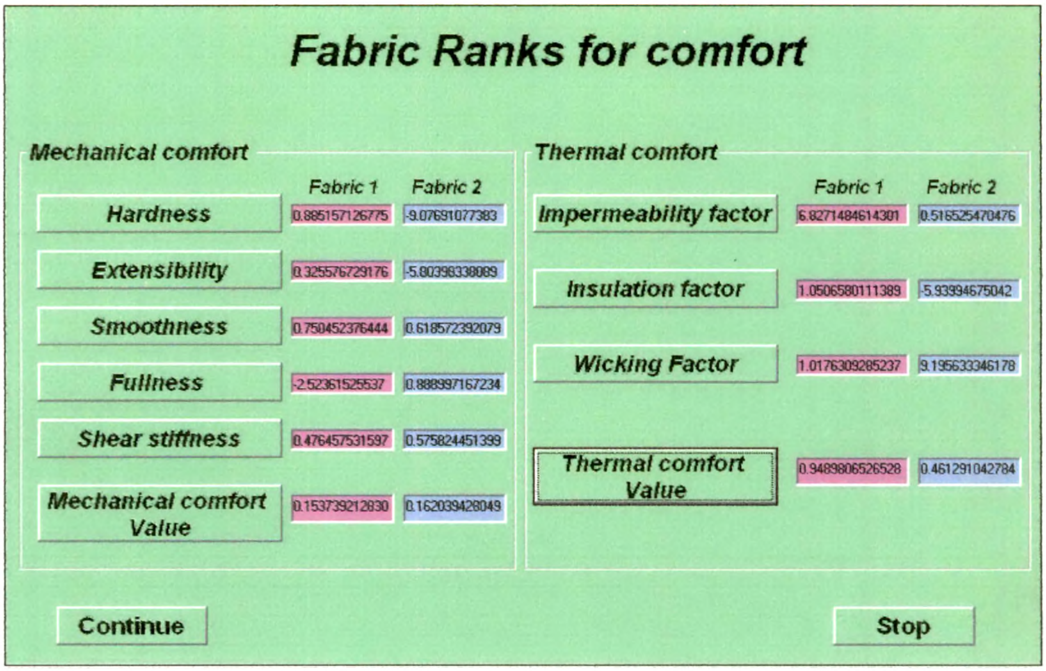
Insulation factor = 1.049 X (clo) + 0.0064 X (wc cm-$min^{-1/2}$) – 0.0068 x f - 0.026;

wicking factor= 0.65 X (wc cm-$min^{-1/2}$) - 0.72 X (f) + 0.058 x (MVTR $mg/cm^2/hr$) - 0.58

And the over thermal comfort Value is predicted as

Thermal comfort value = 0.78 X (insulation factor)- 0.033 X (permeability factor) +0.000298 X (wicking factor) - 0.194;

Form 8. It gives the results of the analysis.



Fabric samples are ranked on 0 - 1 scale for each hand value and also over all fabric comfort values for mechanical comfort (in table 22) as well as for thermal comfort (in table 26). The rank value is obtained in this form are based on the regression equations for fabric ranks from fabric comfort values obtainedin previous forms. These equations are :

R_{MI} = 4.03 X Hardness factor - 0.658 ;

R_{M2} = 0.006 X extensibility factor - 2.857 ;

R_{M3} = 0.13 X Smoothness factor + 2.244 ;

R_{M4} = 0.074 X Fullness factor -1.34 ;

R_{M5} = 0.102 X Shear stiffness factor + 0.229;

R_{MCV} = 0.254 X Mechanical comfort value - 2.632 ;

where R_{M1}, R_{M2},....refers to rank of mechanical comfort factor 1, 2, ...respectively.

R_{T1} = 0.035 X permeability factor + 1.71;

R_{T2} = 21.96 X insulation factor – 10.15;

R_{T3} = 0.326 X wicking factor + 0.067 ;

R_{TCV} = 1.05 X Thermal comfort Value - 0.89.

where R_{T1}, R_{T2} & R_{T3} refers to rank of thermal comfort factor 1, 2 & 3 respectively.

Preferred ranks for these comfort factors are as follows.

Rank	Comfort Factor	Zero	One
R_{M1}	Hardness	Soft feel	Hard feel
R_{M2}	Extensibility	Stiff	Extensible
R_{M3}	Smoothness.	Rough	Smooth
R_{M4}	Fullness	Papery feel	Fuller appearance
R_{M5}	Shear Stiffness	Less (better formability)	Stiff and poor in shear.
R_{MCV}	Mechanical comfort value		
R_{T1}	Impermeability	Permeable	Impermeable
R_{T2}	Insulation	Good	Poor
R_{T3}	Wicking	Poor	Good
R_{TCF}	Thermal comfort Value		

Thus the mathematical model has been made simpler by the software which can easily compare two fabric samples for their comfort value.