Factors Influencing the Seam Efficiency of Goat Nappa Leathers

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Abstract

Apparel making is the process of making shell structures from flat fabrics or leathers to match the shape of human body. During this process, leathers are subjected to various types of mechanical stresses, which are indispensable for the garment appearance. The present study involves investigating the mechanical properties of goat nappa leathers such as seam strength, breaking strength, seam efficiency, tensile strength, percent elongation, double hole stitch tear strength, flexural rigidity, initial tensile modulus and formability and establishing a relationship between seam efficiency and other mechanical properties. Seam efficiency of goat nappa leathers chosen in this study range from 55 to 76% in both parallel and perpendicular directions to the backbone. It has been observed that breaking strength of goat nappa leathers seems to have a significant influence on seam efficiency among the various mechanical properties studied with a negative correlation ($R = -0.92$). This means that modifications in fatliquoring and other related leather processing steps may offer low strength goat nappa leathers with more softness leading to enhanced seam efficiency. These results would help tanners and leather garment manufacturers to make appropriate selection of leather processing steps and sewing procedures, thereby avoiding possible economic losses.

Resumen

Fabricar vestimenta es el proceso de elaboración de estructuras laminares de tejidos planos o de cueros para que coincida con la forma del cuerpo humano. Durante este proceso, los cueros son sometidos a diversos tipos de esfuerzos mecánicos, que son indispensables para la apariencia de la vestimenta. El presente estudio consiste en investigar las propiedades mecánicas de cueros napa de cabra, como resistencia de la costura, resistencia a la rotura, eficiencia de la costura, resistencia a la tracción, porcentaje de elongación, resistencia a la doble puntada, la rigidez a la flexión, módulo de elasticidad inicial y conformabilidad, y establecer una relación entre la eficiencia de la costura y otras propiedades mecánicas. La eficiencia de la costura de los cueros napa de cabra elegidos en este estudio van desde 55 hasta 76% en las dos direcciones paralelas y perpendiculares a la columna vertebral. Se ha observado que la resistencia a la rotura de las pieles de napa de cabra parece tener una influencia significativa en la eficiencia de la costura entre las diferentes propiedades mecánicas estudiadas con una correlación negativa ($r = -0.92$). Esto significa que modificaciones en el engrase y otras medidas relacionadas con el procesamiento de cuero puede ofrecer baja resistencia a la napa de cabra con más suavidad, lo que conduce a una mayor eficiencia de la costura. Estos resultados ayudan a los curtidores y fabricantes de ropa de cuero para hacer la selección apropiada de pasos de procesamiento de cuero y los procedimientos de costura evitando así las posibles pérdidas económicas.

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INTRODUCTION

Leather is composed of interwoven networks of collagen fibers. The condition and the manner in which the fiber bundles interweave will determine major properties of leather for various applications.[1] Leather is produced from skin of individual animals and therefore differs from textiles, which are available in continuous length with roughly consistent properties. Construction of garments from leather involves techniques similar to those used for garments made from woven fabrics.[2] The mechanical properties of apparel fabrics are important from the point of view of stresses applied to the fabrics in the making up as well as physical changes in the fabrics, which result from application of forces in garment during its use.[3] Clothing manufacture is the process of making shell structures from flat fabrics to match the shape of human body. While converting a two dimensional fabric into three dimensional form, there is a strong interaction among thread, machine and fabric.[4] Tailorability is the ability and ease with which fabric components can qualitatively and quantitatively be sewn together to form a garment. Some of the major factors influencing tailorability are formability and sewability. Formability is the maximum compression sustainable by the fabric before the onset of buckling. Good sewability is the ease of formation of shell structures and absence of fabric distortion.[5] The study of sewability in clothing manufacture has considerable influence in today's advanced garment manufacturing process. The appearance and durability of seam form an important component of the quality of finished product.[6] The present research work, by considering specific leather properties, explores the interrelationship between seam efficiency and mechanical properties. Recently, we have studied the interdependence between the mechanical properties of sheep nappa leathers and seam efficiency.[7] It is known that leathers meant for clothing differ in their origin, tannage and mechanical or physical properties. The study therefore involves investigating the mechanical properties of goat nappa leathers meant for apparel such as flexural rigidity, initial tensile modulus, formability, breaking strength, percent elongation, tensile strength, seam strength, double hole stitch tear strength and seam efficiency. This study will serve as a basis for production of leather clothing with desired characteristics.

EXPERIMENTAL

Materials

Commercially available goat nappa garment leathers with thickness 0.6±0.1 mm and an average size of 5±0.5 sq.ft were procured from three different lots and designated as L1, L2 and L3. Each lot contained five goat nappa leathers. The specimens for analyzing seam strength, double hole stitch tear strength and flexural rigidity were taken adjacent to each other in both parallel and perpendicular directions to the backbone.[8] Test specimens used for flexural rigidity measurements were further utilized for measuring thickness and weight and subjected to fabric tensile strength, percentage elongation, initial tensile modulus and formability analysis. Stitches were made using Coats make core spun thread (ticket no.50) on a Pfaff flat bed sewing machine for sewability testing. A number 110 needle was used throughout the study.

Flexural rigidity

Flexural rigidity was determined according to Indian standard IS 6490 test method.[9] Considering the size of the leather, samples of dimensions 25 × 120 mm were cut parallel and perpendicular directions to the backbone of the leather. The rectangular pieces were shorter in length than the specimen length specified in the standard as it has been observed earlier that the deviation in the length of the samples up to 100 mm does not influence the flexural rigidity.[10] For each sample, the length of slacking part of sample (L) was measured by the constant angle method with each side up, first at one end and then at the other. The mean value of L was obtained from which flexural rigidity (G) was calculated.

$$G = W \times \left(\frac{L}{2}\right)^3 \quad (1)$$

where

W = weight per unit area of leather in mN/mm²

G = Flexural rigidity in mNmm

Tensile strength and extension

Tensile strength was measured according to Indian standard IS5914.[11] Leather specimens used for the above study were cut into dumb bell shape. The test was carried out using a Universal testing machine (Instron 4501). The gauge length was 50 mm and cross head speed was 100 mm/min. The machine was allowed to run until the test piece broke and the highest load and extension was recorded and the force - elongation curve registered.

Initial tensile modulus

Initial tensile modulus is defined as a ratio of force to elongation increment taking place in the initial linear shape of force elongation curve related to the sample width.[12] From the force - elongation curve obtained using a Universal testing machine (Instron 4501), change in force, ΔF, was measured for displacement of 0 to 2 mm (ΔD) and initial tensile modulus was calculated as shown in equation (2).

$$ITM = \frac{\Delta F}{\Delta D} \times \frac{GL}{b} \quad (2)$$

where

ΔF = Force in N

ΔD = Elongation in mm

GL = Gauge length in mm

b = Width of specimen in mm

ITM = Initial tensile modulus in N/mm

Formability

Formability (F) is defined as a ratio of flexural rigidity and initial tensile modulus[12] and calculated as shown in equation (3)

$$F = \frac{G}{ITM} \times 10^{-3} \quad (3)$$

where

G = Flexural rigidity in mNmm

ITM = Initial Tensile Modulus in N/mm

F = Formability in mm^2

Seam strength

Assessment of seam strength is basically an estimation of the amount of load required to tear or break the seam of the garment. Seam strength was determined according to ISO 17697 test method.[13] Rectangular test specimens of dimensions 100 × 50 mm were cut from the leather and a plain lock stitch seam was made using Coats make core spun thread (ticket no.50) with a stitch density of 3 stitches/cm. The seam was made midway between the two ends of specimen and the cuts were made perpendicular to the seam as detailed elsewhere.[7] The test was conducted using a Universal testing machine (Instron 4501) and the seam strength was calculated.

Breaking strength

This test is intended to determine the force required to break a test specimen. The test was carried out as per the standard SATRA TM29[14] using Instron. The machine was adjusted in such a way that the jaws were 100 mm apart and the crosshead speed was 50 mm/min. The specimens with dimension 120 x 25 mm were stretched by the machine until it failed and the breaking strength was recorded in N. This procedure was repeated for specimens in both directions (parallel and perpendicular).

Stitch tear strength (Double hole)

Double hole stitch tear strength was determined according to Indian standard IS5914.[11] Test pieces of dimensions 50 x 25 mm were cut both along and across the backbone direction of the leather. Two holes were made in the test pieces and a metal wire made into a 'U' shaped loop was passed through two holes so that both ends project from flesh side of the test piece. The ends of the wire were clamped in one of the grips of the Instron and the free end of the test piece in the other grip. The crosshead speed was maintained at 250 mm/min. The load required to tear the test piece at the moment of initial tear was recorded.

Seam efficiency

Durability of a seam can be measured in terms of seam efficiency, which is the ratio of seam strength to fabric breaking strength of the fabrics' sewn.[15]

Seam efficiency is calculated as shown in equation (4)

$$\text{Seam efficiency (\%)} = \frac{\textit{Seam strength}}{\textit{Fabric breaking strength}} \times 100 \quad (4)$$

where seam strength and fabric breaking strength are measured in N.

Results and Discussion

Seam efficiency

The characteristics of high quality seam are strength, durability and appearance.[16] These qualities are measured in terms of seam efficiency. It is the retention of strength in a seamed fabric after sewing with respect to the original fabric strength. Seam efficiency largely depends upon tensile behavior of fabric and thread, the combination of fabric and thread, the dimensional and surface characteristics of sewing thread and other machine and process parameters.[17] Seam efficiency values of goat nappa leathers from three different lots are shown in Table I along with standard deviation values. Mean values of seam efficiency range between 55 and 67% in the parallel direction and 60 and 76% in the perpendicular direction. The average value for seam efficiency in the perpendicular direction is higher than that in the parallel direction. These values are little lower than that of sheep nappa leathers[7]. Seam efficiency largely depends on the strength as well as the elasticity of the fabric material. Since goat nappa leathers are less elastic compared to sheep nappa leathers, the seam efficiency values of goat nappa leathers are inferior to sheep nappa leathers.

Seam efficiency versus seam strength

Seam strength is the strength of seam assembly in a garment. Failure of seam assembly can occur either by breaking of sewing thread, tearing of the fabric at the seam or a combination of the above factors.[18] The mean values of seam strength of goat nappa leathers procured from three different lots are given in Table I along with their standard deviation. Mean values range from 157 to 191 N in both parallel and perpendicular directions. Results show that the values are higher when the leather was tested for seam strength perpendicular to the backbone. This may be due to the orientation of collagen fibers in the leather matrix, which is mostly parallel to the backbone.[19] Although the samples are cut from perpendicular to the backbone direction for the seam strength analysis, the seam is made perpendicular to the sample direction, which is parallel to the backbone direction. Hence, the combination of seam as well as the orientation of more number of fibers in the parallel direction leads to a higher seam strength and seam efficiency for samples cut from perpendicular direction. A plot of seam efficiency versus seam strength was made after calculating the mean of parallel and perpendicular direction values as shown in Fig. 1. The correlation between them seems to be linear with a correlation coefficient value of 0.84. This shows that seam efficiency is directly proportional to the seam strength, in accordance with equation (4).

Seam efficiency versus breaking strength

The mean values of breaking strength of goat nappa leathers from different lots are given in Table I along with standard deviation. Mean breaking strength values range from 231 to 324 N. The mean seam efficiency values of individual leathers have been plotted against mean breaking strength values as calculated from both directions as shown in Fig. 2. The seam efficiency values decrease with increase in breaking strength because seam efficiency is inversely related to breaking strength for a given sewing thread as per equation (4) and exhibit a negative slope. The value of correlation coefficient is –0.92 and shows a very good correlation between the seam efficiency and breaking strength of goat nappa leathers.

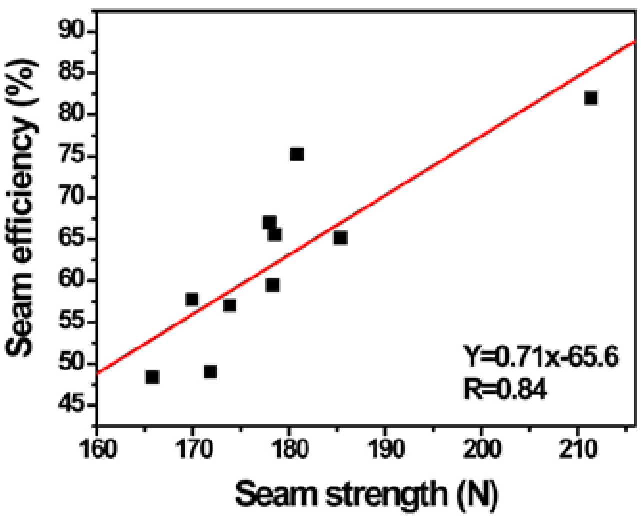

Figure 1. Relation between seam efficiency and seam strength of goat nappa leathers from the mean values between parallel and perpendicular direction

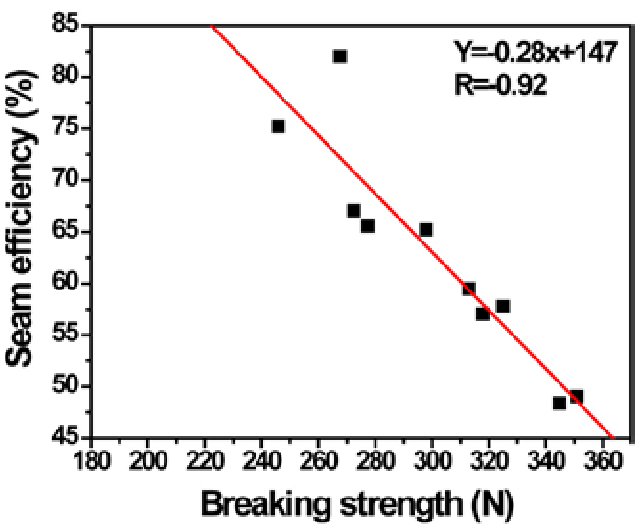

Figure 2. Relation between seam efficiency and breaking strength of goat nappa leathers from the mean values between parallel and perpendicular direction

Seam efficiency versus tensile properties

The results of tensile strength measurements of goat nappa leathers are shown in Table I along with standard deviation values. The mean values range from 16 to 27 MPa. The mean tensile strength values of individual leathers were plotted against mean seam efficiency (calculated from both parallel and perpendicular direction values) as shown in Fig. 3. The correlation seems to be good with a negative slope (R = –0.7). This means that the goat nappa leathers with low tensile strength possess better seam efficiency, which may be due to the soft and pliable nature of the leather with low strength. Percentage extension of goat nappa leathers selected for this study is given in Table I. The mean values range from 37 to 68% in both the directions. The mean seam efficiency values of individual leathers have been plotted against mean percentage extension and the plot yielded a poor linear fit with a correlation coefficient of –0.42 (Figure not shown).

Seam efficiency versus stitch tear strength (double hole)

The mean values of stitch tear strength (double hole) of goat nappa leathers in parallel and perpendicular directions are given in Table I along with standard deviation. The values range between 50 and 82 N in both directions. A plot of mean seam efficiency versus mean stitch tear strength for individual leathers (after calculating the mean of parallel and perpendicular direction values) yielded a correlation coefficient of –0.76 as shown in Fig. 4. This shows that there is a significant inverse correlation between the two parameters. Stitch tear strength depends mostly on the fabric strength. In other words, akin to fabric breaking strength, stitch tear strength also exhibits an inverse relation to seam efficiency (equation 4).

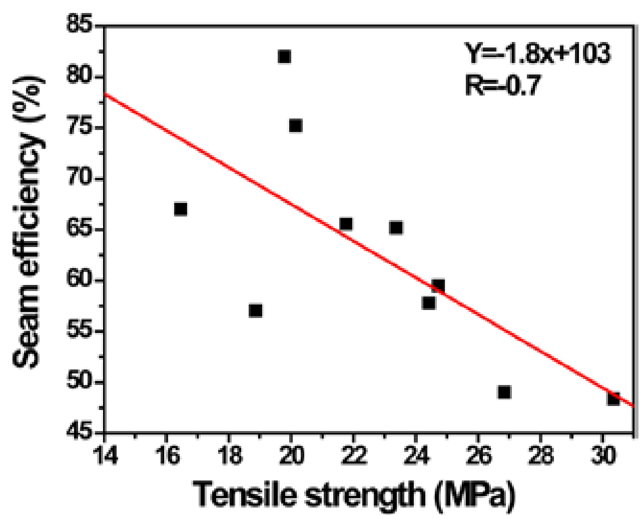

Figure 3. Relation between seam efficiency and tensile strength of goat nappa leathers from the mean values between parallel and perpendicular direction

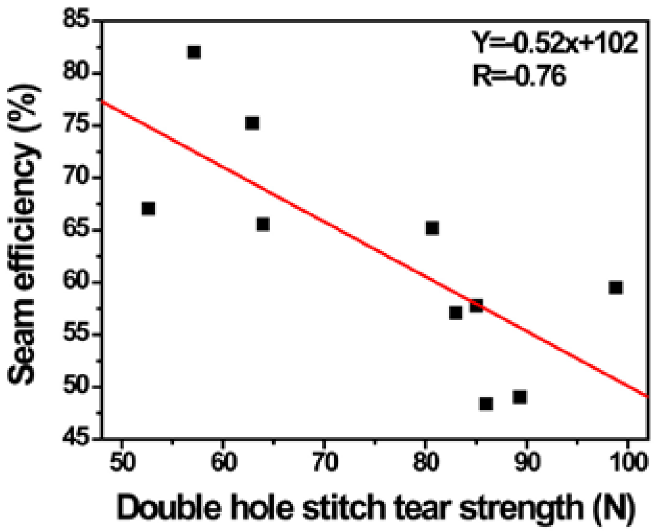

Figure 4. Relation between seam efficiency and stitch tear strength (double hole) of goat nappa leathers from the mean values between parallel and perpendicular direction

Seam efficiency versus flexural rigidity

Flexural rigidity is a measure of stiffness of a fabric and is related to the length of bending of the specimen as a consequence of gravitational force. It is usually attributed to the rigidity of collagen fibers in leather.[3] Flexural rigidity of goat nappa leathers was measured in parallel and perpendicular directions and the mean values are given in Table I along with the standard deviation. It is seen that there is no significant difference in the flexural rigidity values measured in the two directions and the values range from 96 to 124 mNmm. These values are significantly higher than that of sheep nappa leathers.[7] This may be due to the fact that goat nappa leathers possess compact fiber structure compared to sheep nappa leathers. Compact fiber structure generally offers more resistance to flexing thereby leading to higher values of flexural rigidity. The plot of mean seam efficiency versus mean flexural rigidity (calculated from both parallel and perpendicular direction values) reveals that there is fairly less significant correlation between the two properties (R = –0.64; Fig. 5).

TABLE I
Seam efficiency and related mechanical properties of goat nappa garment leathers

Leathers	Seam efficiency (%)		Seam strength (N)		Breaking strength (N)	
	Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular
L1	64.2±19	63.4±11	180.4±18	190.7±20	303.5±49	313.0±24
L2	67.3±8	76.1±9	156.8±34	169.0±15	233.7±32	231.4±36
L3	54.6±12	60.2±10	170.0±8	173.3±8	324.0±56	300.3±34
Mean	62.0±7	67.0±8	169.0±12	178.0±12	287.3±47	281.6±44
Leathers	**Double hole stitch tear strength (N)**		**Flexural rigidity (mNmm)**		**Initial tensile modulus (N/mm)**	
	Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular
L1	78.4±14	76.7±15	107.2±21	115.0±15	8.0±1.5	9.2±1.2
L2	50.5±14	50.0±11	112.0±51	124.0±40	11.5±6	11.0±2
L3	68.7±16	82.4±16	102.5±15	96.0±17	6.9±2	7.3±1.7
Mean	68.8±16	70.0±17	107.0±5	112.0±14	8.8±2	9.2±2
Leathers	**Formability (mm^2)**		**Tensile strength (MPa)**		**Elongation at break (%)**	
	Parallel	Perpendicular	Parallel	Perpendicular	Parallel	Perpendicular
L1	0.015±0.003	0.013±0.002	21.5±3	23.0±5	55.2±3	56.0±6
L2	0.013±0.002	0.011±0.002	16.0±2.3	17.5±3	48.8±5	37.0±5
L3	0.016±0.003	0.014±0.003	27.0±7	23.0±1.2	67.9±7	58.1±9
Mean	0.015±0.002	0.013±0.002	21.3±6	21.0±3.3	57.3±10	50.4±11.5

Values are average of five leathers from each lot

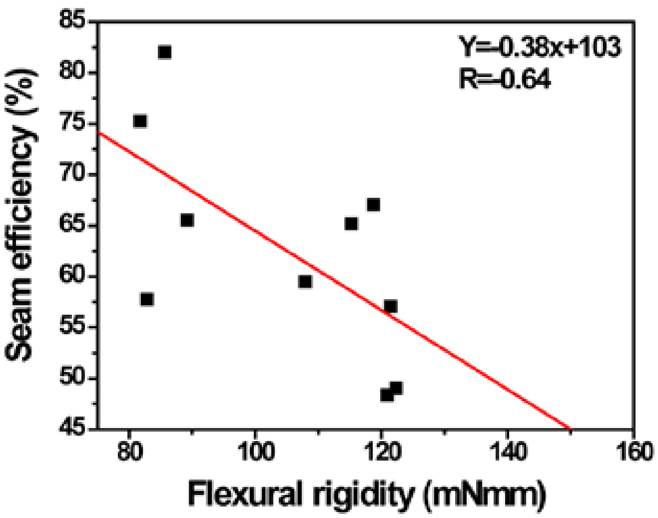

Figure 5. Relation between seam efficiency and flexural rigidity of goat nappa leathers from the mean values between parallel and perpendicular direction

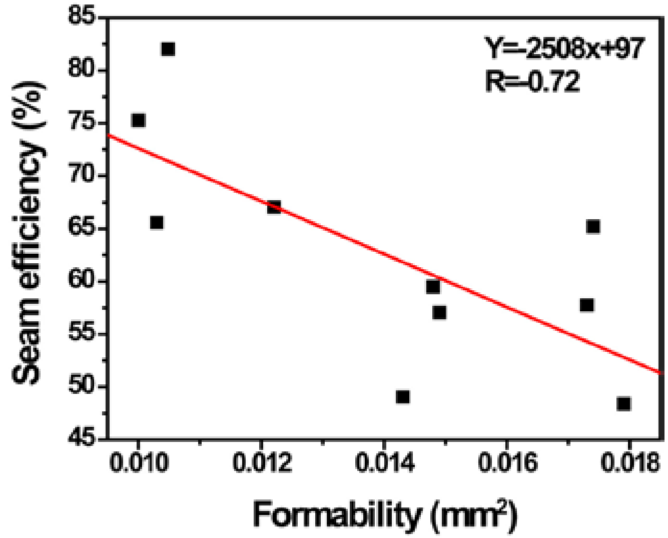

Figure 6. Relation between seam efficiency and formability of goat nappa leathers from the mean values between parallel and perpendicular direction

Seam efficiency versus initial tensile modulus

At very small strain, the tensile stress – strain relationship is often fairly linear and therefore can be used for obtaining initial tensile modulus.[20] Initial tensile modulus of goat nappa leather was measured and correlated with seam efficiency. The mean values of initial tensile modulus are given in Table I. The values range from 7 to 12 N/mm for different lots. The mean initial tensile modulus values have been plotted against mean seam efficiency values for individual leathers after calculating the mean of parallel and perpendicular direction values. It is observed that the influence of initial tensile modulus on seam efficiency is not substantial as there is no significant correlation between the two properties. (R = 0.17; Figure not shown).

Seam efficiency versus formability

Formability is a specific clothing property defined as the ability of leather/fabric to transform from two dimensional into a simple or complex three-dimensional form. It is the minimum compression sustainable by a fabric before the onset of buckling.[21] The lower the formability, the more likelihood of seam pucker, because the fabric is unable to accommodate the small compression placed on the fabric by sewing thread. The mean formability values of individual leathers are given in Table I along with standard deviation. The values range from 0.010 to 0.016 mm^2. Mean formability of individual leathers has been plotted against mean seam efficiency values after calculating the mean of parallel and perpendicular direction values as shown in Fig. 6. It is observed that seam efficiency is inversely related to formability and exhibit a negative slope. Seam efficiency values decrease with increase in formability values. The value of correlation coefficient (R = –0.72) shows a fairly good correlation between the two parameters.

CONCLUSIONS

Sewability of goat nappa leathers was measured and related to the relevant mechanical properties. On the basis of the experiments carried out, it was observed that seam efficiency increases with the increase in seam strength and decreases with increase in breaking strength as well as tensile strength. This implies that low tensile strength goat nappa leathers with more softness are preferable for garment construction. In other words, fatliquoring process and mechanical staking may play a major role in achieving high seam efficiency in garment production from goat nappa leathers. Double hole stitch tear strength and formability do influence seam efficiency reasonably. Flexural rigidity of goat nappa leather moderately influences the seam efficiency with a correlation coefficient of –0.64. Percentage elongation and initial tensile modulus do not have significant correlation with seam efficiency. Of all the mechanical properties studied, it has been observed that the breaking strength seems to be the best predictor of seam efficiency of goat nappa leathers. The findings from this study provide insight into understanding the preferred properties for assembling garment leathers, and will help in designing and fabrication of leather garments as well as selection of proper leather processing steps by tanners.

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