10.1 **Introduction:**

Any amount of fabric testing for their performance characteristics will be of no avail, if they do not possess sufficient 'formability' qualities. Fabric formability is of prime importance in garment-making, while problems like seam puckering, seam failure etc. which can be rectified if proper attention in garment-making is given.

Formability of fabrics is the maximum compression it can take up before it buckles, given a certain geometrical arrangement. It partly determines the tailorability and crease patterns of fabrics and is dependent on fabric direction \( \sqrt[433]{7} \).

10.2 **Experimental:**

10.2.1 **Materials:**

The fabric samples as mentioned in 4.2.1 were used in their washed and unwashed states for assessing their tailorability.
10.2.2 **Methods:**

10.2.2.1 Assessment of drape accompanied by handle was done following Sudnik's method. By introducing coordinates of bending rigidity and fabric shear, fabric behaviour could be expressed in terms of drape and handle in addition to their tailorability.

A graph was plotted, with shear angle ($\alpha$) along the abscissa and bending rigidity ($G$) on the Y-axis. The area was divided into several segments, using ratio of 1000 $\alpha/G$ and product of $\alpha \times G$. Basing on the shear angle (obtained in 9.2.2.9.1) and bending rigidity (as obtained in 9.2.3), the positions of the fabrics in the graph were located and depending on the range within which they fall, the drape and handle of the fabrics were determined as follows:

**Group I:** When ratio of 1000 $\alpha/G$ is less than 10 and the product of $\alpha \times G$ is more than 250, fabrics are firm, boardy with a high drape coefficient, as a result, garments made out of them protrude from the body without bending.

**Group II:** When ratio of 1000 $\alpha/G$ is less than 10 and the product of $\alpha \times G$ is less than 250, fabrics tend to have a lean handle, to be boardy reminiscent of plastic and drapes badly. The garment flares out fully with a few rather rigid folds and yet bend over the contours of the body.
Group III: Fabrics falling into the range of 1000 $\alpha/G$ ratios ranging from 10-100 and having products of $\alpha \times G$ higher than 250, exhibit varying degrees of firmness, fullness, suppleness, liveliness and drape.

Group IV: Fabrics with 1000 $\alpha/G$ ratio higher than 100 and $\alpha \times G$ product lower than 1000, are soft, limp and have low drape coefficients. Made-up into garments, they tend to follow the contours of the wearer's body, occasionally cling to it, flare very little and form folds which move about readily while in wear and covers fully by bending over contours fully well.

10.2.2.2 Assessment of Fabric Formability:

Though Sudnik's method (10.2.2.1) of classifying fabrics for their drape also gives an indication for their sewability, a combination of Westerweld's and Van Krugten's methods was followed for assessing fabric formability.

According to their concept of fabric sewability, the fabric flexural rigidity requirements must be coupled with the minimum requirement of a minimum value of the shear angle (averaged over both length and width directions) in order to avoid fabric damage during the sewing operation in the form of needle 'cutting' and the appearance of holes.
at the garment seams. A minimum value of 3-4° of shearing angle has been recommended by Van Krugten while a range of 3-7° has been recommended by Westerweld for woven fabrics. Van Krugten also has recommended that the minimum flexural rigidity requirement for woven fabrics designed for men's slacks and suits should be greater than about 1.962 mN cm⁻¹ (200 mg cm⁻¹). This flexural rigidity requirement is applicable to knitted suitings and shirtings though not for sample L under study.

Since the graph developed for assessing drape and handle also makes use of the same parameters, which were considered by Van Krugten and Westerweld, for assessing fabric formability, this aspect of the test materials have also been critically studied in the same graph by providing additional constants indicating the G requirements and α requirements, across the X and Y coordinates.

10.3 Results:

10.3.1 Fabric Drape and Bending Rigidity as Related to Formability:

As seen in Figures 10.1, 10.2 and 10.3, the test fabrics fall into two broad groups out of the four groups identified by Sudnik (Table 10.1).
<table>
<thead>
<tr>
<th>PN/PE</th>
<th>UL</th>
<th>DG\textsubscript{1}-30L</th>
<th>DG\textsubscript{2}-30L</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.036*</td>
<td>0.015*</td>
<td>0.013* ((-58.33))</td>
</tr>
<tr>
<td>B</td>
<td>0.047</td>
<td>0.060</td>
<td>0.038 ((-27.66))</td>
</tr>
<tr>
<td>C</td>
<td>0.041</td>
<td>0.046</td>
<td>0.045 ((-12.20))</td>
</tr>
<tr>
<td>D</td>
<td>0.150</td>
<td>0.071</td>
<td>0.053 ((-52.67))</td>
</tr>
<tr>
<td>E</td>
<td>0.158</td>
<td>0.175</td>
<td>0.141 ((+10.76))</td>
</tr>
<tr>
<td>F</td>
<td>0.110</td>
<td>0.097</td>
<td>0.101 ((-11.82))</td>
</tr>
<tr>
<td>PN/C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>0.084</td>
<td>0.085</td>
<td>0.059 ((+ 0.91))</td>
</tr>
<tr>
<td>H</td>
<td>0.049</td>
<td>0.110</td>
<td>0.086 ((+124.49))</td>
</tr>
<tr>
<td>I</td>
<td>0.45</td>
<td>-</td>
<td>0.585 ((-))</td>
</tr>
<tr>
<td>J</td>
<td>0.145</td>
<td>0.324</td>
<td>0.150 ((+123.45))</td>
</tr>
<tr>
<td>PN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>0.139*</td>
<td>0.295*</td>
<td>0.086* ((112.23))</td>
</tr>
<tr>
<td>L</td>
<td>0.04*</td>
<td>0.053*</td>
<td>0.053* ((+32.50))</td>
</tr>
</tbody>
</table>

* Indicates approximate values
FIG. 10.2 FORMABILITY AND SEWABILITY OF DG1-30L PN BLENDS.
The UL fabrics D, E, F, G, I and J fall under group III, while fabrics B, C and H fall under group IV. Fabrics, A, K and L can also be grouped under this category as they have registered lower bending rigidity even at 245.25 mN cm\(^{-1}\) stress which is lower compared to the shear stress considered for the other fabrics (294.3 mN cm\(^{-1}\)).

10.3.1.1 Effect of Laundering on Drape and Bending Rigidity:

In case of laundering with \(DG_1\) upto 30L level, fabrics D, E, F, G, I and J which were in group III before laundering have fallen into other groups with exceptions of G and F. J has entered a group beyond IV - probably a new group V (not identified by Sudnik). A, H and K have entered group IV while B, C and L continue to be in their group or region whereas D and E join them (Table 10.1).

In case of fabrics laundered with \(DG_2\) upto 30L level, D, F, I and J continue to be in their original group IV, while K joins them from group II. B, C and L continue to be in their region whereas H, E and G join them from group III.

10.3.2 Shear Angle Related to Sewability:

All fabrics excepting I in their UL condition show good sewability (Table 9.4). If the range 3-7° is further
subdivided as given under:

- $3-4^\circ$ — low (not poor)
- $4-5^\circ$ — medium
- $5-6^\circ$ — high
- $6-7^\circ$ — very high

It can be considered that fabric A in UL condition, fabric K with DG, $-30L$ show low sewability. This is supported by the observation of the author of the loom state suiting K two pieces of which had been attached by sewing, showing needle 'punch' marks. All the other fabrics can be considered to have good sewability in their UL as well as $30L$ conditions, when laundered with either of the detergents.

**10.4 Discussions:**

The bulk of the fabrics namely D, E, F, G, I and J which fall under group III in their UL condition are characterized by varying degrees of firmness, fullness, suppleness, liveliness and drape. But they could not be subdivided further on the basis of the data available.

All the other fabrics which have fallen into group IV in the UL condition could tend to follow the contours of the body when made into garments, would occasionally cling to it, would flare out very little and would be capable of forming even small folds which would move
about readily as the wearer moves around and would cover the contours of the body when worn.

All fabrics excepting I in their UL state conformed to the sewability limits laid down by Westerweld. After laundering up to 30L with DC₂, its sewability crucially falls within the range. However, as garments are made up from new fabrics which may be only pre-shrunk by a professional dress designer, fabric I can be considered unsewable. Fabrics A, K and L form a category by themselves though they have acquired sewability but not formability owing to their very low bending rigidity. Problems in their 'formability' is predicted owing to their extremely low bending rigidity. These fabrics especially A and L will tend to pucker unless extreme care is taken in sewing techniques. Handling them also will be difficult as they will tend to slip away while sewing and therefore would necessitate 'basting' before 'seaming' on account of their extreme limpness, added fineness in case of A and L and silky feel. In spite of careful pressure setting, needle choice, thread size and stitch tension, in an attempt to minimize this problem, it will be difficult to get a good 'tailored-effect' especially in case of A. The sewing of fabrics - K and L need special care.
Fabrics A and K acquired improved sewability on repeated laundering with DG while shirting E and suitin D have registered a loss in their sewability and therefore it is not desirable to effect any pattern alterations or renovation after use and wash of E and D.

Among the UL suitings, D, F, I, J and K, K can be considered to have very poor formability owing to its extremely low bending rigidity and hence a low drape, though its shear angle is just above the requirement. The same can be expected with the other suitings also for the same reasons.

Among the UL shirtings only E of the PN/PE blend has better bending rigidity and sewability unlike A, B and C which are characterized by very low bending rigidity. However, these being shirtings with better sewability, cannot be compared with the minimum bending requirements stipulated for suitings. Probably a new range for bending rigidity requirements for them has to be stipulated which can be between 0.30 mN cm\(^{-1}\) to 2.50 mN cm\(^{-1}\) in case of PN/PE blends and 0.60 mN cm\(^{-1}\) to 2.50 mN cm\(^{-1}\) for PN/C blends. Fabric A has the lowest formability followed by L.
Effect of Laundering on Formability and Sewability:

With $DG_1$ at 30L level, only suiting J satisfies the bending rigidity requirements as well as that of shear angle and consequently its formability and sewability into suitings according to the norms. However, this fabric has to be treated in par with I as formability when new is more important. Probably it can be assumed that this fabric, after preliminary shrinking, usually resorted to by professional dress makers, may acquire sewability for suiting.

Among the shirtings laundered with $DG_1 - 30L$, most of them retained their sewability within the range stipulated. While the formability of A and H improved, that of E has come down whereas B, C and L continue to retain their low formability.

Fabric I because of its low shear angle, is like a thin cardboard and so will not yield readily under the poking pressure of the needle. Therefore, it is liable to be damaged due to needle 'wetting' during sewing and the use of finer needle to minimize this tendency may not be practicable. It is also likely to show stitch marks, if any renovation or alteration involving ripping open of seams is carried out in the used-washed garments and the needle punch marks will detract
the appearance of such renovated garments and so any pattern-alteration undertaken on this will not be successful. In spite of this fact, if pattern alteration is carried out, the garment will tend to tear along the original seam lines, more readily than anywhere else, especially in case of fitting seam like the centre back seam of a knicker. Thus the useful life of the garment is affected. However, as the same fabric shows an improvement in its sewability after 30L with DG\textsubscript{2}, it can be presumed that further alterations in the used-washed-altered garments will not show any stitch marks.

In case of suitings laundered with DG\textsubscript{2} - 30L, all have retained their formability though they have not achieved the requirements. All shirtings irrespective of their fibre components have lost their formability after 30L with DG\textsubscript{2} and have come down to the level of A and L. Thus, this tremendous effect of DG\textsubscript{2} on shirtings could be due to its chemical nature. The increase in bending rigidity of D, F, J and K could be due to their constructional details. The low shear angle registered by I at UL level gives an important indication of its paperiness and consequent needle 'punching' tendency.

As most of the suitings do not conform to the bending rigidity requirements of 1.962 mN cm\textsuperscript{-1} in their
UL state, these cannot be used for making suits. Probably these can be used for regular work wear pants and 'safari' dresses.

10.5 Conclusions:

1. Fabrics falling under group IV, namely, A, B, C, H, K and L would also be suitable for children's and ladies' wear though they are meant for men's shirts, because of their tendency to follow the contours of the body.

2. Fabric A is unsuitable for shirting because of its low formability.

3. A bending rigidity of 0.3 mN cm$^{-1}$ to 2.5 mN cm$^{-1}$ is recommended for PN/PE shirtings and 0.6 mN cm$^{-1}$ to 2.5 mN cm$^{-1}$ for PN/C shirtings to consider them sewable.

4. It is advisable that no pattern-alteration is attempted on E and D.

5. The so-called suitings I, J and K are not suitable for use as suitings owing to their low formability. Probably the use of stiffer linings and interlinings may boost their formability. However, this possibility also has limited application. E and F though have low formability, because of the PE content, should make them suitable for use as suitings, as it also gives better aesthetic quality.
6. Suitings other than I can probably find alternative use as daily work wear.

7. Suiting I is unsuitable for making any garment because of its low sewability.

8. Detergents have a significant effect on the formability of fabrics.