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Compatibility of mulberry silk fabric with cow nappa leather for product development

V Vishnupriya[1], K Phebe[1,a], K Karthikeyan[1], K Krishnaraj[1], R Mohan[2] & N Vasagam[3]

[1]Shoe and Product Design Centre, [2] Centre for Analysis, Testing, Evaluation and Reporting Services,
[3] Project Planning and Business Development, CSIR-Central Leather Research Institute, Chennai 600 020, India

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The present work describes the application of silk fabric for leather garments and goods to support the leather products industry in identifying alternate raw material. The results show that the quilted silk fabric has the potential to be combined with cow nappa leather to make products with improved strength and enhanced aesthetic appeal. The major findings of this study also prove that on treatment with artificial alkaline perspiration, leather and silk-based samples behave inversely and this relation gives a clear direction to product designers and developers about the placement of leather and silk panels while making combination products. Apparently, this study helps the silk industry to attain the major share in the domestic and global market.

Keywords: Cow nappa leather, Natural fibre, Quilted silk, Silk fabric

1 Introduction

Leather is a unique bio-fabric with network of randomly interwoven fibre bundles which is obtained by converting hides and skins of animals through the process of tanning[1,2]. The physical property of leather depends on the animal type and its origin, position and direction of sampling. Leather is one of the most widely traded commodities in the world. Leather industry in India accounts for around 12.9% of the world's leather production of hides/skins and handles a robust annual production of about 3 bn sq. ft. of leather[3]. This industry employs more than 2.5 million people[4]. The industry has potential to make high quality products that can address socio - economic problems and create employment and wealth.

Though the leather industry plays a significant role in the economy of our country through employment and export earnings, sustainability has become a great challenge for the industry due to various factors including high cost of treating tannery effluent. Processing of one metric ton of raw hide produces 200 kg of tanned leather, 200 kg tanned waste leather, 250 kg of non-tanned waste and 50,000 kg of waste water[5]. As leather is a by-product of meat industry the supply of leather raw material is fairly constant. However, the demand for leather products is continuously increasing. Lack of availability of good quality raw material and environmental problems has made the industry less competitive in the world market[6]. All these factors forced the researchers to pursue for alternative biodegradable materials. Natural fibre based fabrics are the first choice when it comes to biodegradable materials[7].

Silk is a kind of traditional material which is always associated with beautiful moments and creates emotional elements with products while handling[8]. It is called as queen of fabrics for its lustre, sensuousness and glamour. Besides its luxurious softness and lustrous beauty, it has its own strength properties. Mulberry silk comes from the silk worm *Bombyx mori* , which solely feeds on the leaves of the mulberry plant[9]. Silk material can be broadly classified as mulberry silk and non-mulberry silk. India is second largest producer of mulberry silk next to China[10]. Silk is a special natural fibre with smooth feel, drapeability and aesthetic appeal[11]. India is also the largest consumer of silk in the world. Silk is considered to be a symbol of royalty and historically, silk was used primarily by the upper classes. In this study, an attempt has been made to assess the physical and structural properties of silk and evaluate the possibility of combining these fabrics with leather for making lifestyle products. It is expected that the consumption of leather will be reduced by about 60-70% in combination products, which is a

[a]Corresponding author.
E-mail: kphebejohn@yahoo.co.in

significant achievement towards addressing the environmental issues and limited raw material supply.

2 Materials and Methods

2.1 Materials

Commercially available cow nappa leathers with thickness of around 0.6 mm were procured for this study along with commercially available silk material from the North Eastern part of India. Silk fabric was evaluated in three different forms, such as plain silk, fused silk (silk fabric fused with non-woven fabric), quilted silk (silk fabric reinforced with non-woven fusing and 2 layers of soft cotton foam followed by quilt stitching) (Fig. 1). Pure core-spun thread with needle size 90 was used for stitching. Specifications of the silk fabric taken for the study are given in Table 1. As leather products have to undergo various mechanical forces and other stresses while handling and loading things, it is imperative to evaluate these properties to facilitate design and fabrication of the product[12].

2.2 Methods

2.2.1 Seam Strength

Seam strength is the amount of pressure required to break or tear the seam of the product[13]. Seam strength was determined according to SATRA TM 180 test method using Instron tensile testing machine UTM 3369[14]. This value helps to determine the load bearing capacity of product made from those specimens.

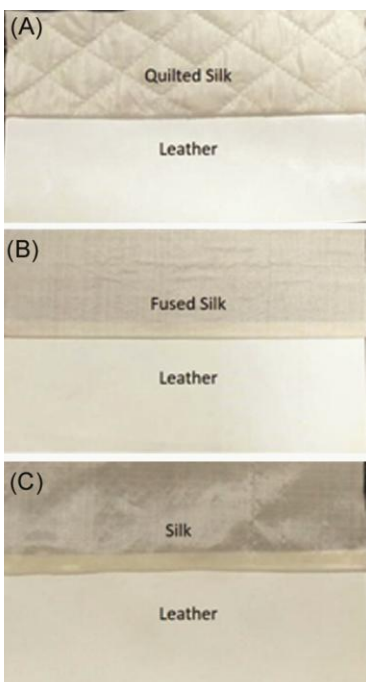

Fig. 1— Leather combined with silk based samples (A – leather with quilted silk, B – leather with fused silk, and C – leather with silk)

2.2.2 Elongation

Elongation is the average increase in length of the sample at its breaking point. Elongation was tested according to SATRA TM 43 for leather samples and SATRA TM 29 for silk based samples[15,16]. Percentage of elongation-at-break was determined by the difference between original length of the sample and the length at the time of rupture. This test helps to determine suitability of the sample for making goods and garments.

2.2.3 Stiffness

Stiffness is the degree of resistance of fabric to bending. Bending of the samples was measured using SASMIRA stiffness tester according to the Indian standard IS6490[17]. For evaluating the bending length, eight sets of rectangular samples of length 120 mm and width 25mm were cut from leather as well as silk based samples. Low value of bending length refers to low stiffness or better drapability, and a high value of bending length indicates high stiffness or poor drapability.

2.2.4 Softness

Softness is the most important physical property to be considered when assessing the quality of fabric or leather. Softness of the specimens was determined as per the standard ISO 17235 test method[18]. Softness was measured at five different locations for leather and silk based samples. Difference in value of softness is due to difference in material, thickness, fusing and reinforcement used.

2.2.5 Color Fastness to Alkaline Perspiration

Perspiration may change color of the fabric, cause uneven repositioning of color on colored fabric or staining of material. This test helps to determine degree of discoloration or transfer of color from leather or silk fabric to adjacent fabric specimen, when it comes in contact with perspiration. SATRA TM 335 standard

Table 1 — Specification of mulberry silk

Property	Value
Type of weave	Plain weave
Silk yarn denier	35.0 : 69.1(warp : weft)
Ends/inch	101
Picks/inch	97
Weight, g/m^2	42.7
Fibre content, %	100
Pilling	4-5
Tensile strength, N	196.8 : 444.4 (warp : weft)
Seam slippage, N	188 : 73 (warp : weft)

was followed to determine color fastness[19]. Degree of color transfer was graded using a gray scale.

2.2.6 Breaking Strength with respect to Alkaline Perspiration

Breaking strength test helps us to determine the degree to which silk deteriorates. When silk comes in contact with human perspiration for a prolonged time, deterioration of silk occurs which is mainly due to the presence of acid, alkali or both in human perspiration[20]. The strength of silk decreases when the moisture content present in it increases and strength will be regained when excess of moisture evaporates[21]. Breaking strength is determined by using standard SATRA TM 29. Three sets of rectangular pieces of dimensions 110mm length and 55 mm width were taken. Each set comprises plain silk, fused silk and quilted silk specimens. Breaking strength was analyzed for one set initially. The remaining two sets of specimens were allowed to be in contact with artificial alkaline perspiration solution for about 30 min and breaking strength was determined at two different intervals, such as 24h and 48h after treatment. The values obtained were inferred statistically using SPSS software.

2.2.7 Air Permeability

Air permeability of a fabric is a measure of how well a fabric allows the passage of air through it, indicating the breathability of the fabric. Air permeability test was carried out using Textest FX3300 air permeability tester as per standard ISO 9237[22].

2.2.8 Scanning Electron Microscopic Analysis

The SEM and microscopic analyses was carried to understand the surface and cross-sectional fibre alignment of leather, silk, fused silk and quilted silk. The samples were mounted on a circular metallic sample holder using adhesive tape and then examined using a Phenom Pro, the high end imaging desktop scanning electron microscope at various magnifications. The grain surface and cross-sections were captured using optical microscopic imaging. Sliced samples with dimensions of 8 mm width and 2 cm length from an identical location were imaged in a Magnus Stereo Zoom Microscope with Trinocular Body micro imaging facility.

3 Results and Discussion

Compatibility of cow nappa leather with silk was analysed by comparing the physical properties like seam strength, breaking strength, elongation, perspiration resistance, softness, etc. and fastness property namely color fastness. Seam strength in particular was evaluated for different combinations of cow nappa leather and silk, such as leather with leather, leather with silk, leather with fused silk, and leather with quilted silk; leather with silk based samples shown in Fig. 1.

3.1 Seam Strength

Seam strength of leather with leather/silk based samples is presented in Table 2. It is evident from the results that the seam strength of all silk based

Table 2 — Properties of leather and silk based fabric

Property	Leather	Silk	Fused silk	Quilted silk
Elongation, mm	8.9 (along) 10.5 (across)	17.7 (warp) 15.6 (weft)	14.8 (warp) 12.6 (weft)	31.2 (warp) 28.4 (weft)
Stiffness, cm	3.2	2.6	4.2	5.3
Softness, mm	3.9	6.7	6.2	4.5
Colour fastness	4/5	4/5	4/5	4/5
Breaking strength[a], N				
Initial	5.5	8.6	9.3	8.**8**
After 24h	10.1	6.4	7.3	8.0
After 48h	4.9	8.4	9.8	8.6
Seam strength[b], N/mm				
L *vs* L	5.6 ± 0.3 (along) 4.1 ± 0.2 (across)	-	-	-
L *vs* S	-	5.2 ± 0.1 (warp) 3.0 ± 0.1 (weft)	-	-
L *vs* FS	-	-	5.7 ± 0.2 (warp) 3.2 ± 0.1 (weft)	-
L *vs* QS	-	-	-	6.7 ± 0.1 (warp) 3.6 ± 0.4 (weft)

[a] Estimated marginal means.
[b] L – leather, S – silk, FS – fused silk and QS – quilted silk

combinations is higher in warp direction as compared to that in weft direction. This is because warp yarns have more strength than weft yarns[23]. Seam strength of cow nappa leather is also higher in the parallel direction as compared to that in perpendicular direction, which indicates that a greater percentage of collagen fibres is oriented mostly in parallel direction[24]. It is much interesting to note that the seam strength of all silk based combinations is comparable to that of leather and with quilted silk seam strength is maximum (with a value of 6.7 N/mm) in warp direction. This is because cross stitches made for quilting impart cohesive forces between the fibres, which restrict the movement of warp and weft yarns. Therefore, more load is required to break the seam. The layers of reinforcement reduce the area of contact between fibres and thread, thereby reducing the interfibrillary frictional force which adds to the strength as compared to rest of the samples.

3.2 Elongation

It is evidenced from Table 2 that the percentage elongation-at-break is less in leather as compared to that in silk based fabrics. The reason being, in leather the fibres have a very low angle of weave and hence their movement during extension is limited[25]. However, among the silk based samples, quilted silk shows better elongation, because the load applied is distributed between the reinforced layers and the fabric. Apparently an increase in elongation of warp over weft may be due to the degree of twist in yarn fibre used[26]. Though warp yarn is finer than weft yarn, when load is applied, due to twist in the warp yarn, it elongates more to untwist the yarn fibre and then it breaks.

3.3 Stiffness

The stiffness values of leather, silk, fused silk and quilted silk were evaluated and presented in Table 2. Silk shows comparable bending length (stiffness) to that of leather, indicating their suitability for garment applications. Fused silk and quilted silk possess marginally higher stiffness values. The reason being, in quilted silk the closely spaced lines of stitching where one thread crosses another thread lead to high stiffness. The reinforcement material used in quilted silk also contributes to stiffness. Fabrics with high value of stiffness have strong resistance to bending. Therefore, while designing products it is suggested that quilted silk be used to replace leather components in places where the dimensional stability or shape retention property is required. Fused silk can be used for flaring in leather goods and garments.

3.4 Softness

Softness is one of the major requirements for apparel applications. Degree of softness helps to quantify the feel and handle of the material[27]. It has been observed that silk and fused silk show excellent softness. There is a decrease in softness for quilted silk as shown in Table 2. This is mainly due to the reinforcement layer and stitches used for quilting. However, it is found to be better than that of leather. Type of fusing and foam material used for reinforcement and types of stitches made for quilting also have an impact on softness.

3.5 Color Fastness to Alkaline Perspiration

Color fading or alterations are caused by the reaction between dyes in the products and perspiration. It varies for different individuals and conditions. Results obtained are shown in Table 2. Color fastness to perspiration for silk, fused silk and quilted silk is same as that of leather. Since there are no visual changes in the silk fabrics experimented, it confirms its strong resistance to alkalinity present in the sweat or perspiration solution.

3.6 Breaking Strength with respect to Alkaline Perspiration

Breaking strength with respect to alkaline perspiration for leather, silk, fused silk and quilted silk has been determined at three different time intervals (before and after treatment with alkaline perspiration). Tests have been carried out both along warp and weft. It is observed that the breaking strength along the warp is less as compared to that along weft direction, because yarns along weft are coarser as compared to warp direction. Hence in our study for breaking strength analysis, we have considered only weft direction which has higher breaking strength for combination with leather. This observation on breaking strength is found to be in congruence to the work carried out by Nassif[28]. In view of the above, it is recommended that silk fabric needs to be affixed along weft direction according to the loading requirements of leather products.

After 24 h of treatment with alkaline perspiration, breaking strength declines for silk based samples, whereas for leather the strength increases. This is because excess moisture content leads to break down of fibres in silk, but in the case of leather, it improves the elasticity of fibres. After 48 h, once it becomes dry, breaking strength increases for the silk based samples. The reason being, fibres start to regain strength when the moisture content present in it evaporates, whereas for leather, breaking strength starts to decline.

This inverse behaviour between leather and silk is a significant relationship which gives knowledge to product developers to avoid silk based components in places which are prone to human perspiration or moisture content in order to retain the strength as ever in leather products. These results are substantiated using statistical analysis of estimated marginal means through GLM using SPSS software, as shown in Table 2. It is also evidenced from the results that after 48 h of treatment quilted silk exhibits nearly uniform breaking strength than rest of the silk based samples.

3.7 Morphological Analysis

The scanning electron micrographs of silk, fused silk, quilted silk and leather showing surface fibre alignment are shown in Figs 2 (a-d). It is inferred that fibre bundles in silk and fused silk are loosely woven along warp and weft directions, whereas in quilted silk the fibres are compact. The reason being, in quilted silk cross stitches made between the fibres develop inter fibrillary cohesive forces that restrict the movement of warp and weft fibre bundles and hence remain intact with each other. It is also seen that leather possesses a continuous porous structure with fibre bundles running parallel to the skin.

The scanning electron micrographs of silk, fused silk, quilted silk and leather showing cross-sectional fibre alignment is shown in Fig. 3(a-d). It is clearly seen from cross-sectional view of silk fabric that the alternate weaving of warp and weft fibre bundles forms spindle shape uniformly throughout the cross-section, which permits the air to pass through the small pores at the overlapping points of warp and weft. This is in accordance with air permeability value of 350.9 mm/s for silk fabric, which is a measure of breathability, thereby enhancing the comfort.

In case of fused silk, as the non-woven material comes in contact with spindle shaped fibre bundles, pores at the point of contact remain closed and rest of the pores remain open. Air permeability of fused silk is only 156.6 mm/s, which is much less compared to that of silk fabric. Decrease in air permeability enhances the stiffness, as reported by Fatahi and Yazdi[29]. This is the main reason for decrease in comfort property of fused silk than plain silk fabric. In case of quilted silk, silk is first fused and thereafter layers of foam are placed and stitched. The pattern observed in fused silk is found here, but cross stitches made between warp and weft fiber bundles restrict the movement of air within the dimension. As a result, there is increase in stiffness of quilted silk than in the rest of the silk based samples. Air permeability test for quilted silk could not be performed due to the presence of stitch holes. However, in cow nappa leather, the fibre bundles are interwoven with each other closely and randomly throughout the leather matrix.

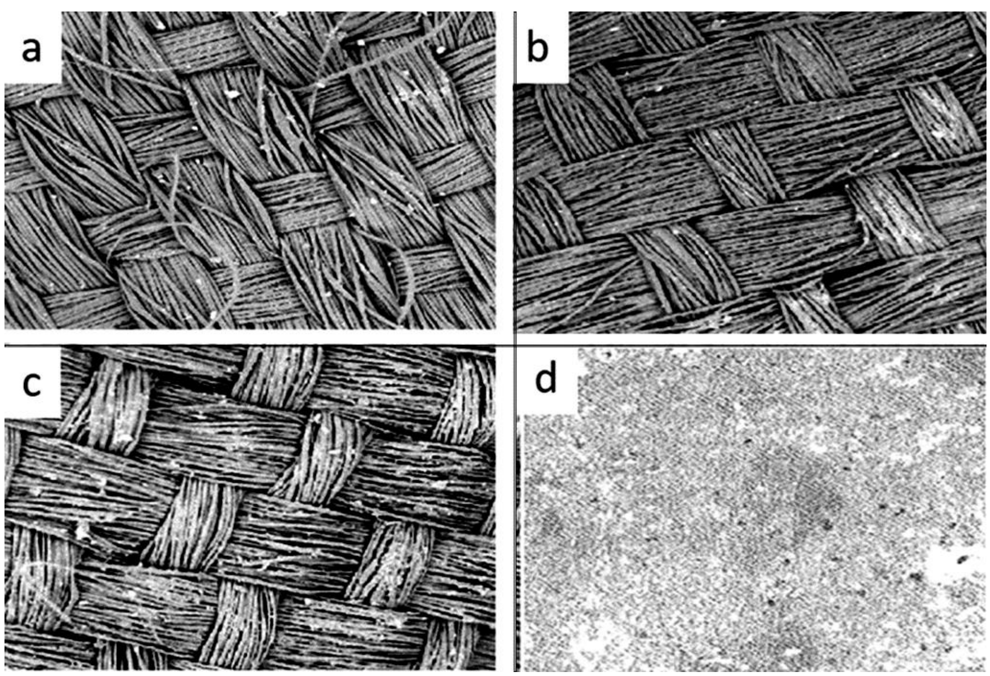

Fig. 2 — Scanning electron micrographs showing surface fibre pattern of silk based samples and leather (a) mulberry silk, (b) mulberry silk fused with non-woven fusing material, (c) mulberry silk quilted with foam and (d) leather

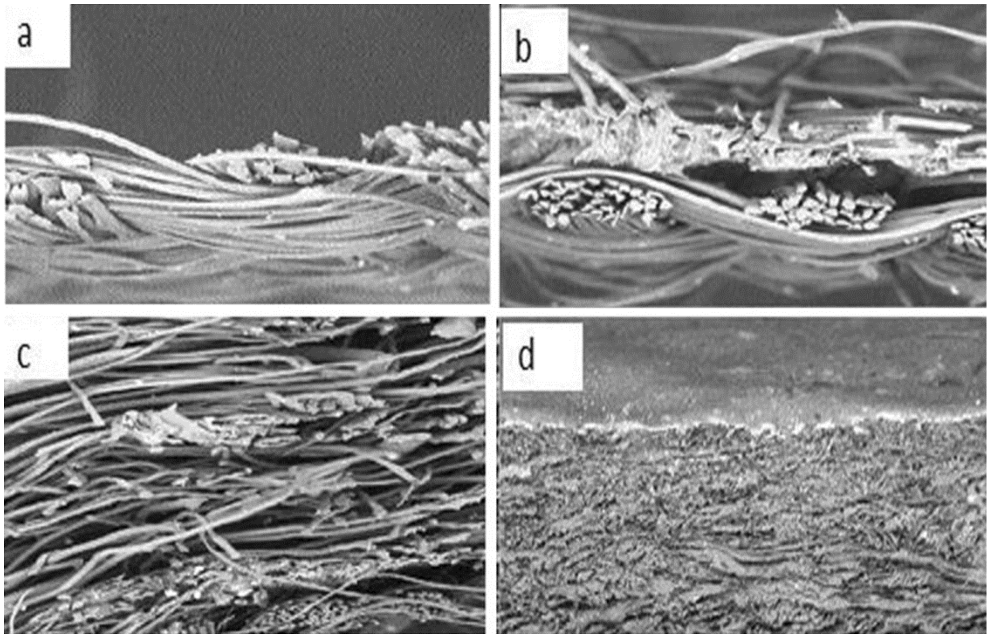

Fig. 3 — Scanning electron micrographs showing cross sectional view of silk based samples and leather (a) mulberry silk, (b) mulberry silk fused with non-woven fusing material, (c) mulberry silk quilted with foam and (d) leather

From the above results and discussion, it is inferred that the strength and fastness properties of silk are found to be comparable to that of leather. The study also shows that quilted silk has good compatibility with cow nappa leather.

3.8 Product Development

Globally leather is perceived as a premium product and integration with silk would definitely amalgamate as a Niche product. Since findings are favourable for the compatibility of silk fabric with cow nappa leather, an attempt was made to fabricate products, such as bags, from different combinations of nappa leather with quilted silk, fused silk and plain silk. These products exhibit unique aesthetic appeal with ethnic touch and luster and crave a new market segment catering to high end consumers. Since leather has become scarce as well as expensive and to meet the growing demand, combination products will definitely fetch a huge market potential.

4 Conclusion

The unique properties of silk, such as luster, handle and smoothness, render enormous value to combination products. The aesthetic appearance and feel of products made from quilted silk outshine rest of the products made. The strength properties of quilted silk are found better than that of leather samples taken for the study and hence it is preferable to choose quilted silk as a major substitute for leather products to target high end customer oriented market in near future. The exceptional relationship between leather and silk in alkaline perspiration gives lead to product designers in designing the combination products, thereby keeping in line with global market trends. Also the judicious combination of leather with quilted silk helps to reduce the leather consumption in fabrication of products and to meet the demand for growing leather products.

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