Studies on abrasion resistance of silk fabrics

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Around 100 different samples of commercially popular silk fabrics were collected and tested for fabric constructional particulars and two functional properties, viz. abrasion resistance and bursting strength. The silk fabrics were tested for abrasion resistance on both Taber type and Martindale testers and the end point of the test was determined as per the pin-hole and weight loss methods. Abrasion resistance, expressed in terms of number of cycles to form a pin-hole, showed better consistency in terms of various inter-relationships. The interdependence of factors influencing the abrasion resistance with other functional properties have also been deduced.

Keywords: Abrasion resistance, Martindale tester, Silk fabric, Taber tester
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1 Introduction

One of the most important physical properties of a textile fibre in relation to durability is its ability to withstand abrasion. Fibres with poor abrasion resistance break and splinter, leading to the formation of holes in the fabric\textsuperscript{1}. Abrasion of fabrics may take place in normal usage when they are flat, folded or curved such that the fibres are subjected to three types of abrasion, namely flat, flexed and edge. Prediction of performance in relation to abrasion is considered to be difficult as many factors influence abrasion\textsuperscript{1}. Some fibres have better abrasion resistance than do others. Yarn construction is also an influencing factor. Loosely twisted yarns abrade more easily than do tightly twisted yarns. In the loosely twisted yarns, the individual fibres are more likely to be subjected to being pulled out from the body of the yarn onto the surface of fabric\textsuperscript{2}.

In woven fabric construction, the aspect of crimp distribution seems to be particularly important. The crown, a part of the yarn that protrudes above the surface of the fabric, is subjected to the pressure and surface or edge abrasion. If there are more crowns of the same height in a given area of cloth, the wear will be distributed over the surface of the fabric more evenly\textsuperscript{3}. Fabrics made from uneven loosely twisted slubbed yarns with higher unevenly spaced crowns have poor abrasion resistance\textsuperscript{1}.

Some abrasion effects are immediately recognizable. Where the rubbing is general over a large area, there may be a thinning of cloth and a loss of strength, leading eventually to bursting or tearing. If the wear is concentrated, the first effect to be noticed is likely to be a hole. If the cloth is square in construction, i.e. having equal numbers of similar yarns in both the warp and weft, it is possible that the hole will be formed by the destruction of both sets of threads in the same area. If, however, one set of threads is predominant on the surface of the cloth, as in the case of dupion silk fabrics, these threads are abraded preferentially and the hole will be seen to be crossed by a ladder of the opposing threads. Such a hole may be the starting point of a tear if the cloth is sufficiently stressed in that area\textsuperscript{4}.

The reports\textsuperscript{4,7} on the abrasion resistance of a wide range of fabrics do not include silk. However, silk is rated as one with poor abrasion resistance. It is found that the problems associated with the characterization of textiles in respect of abrasion resistance are serious and by no means solved\textsuperscript{1,2}.

The imitative test for wear resistance is branded as a snare and a delusion\textsuperscript{7}. It is not required that service life be forecast in same unit of time, but a relative comparison of one fabric with another would be more meaningful\textsuperscript{9}.

In the present work, around 100 different samples of commercially popular silk fabrics were collected and two tested for fabric constructional particulars and two functional properties, viz. abrasion resistance and bursting strength. The silk fabrics were tested for

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abrasion resistance on both Taber type and Martindale testers

2 Materials and Methods

Around 100 samples of various types of commercially popular silk fabrics were collected and tested for fabric constructional particulars and two of the functional properties, viz abrasion resistance\textsuperscript{10} and bursting strength. The range of fabric particulars of these samples are given in Table 1. Crimp ratio (warp crimp/weft crimp) has been used instead of absolute values of warp crimp and weft crimp since the relative magnitude is what is known to influence the abrasion properties of any fabric\textsuperscript{8}.

The two philosophies, one of duplicating actual conditions of wear and the other of selecting the most important causes of wear and correlating them with service tests, have led to the development of more than 50 abrasion and wear testing machines\textsuperscript{11}.

In the present study, the silk fabrics were tested for abrasion resistance on two types of abrasion testers, viz Taber type and Martindale testers. The end point of the test was determined as per the pin-hole method and weight loss method. In the pin-hole method, the fabric was abraded till a hole was formed on its surface, while in the weight loss method, the fabric was abraded for 50 cycles. The initial weight and the final weight were determined for calculating the per cent weight loss.

2.1 Martindale Tester

The tester is designed to ensure that the specimen under test is subjected to rubbing and flexing from all directions. The pattern traced by the abrading heads is the well-known ‘Lissajous’ figure. An area of 100 cm\textsuperscript{2} was subjected to abrasion in all the directions. It was used to compare the resistance to abrasion of different types of cloths.

2.2 Taber Type Tester

Materials to be tested are subjected to wear action of two abrasive wheels at a known pressure. The abrasive / wear action results when a pair of abrasive wheels is rotated in opposite directions by a turn table on which the specimen material is mounted.

An exclusive feature of the Taber abraders is a patented “X” pattern of abrasion, produced by a rotary rub-wear action of the wheels. The wear pattern formed is that of two intersecting areas or a slightly curved herringbone configuration from the outside to the centre and from the centre to the outside of the specimen. An area of 30 cm\textsuperscript{2} was subjected to test and a complete circle on the material surface was abraded at all angles of grain or weave. There was provision for vacuum pick-up for removing abraded particles from the surface of the fabric.

The test results were later analyzed statistically to study the inter-relationships and to draw inferences. The analyses were carried out variety wise and the pooled data across all the varieties of silk fabrics have been referred to as ‘Overall’. The following observations were made:

(i) Correlation of the abrasion test results of Martindale and Taber type testers was studied.

(ii) Correlation between the abrasion test results was also determined on the basis of weight loss and pin-hole methods.

(iii) The abrasion test results were correlated with different fabric parameters, viz weight/m\textsuperscript{2}, thickness, cover factor, etc.

(iv) ‘t’ tests were carried out to establish the significance of differences in the abrasion resistance of the most common varieties of silk fabrics.

3 Results and Discussion

The abrasion resistance values of various types of silk fabrics tested are given in Table 2.

3.1 Influence of Method of Test

Abrasion resistance, expressed in terms of number of cycles to form a pin hole, shows better consistency in terms of various inter-relationships, while the weight loss method does not show any trend. The probable reasons for the lack of correlation in the case

<table>
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<tr>
<th>Table 1—Range of fabric parameters for different silk fabrics</th>
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<td>Fabric</td>
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<td>Crepe</td>
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<td>Sateen/Twill</td>
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3.2 Influence of Type of Tester

Table 2 shows that the abrasion resistance measured on Taber tester in terms of cycles to form a pin hole is lower than the corresponding results obtained on Martindale tester in all the varieties. The reason could be that the two abraders act on the fabric surface simultaneously in case of both Taber and Martindale testers and the fibres separated from the fabric surface due to abrasion gets clogged onto its surface, thereby delaying the end point.

There exists significant correlation between Martindale and Taber in the case of abrasion resistance expressed in terms of number of cycles to form a pin hole (Table 3). It is also observed that the weight loss on the Taber tester is much more than that on the Martindale tester. One of the reasons for this is the presence of vacuum suction arrangement in Taber. The abraded fibre particles are duly sucked away from the fabric, while this has to be done manually in the case of Martindale tester at regular intervals.

3.3 Influence of Variety of Fabric

Chiffon and georgette fabrics show the least resistance to abrasion followed by the crepe fabrics. Chiffon and georgette have high twisted yarns in both warp and weft, while crepe has high twisted yarn only in the weft. It is observed that the high twist stiffens the yarn to a point where very little contact is made between yarn and abrasive. This, in turn, results in high localised abrasive pressure and early breakdown of yarn structure. It has been shown that an optimum twist is recorded beyond which the increase in number of twists results in lower abrasion resistance.

The plain fabrics exhibit lesser abrasion resistance than taffeta, while the abrasion resistance of dupion silk fabrics is lower than that of plain fabrics. The reason for the low abrasion resistance of dupion fabrics could be attributed to the greater imbalance in the construction of fabric owing to the huge difference in the denier of dupion yarn used as weft and reeled silk yarn used as warp. This also results in greater difference between warp crimp and weft crimp. Increased fabric thickness and larger yarn diameter are generally related and provide marked improvement in abrasion resistance of textile structures. However, the largest diameter of the abrasion bearing yarns must be accompanied by yarn uniformity if increased wear life is desired. This is not so in the case of dupion silk fabrics. It is reported that the non-uniform heavy yarns actually cause fabric degradation because of the high pressure concentration at their crowns.

The better abrasion resistance of taffeta can be attributed to the higher warp density. It has been shown that when all other factors are taken constant, the abrasion resistance of warp flush fabrics is improved by increasing the number of warp crowns per square inch of the fabric. It is also stated that the warp texture should not be increased to the point of jamming the warp threads and reducing the flexibility of fabric structure.

Twill and sateen silk fabrics show the highest abrasion resistance. This reiterates the fact that weave has an influence on the abrasion resistance of fabrics.
This is in agreement with the earlier observations. In fabrics with floats, the yarns and fibres are more free to move and are less consistently exposed to abrasives. For this reason, twill and sateen fabrics may show better abrasion resistance. However, the longer floats do have adverse effect on the abrasion resistance of fabrics as already observed in the case of some jacquard designs.

### 3.4 Influence of Fabric Parameters

Correlation studies between abrasion resistance and fabric parameters were carried out for the four varieties of silk fabrics, viz plain, taffeta, dupion and crepe, which showed moderate abrasion resistance. The varieties at the two extremes, viz. chiffon/georgette with very low abrasion resistance and sateen/twill with very high abrasion resistance, were excluded. The abrasion resistance of these four varieties of fabrics shows significant dependence on weight, thickness, cover factor and bursting strength of the fabric (Table 4). However, there are some exceptions.

Wherever the thickness of the fabric is primarily due to the coarseness of either the warp or the weft resulting in an imbalance of the structure, a higher fabric thickness is not contributing to abrasion resistance as can be observed in the case of dupion fabrics. Here, the increase in thickness is largely due to the greater imbalance in the crimp of warp and weft because of the coarser weft used and a higher warp density. The abrasion resistance in this case is not showing any improvement with the increase in fabric thickness while in the case of taffeta, where the increase in thickness is due to a closer construction (increased sett in the fabric), the abrasion resistance is positively correlated with thickness.

The abrasion resistance is related to the thickness or diameter of that part of the textile structure which is exposed at the rubbing surface. For plain fabrics with high warp crimp and low weft crimp, the rate of damage is higher. Non-uniform yarns actually cause fabric degradation because of the high pressure concentration at their crowns.

There is a significant correlation between cover factor, weight and abrasion resistance in all the cases. The dependence of fabric abrasion resistance on the cover of the fabric and its weight is established beyond doubt in all the sorts tested.

Incidentally, there has been a significant relationship between bursting strength and abrasion resistance in almost all the varieties tested (Table 4). Bursting strength is the composite strength of both warp and weft and it indicates their ability to withstand the multidirectional loading. Abrasion is recognized as a series of repeated application of stress and therefore a capacity to absorb the stress is required on the entire fabric structure including the fibres. This similarity could be the contributing factor for the interdependence of these two factors across all the varieties of silk fabrics tested.

Multiple regression analysis was carried out to estimate the strength of relationship between the abrasion cycles and all the fabric parameters. The multiple regression equations along with the $R^2$ values are given in Table 5. The explanation for the significant relationships observed in the analysis can very well be explained in the context of the findings of the earlier studies. The variety-wise explanations are as given under:

**Soft Silk Fabrics**—The abrasion resistance of soft silk fabric is observed to be a function of its cover factor. Soft silk fabric being almost a square fabric, it is quite understandable that its cover factor significantly explains the abrasion resistance with equal role of warp and weft.

**Dupion Silk Fabrics**—Here, ends/inch, crimp ratio and cover factor explain the abrasion resistance of the fabric. Dupion fabrics are weft predominant. The warp denier is much finer than the weft denier and the warp crimp is also much higher. It is observed that the
crimp distribution plays an important role in the abrasion resistance of fabrics and higher the crimp imbalance, the lower will be the abrasion resistance. The difference in warp and weft deniers will result in the warp yarns bending freely while the weft yarns remain uncrimped. This condition will lead to an actual reduction in geometric area of contact and to an early damage to the warp yarns. The damage can be delayed with more warp crowns in a given area of fabric. Weft, being a highly irregular yarn in spite of having a larger diameter, is more prone to damage and this perhaps makes the cover factor as one of the parameters explaining the abrasion resistance along with crimp ratio and warp density.

Taffeta—Ends/inch happens to be a significant parameter explaining the abrasion resistance. Taffeta is a warp flush fabric and the abrasion resistance of warp flush fabrics is known to be a function of warp density, other factors being the same:\(^1\) It is observed that the higher number of warp crowns per square inch of the fabric reduces the normal load per crown, thereby imparting better abrasion resistance.

Crepe—Crepe fabrics have untwisted or low twisted yarns in the warp and high twisted yarns in the weft. It is reported \(^4\) that the abrasion resistance is related to the diameter of that part of the textile structure which is exposed at the rubbing surface. In the case of crepe fabrics, the high twisted weft yarns relax on finishing, imparting a wrinkled and uneven surface to the fabric. Thus, the highly twisted yarns in the crepe fabric provide less contact with the abradant and the warp yarn takes the brunt of the abrasive action. It is confirmed \(^4\) that the abrasion resistance is related to the diameter of textile structure which is exposed at the rubbing surface and in this case it is warp.

4 Conclusions
The abrasive wear of silk fabrics depends, to a considerable extent, on the construction of yarn and fabric. Wear resistance is more likely to be a complex interaction of several properties whose relative influence is different in different end uses.

The study has enabled ranking of silk fabrics in the order of merit of their resistance to abrasion with chiffon and georgette having the lowest values and taffeta and twills/sateens exhibiting the best abrasion resistance. Abrasion of textile fabrics is a complex mechanism that the effect of individual structural parameter is often masked by the interactions with each other. This is well reflected in the difference in behaviour of different varieties of silk fabrics. The abrasion resistance of silk fabrics can be increased by increasing the geometrical area of contact between the cloth and the abradant which can be done by using the higher cover factor and equal crown heights in warp and weft. However, the exact nature of influence of these parameters becomes specific to the type of fabric that includes all possible structural variations and their interactions.

References
10. ASTM D3884-92 and IS 12673:1989