Leather for Musical Instruments: Effect of Surface Crosslinking on the Mechanical and Acoustic Properties

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Leather for Musical Instruments: Effect of Surface Crosslinking

on the Mechanical and Acoustic Properties

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Abstract

Leather-based percussion instruments have long served as vital conduits of cultural expression and emotional resonance within Indian society. Their presence spans a wide spectrum of communal and personal experiences - joy, sorrow, valor, entertainment, celebration, festivals, and matrimonial ceremonies. Far beyond their acoustic function, these instruments embody the emotional and symbolic dimensions of our heritage. Despite their enduring cultural significance, such instruments have received limited attention within the domains of scientific research and technological innovation. A notable Gap persists in efforts to adapt and evolve them in alignment with contemporary cultural dynamics, societal expectations and sustainability imperatives. In response to this gap, we have developed a process for manufacturing leather tailored to musical instruments. This innovation emerged through a series of scientific interventions aimed at enhancing material performance while respecting traditional craftsmanship. Our findings reveal that surface crosslinking of pretreated leather significantly improves tonal characteristics, and the acoustic properties can be tuned by varying the degree of crosslinking.

We systematically studied the effect of surface crosslinking on mechanical and acoustic characteristics and compared these with traditional leather. While tensile and tear strengths of the

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experimental leathers decreased relative to conventional processing, relaxation studies indicated an increase in overall elasticity. This enhancement suggests that the experimental leathers are more suitable for percussion instruments due to their improved reverberation characteristics, as corroborated by acoustic studies.

This work establishes a simple yet efficient surface crosslinking method that enables tuning of leather’s mechanical properties, thereby achieving desirable acoustic behavior for musical applications.

Keywords: Traditional leather; Crosslinking; Mechanics; Acoustics; Viscoelasticity.

1. Introduction

Leather, a material widely used in many industrial and fashion industries, is primarily made of collagen, a fibril protein network. Traditionally, leather is also being used in making of musical instruments at a global level. The process used by the instrument makers are predominantly depend on the not-so-controlled manner having issues at several stages starting from incomplete removal of flesh and hairs from hides and skins, leathers prone to microbial decay, inability to tune the acoustic and mechanical properties and finally the aesthetics of the instruments with the advent of latest technologies. Leather tanning is a controlled chemical process in other words called as crosslinking between the collagen fibers thereby stabilizing the hide against environmental degradation and mechanical

deformation. This particular process is not followed by the traditional leather makers for musical instruments currently. The nature of chemical crosslinking and its degree of crosslinking significantly influence the tensile strength, viscoelasticity and frequency distribution when made as an instrument and they are directly proportional to the tensile strength, microbial degradation and inversely proportional to the elongation (doi.org/10.1016/ j.heliyon.2024.e36263; https://doi.org/10.24264/lfj.18.4.4).

In general leathers used in musical instruments have been extensively studied for their core strength properties with more emphasis on elongation, density, water absorption and stiffness indicators and show that more than any other synthetic materials, leather have the ability to efficiently transmit vibrational frequencies due to their complex fibreladen porous architecture

(Alaskan, Ali & Basaran, Bahri & Nalbat, Sevgi. (2013). Structural and physicomechanical characteristics of leatherheads used in various percussion instruments.

Traditional Process

Developed Process

*PT: Pre-treatment – pH adjustment and surface cross-linking with glutaraldehyde

Tekstil ve Konfeksiyon. 23. 62-66. https://doi.org/10.1007/ 978-3-030-98650-6_16). While the above existing findings shows that the physical properties of leathers such as mechanical and acoustic characteristics are curcial, the relation between them and how to tune the same to meet the specific acoustic requirement is still scarce. In this work, we have addressed the above-mentioned gaps in making leathers for musical instruments where the mechanical and acoustic properties are not only retained but also can be tuned based on the nature of pitch and frequency the instrument demands. This work forms a robust foundation towards understanding the optimization of acoustic parameters by tuning the physicomechanical properties.

The leathers processed using traditional method is compared with the modified process adapted in this work. The initial characterisation of the mechanical properties for their strength analysis has been studied.

2. Methodology

2.1 Leather process:

2.2 Mechanical properties:

To carry out the mechanical studies, the TL and ML leathers were conditioned under standard atmospheric conditions of 23±2 °C and 50±5% RH for at least 24 hours. The thickness of each specimen was measured at multiple points using a calibrated thickness gauge and the average value was recorded ensuring uniform thickness and absence of visible defects. Test specimens were cut according to ISO 3376 to determine the tensile strength and elongation at brake.

To determine the viscous, elastic and plastic components of the TL and ML, cyclic loading and stress relaxation studies were evaluated. A minimum of four repeated loading-unloading cycles were measured to determine the strain and relaxation loops, for a given time. From this the viscous expansion and elastic recovery was calculated and the time-dependent response was used to characterize the viscoelastic nature of leather.

Water vapor absorption measurements were measured using the standard SATRA TM 178. Initial residual moisture were removed through similar conditioning as mentioned above. After conditioning, each specimen was immediately weighed using an analytical balance with an accuracy of ±0.001 g and the initial dry mass (M0) was recorded. The dried specimens were placed on a support above the distilled water inside a sealed humidity chamber

Sample Tensile Elongation Thickness Elasticity

Con vs Hot toggle

16% Reduction

19% Reduction

23% increase -20.19 6.35 0.43

Con vsNatural

29% reduction

8% reduction

14% increase -43.62 16.85 0.166

dried

The leathers processed using modified process shows enhanced water vapor absorption (10.2±0.6) than the traditionally processed leathers (8.1±0.8).

to generate a controlled relative humidity. Care was taken to ensure that samples were exposed only to water vapor and did not come into direct contact with liquid water. The after-weight of the specimens at

predetermined time intervals of 1 hr, 2 hrs, 8hrs, etc. were measured immediately (Mt). The difference between initial and final weight to the total area of the sample taken is calculated for TL and ML leathers.

2.3 Acoustic properties

The acoustic measurement was performed for TL and ML leathers using Sigview v7.1.0.0 with FFT analysis. The data obtained were processed for the leather in nondamp and damp conditions. The representative data for leathers measured at damp conditions are given in Fig. 1.

3. Result & Discussion

Higher the value; Faster the relaxation

Faster the relaxation; viscous region should below:

Interpretation

Lower strain (8%) Higher strain

Con elasticity is high Control elasticity is high

Con plasticity is low No difference in plasticity

No difference in viscous region Con viscous region is low

Viscosity

Plasticity

(14%)

(14%)

(14%)

This is mainly because of the ability to retain the moisture within them due to the chemical process it underwent.

The data show distinct sound decay behaviors for comparable source signals recorded over similar time intervals. While tone excitation in the non-damp control and processed samples produces a smooth and monotonic decrease in sound pressure, the damp processed parchment (Fig. 1b) exhibits a pronounced wavy decay envelope. This altered decay pattern is attributed to moisture-induced changes in the material’s structural and acoustic properties including fiber swelling, increased internal friction, and enhanced viscoelastic damping, which promote greater energy dissipation and non-linear decay.

Notably, damped control sample (Fig. 1a) retains tonal characteristics similar to the non-damp samples. This suggests that crosslinking in combination with moisture retention and ability to absorb the moisture is due to the process-related modifications the leather underwent influencing the resonance behavior during decay. Overall, moisture presence significantly modifies the mechanical response and acoustic damping of parchment leather, leading to distinct decay envelopes. The results correlate with the WVA values discussed above.

From the Fast Fourier Transform (FFT) data analysis, it is observed that the dominant frequency of the control sample decreases from approximately ~145 Hz to ~125 Hz. This represents a frequency shift of about 12%, indicating a moderate impact of moisture absorption on the control sample. In contrast, the experimental sample exhibits a more significant frequency drop, decreasing from 128 Hz to 96 Hz, which corresponds to a shift of approximately 25%.

4. Conclusion / Inference

This study demonstrates that leather, when processed through a modified tanning approach involving controlled pre-treatment and crosslinking, exhibits superior mechanical and acoustic properties compared to traditionally processed leather used in musical instruments. Importantly, the tonal characteristics of the leather can be tailored by adjusting the degree of crosslinking. The findings further reveal that the pitch and sharpness of the leather’s tonal response are inversely related to the extent of crosslinking, thereby establishing a clear correlation between physicochemical modifications and acoustic performance.