Paper A24

Vibroacoustic characterisation of drumheads

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Abstract: In this study, structural characteristics and features of leather and their relations with musical sounds were investigated. Mechanical behaviours as well as elastic and plastic characteristics of natural hides resulted in three dimentional structure were determined. Sound emission and energy spread over the heads were examined. Due to the structural differences and mechanic behaviours of heads sound analysis seemed to be differentiated. For vibroacoustic characterization the eigenmodes and eigenvalues of the drum heads were obtained using the high-resolution numerical method.

In the reseach; 12 drum heads processed with proper guideline were stretched over the mechanical streching apparatus (MSA) to record sound signals for analyses. Vibrations (frequencies from MSA) emitted were recorded by an appropriate microphone. In the vibroacoustic characterisation, frequencies were monitored by using a high-resolution numerical method and evaluations were carried out using licensed software (Wavelab). From structural and vibroacoustic analyses, the sound signal characteristics were found to be in parallel with the structural features. Variations in sound characteristics seem to be dependent on the structural differences.

In the research it is aimed to develop a new technique for determination of interrelations between sound emission and energy spread over heads with regard to the diversities of fibrous structure. Some mechanical properties of the heads were determined for definition the behaviour of the heads during manuplation in stretching and beating. The dependence between structural features and sound characteristics was assessed by vibroacoustic characterization methods (Eigenmodes and Egenvalues). For the purpose; after stretching drumheads over the MSA vibrations emitted were recorded by an appropriate acceleorometer and microphone. Recorded signals were evaluated by using software analysis.

According to mechanical, structural and vibroacoustic analysis of heads carried out, sound signal characteristics were found to be parallel to structural features. Accordingly, it has been thought that vibroacoustic characterization might be an option for assesment the end use characteristics of final products.

Keywords: *Leather, Drumhead, Frequency Analysis, Vibroacoustic Characterisation, Musical Sound*

Introduction

In music acoustic, the timbre of the musical sound depends on the amplitude of the different ordinary harmonic sounds composed together [1]. In music, rhythm is the term referring to the pulses which are repeated periodically in a harmonic composition or an arrangement of sounds in sequence. Usually, it is emitted by well-balanced beats of percussion instruments. Musical sounds and rhythm were produced by beating onto a membrane stretched over a shell. However, it is well-known that the musical sound quality strongly depends on the membrane materials; such as natural hides and skins or synthetic sheet materials. Although natural hides and skis have a preference in musical sound because of their unique sound quality, they have some disadventages due to their strucural characteristics. Nevertheless, studies on the sound quality assesment depend on the structural features [2].

Structural characteristics are based on nonuniformity and inhomogeneity. When using the natural hides and skins, the inhomogeneous structure is responsible for many properties; for example, durability, flexibility, compatibility to demands in usage, etc[3]. From the musical viewpoint, both natural sound quality and the influence of the surrounding athmosphere are the most prominent characteristics of the fiber network. Natural sound changing as a function of natural structure of hides and skins is considered as the most desirable timbre in music. The fibers weaved closely are vibrated by subsequent hits due to their mobility and three-dimensional texture [4-5-6]. On the other hand, athmospheric conditions in which the instrument is used causes alterations in mechanical behaviour based on the structure; hence resulting in discordancy in tonality of musical sound. Consequently, indentifying the structural dynamics means to describe the effective factors on timbre.

Determining the mechanical behavior and strength properties of the skin, used to determine the compatibility of the intended use of the area and is recognized as an important evaluation criterion. Percussion skins, instrument production and use of the possible physical effects at the time and strength to be able to provide resistant. Instrument tuning during the production process of the skin stretching and the mechanical behavior is important in terms of sound quality. In addition, this instrument may occur during the stretching process is continuously repeated for tuning and non-executive is exposed to shocks with a continuous hand or mallet. This effect is related to the performance of its response to the skin of percussion instrument. Research materials to evaluate the performance of his skin percussion instruments on the tensile strength, modulus of elasticity, and energy have been tested with real stress.

Timbre is the dynamic response of the structural elements in music. Accordingly; understanding the dynamic response of the structure of skins and hides is at the core understanding of how the instrument (percussions) produces sound [7]. The identification of timbre is strictly bound to vibriacoustic characterization [8]. In this research, we studied the dependence between structural features and sound characteristics and also interrelations assessed by vibroacoustic characterization methods.

Materials and Methods

Materials

In the research, 12 different cattle hides with two group of thickness were used to cut out drum membranes. Being reseach materials, hides were selected considering the mechanical defects, such as such as holes, cuts, scores and microorganismal damages, which are prominent in percussion instrument making. Membranes were cut out from cropon area of the hides for stretching using the mechanical streching apparatus (MSA) in 55 cm diameter.

Methods

In the first step of the study, the hides for drumheads were processed by a proper recipe in order to obtain firm and compact structure which is of fundamental importance for sound emission. Structural features involved in surface smoothness and fibrous structure affecting the sound quality were examined by SEM. Magnification rates were adjusted to 100 X 3500 X to display the surface and fibrous structures. At the second we studied physical and mechanical behavior of leather. It is known that physical and mechanical features are depends on structural characteristics of hides and skins. In this study when studying on mechanical tests, we take into account untanned skin. Because our test materials are untanned skins. Tensile strength of skin in terms of quality assessment and diagnosis of the structural stability test method for making the most referenced. In this test, the force applied to the skin effect is doing a relatively homogeneous cross-section of all skin collagen of skin tissue, forming the basis for providing information about the strength and relative strength as a whole is considered.

In the frequency analysis; drumheads were streched out over the mechanic stretching apparatus for vibroacoustic characterization of drum head without using any drum vessel. A proper microphone was used for recording vibrational signals from stretched hides on MSA. (Fig.1)

Fig.1. Mechanic Streching Aparatus

From the viewpoint of musicality, sound signal characteristics involved in the fundamental frequency, harmonics, hardness, softness, sharpness, warmness, brightness and lowness-shrillness are of main importance [9]. The describtion of sound signals were studied considering these important characteristics.

Results and Discussion

Mechanical and Structural Analysis

Sound is a moleculer displacement by mechanical pressure propagating through compressible media. Sound propagation is directly related to density and pressure, and also affected by the motion of the medium itself. This relationship, affected by temperature, determines the speed of sound within the medium [1]. Drumheads are the basic parts of the percussion instruments. Natural sound qualities of hides and skins have had a preference in music for the ages. Understanding the dynamic response of hides and skins heads with beats is at the core of understanding the structure and how the fibrous network is vowen. Due to its fibrous network, natural hides and skins have an interesting elasticity and plasticity; thereby, having frequencies at which it tends to vibrate like any elastic structures. Flexibility is an important feature of the process of stretching the skin in mind, to be effective in indirectly on the pitch and sound emitting evaluated. Therefore, the behavior of Drum skins strength tests were investigated. However, leather tanning, known as a pseudo some preliminary actions, a certain level, without ensuring full strength of fiber insulation for recovery comparison could be made about the mechanical behavior.

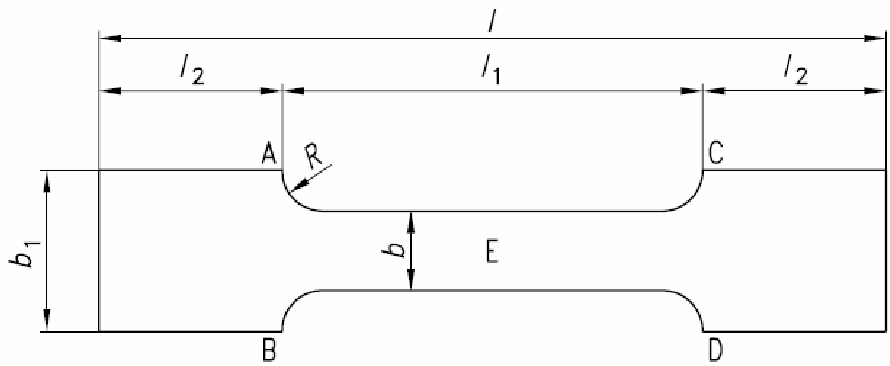

Figure 2. Tensile test, a standard measure of the sample template.

Percussion group devoted to the two thickness skin tensile strength values is examined, No. 12 0.60 -1.50 mm thick leather skin has the highest strength value (118.025N/mm2) determined the value of the same skin group and lowest in the strength of the skin No. 11 (33.51 N / mm 2) were determined. 1:50 to 2:50 mm in thickness of the leather, no leather to the highest strength with a value of 4 and 8 were found to be (4: 76.45N/mm2, 8: 76.67 N / mm 2). The lowest tensile strength value of the same skin group, leathers were 6 and 9 (6: 51.66N/mm2, 9: 51.84 N / mm 2).

Deriler	Kalınlık grupları	Deri no	Kalınlık mm	Kopma mukavemeti N/mm2	Gerçek gerilme N/mm2	Elastikiyet modülü N/mm2	Sertlik A-D	Yoğunluk kg/mm3	Uzama %
Ciltli	0.60-1.50mm	1	0.60	36.44	40.348	596.261	95/75	760.45	17.97
		2	0.83	61.80	71.591	391.096	96/69	1000.86	19.56
		3	2.42	39.26	44.682	15.25	94/77	720.08	34.29
		4	2.00	76.45	100.143	12.71	92/64	1177.03	32.56
		5	1.70	64.64	75.99	384.79	97/69	848.66	45.29
		6	1.58	51.66	60.95	296.37	97/70	1035.76	51.72
	1.50-2.50mm	7	0.87	76.64	87.391	290.26	98/76	1132.68	33.12
		8	1.56	76.67	88.077	286.37	98/65	1013.79	29.69
		9	1.61	51.84	59.077	118.99	92/68	1127.71	49.29
		10	1.73	60.43	69.146	326.423	98/62	1139.41	43.92
		11	0.71	33.51	32.506	634.00	94/74	768.34	16.59
		12	1.24	118.025	117.770	194.99	96/70	967.14	54.58

Fig.3. Tensile Strength of the processed skins in project, the real stress, Elongation and Elasticity Module Tests Related Results.

True stress at the time of the maximum tensile strength, skin thickness and width multiplied by the current instance breaks were found by dividing the results are given in N/mm2. Slope of the force-elongation curves of tensile strength tests were used in the calculation of the skin elasticity module.

In the cross-sectional microscopic investigations of hides and skins, whilst the grain consists of tightly knitted fine fibers laying to the surface, fibrous layer interweaves in a three-dimensional way through the cross-section of hides and skins where the structure is inhomogeneous. All fiber bundles vary in thickness, length, bulkness and weave due to the position within the cross-section [10]. The elastic fibers could be stretched excessively, so the free motion of fibers emits the sounds and conducts them to adjacent fibers only when beating.

According to Reich (1998), from the macroscobical and microscobical examinations of skins and hides, it is constituted by the framework of fibers, fibrils, protofibrils and molecules of collagen, that he named all the fragments as “collagen structure elements” (CSE). At the same time; in the case of dry leather, there is air in the interstices betwen these CSEs; that means a certain degree of porosity. The fact that the structural state of the CSE should be responsible for the visco-elastic characteristics and all the properties of leather are considered as the main function of natural leather [11]. From this point of view, mechanical waves and sound emission during beating are completely bound to the structural fibrous network as shown in figure 2.

Vibroacoustic Analysis of Drum Heads.

One of the most important issue is to understand the relations between acoustic properties of musical instrument sounds and specific perceptual features while sythesizing a wide variety of musical sounds. That is; specific perceptual features must correspond to the expected sound characteristics which are rather comprehensive in explanation. Amplitude and fundamental frequency of a sound are the most basic reference criteria which easily control loudness and pitch musically. Other perceptual features are related to sound spectra and they are understandable with graphical variations from propagation until fade-out with time. Some sound qualities are illustrated by spectral graphics. For example; as shown in Figure 3, “tonal brightness” is strongly connected to the centroid or tilt of a spectrum, “attack impact” (some times called “bite” or “attack sharpness”) is strongly connected to spectral features during the first 20–100 ms of sound, as well as the rise time of the sound. Tonal “warmth” is connected to spectral features such as “incoherence” or “inharmonicity [9].”

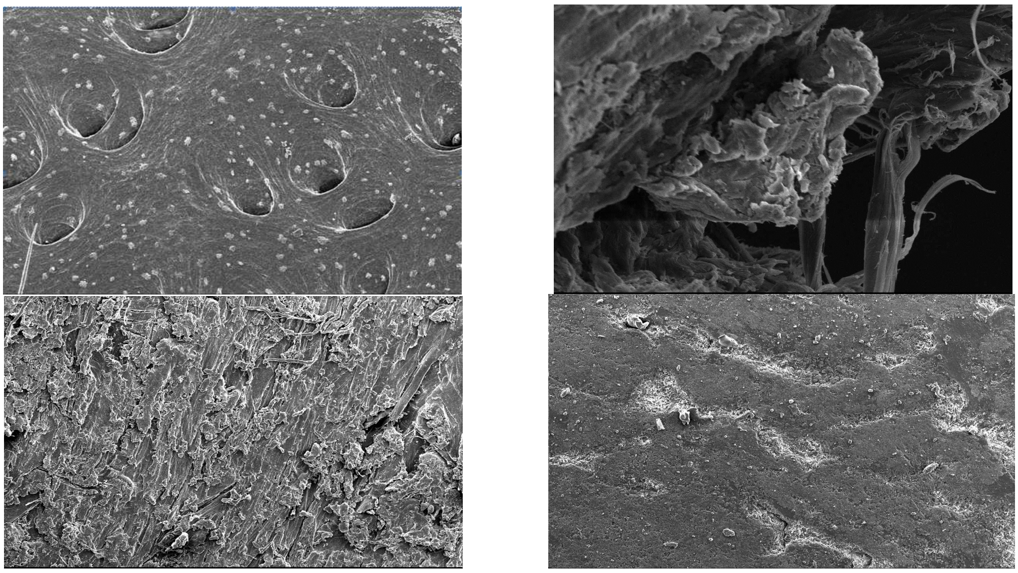

Fig. 2. Surface and fibrous structural images obtained SEM analysis.

As understood from graphical illustration in Figure 3, analytical grading of sound quality depends on the examination and describtion of sound spectra during *attack, sustain and decay*[9]. Above mentioned criteria based on analysing and identifiying the sound quality were used in our study. Sound characteristics were analyised on the signal graphics obtained in two and three dimentionally with regard to coherency, harmonicty, amplitude, sustain and decay. Especially rise times between 20-100 miliseconds were considered to be the main range of characteristic assesment in a sound.

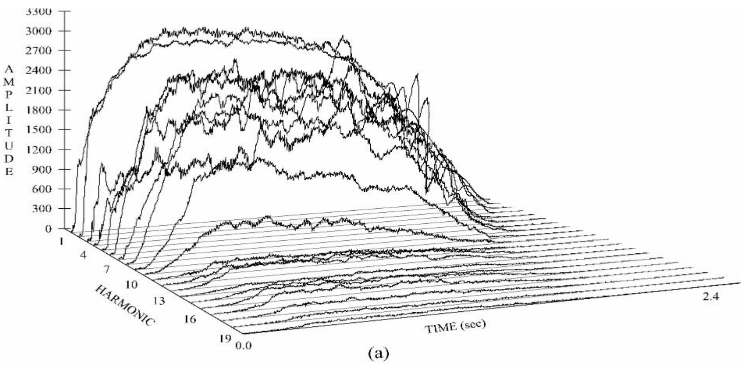

Fig.3. Graphics of Foundamental and Hamonic Frequncies (Beauchamp, 2005).

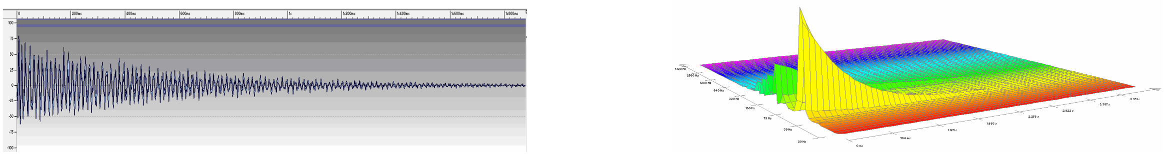

Fig.4 Two and Three Dimentional Signal Graphics Obtained From the Leather Number 1

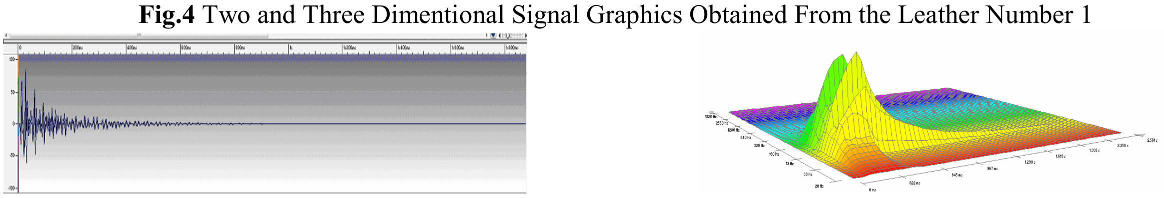

Fig.5 Two and Three Dimentional Signal Graphics Obtained From the Leather Number 2

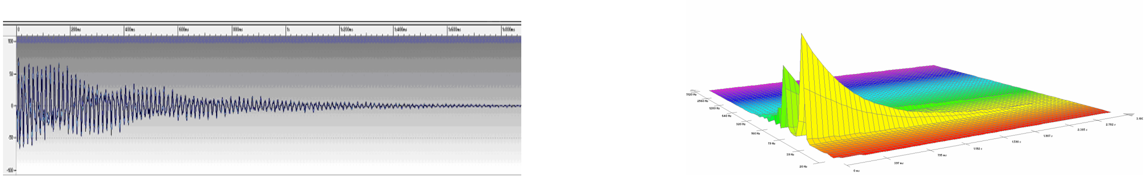

Fig.6 Two and Three Dimentional Signal Graphics Obtained From the Leather Number 3

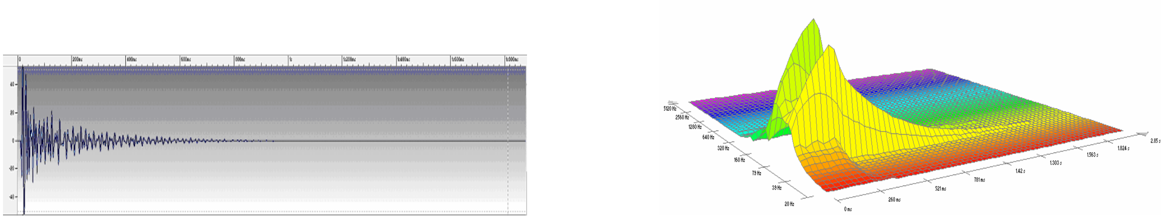

Fig.7 Two and Three Dimentional Signal Graphics Obtained From the Leather Number 4

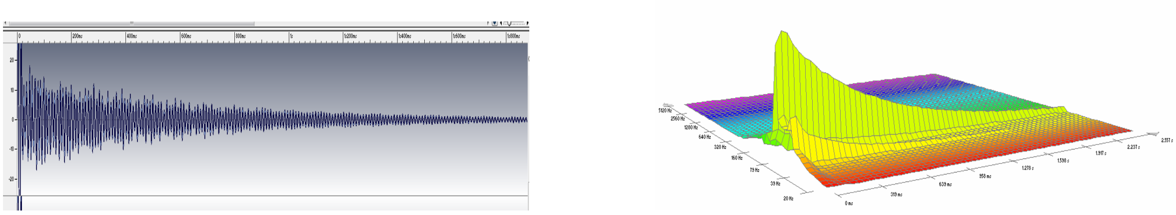

Fig.8 Two and Three Dimentional Signal Graphics Obtained From The Leather Number 5

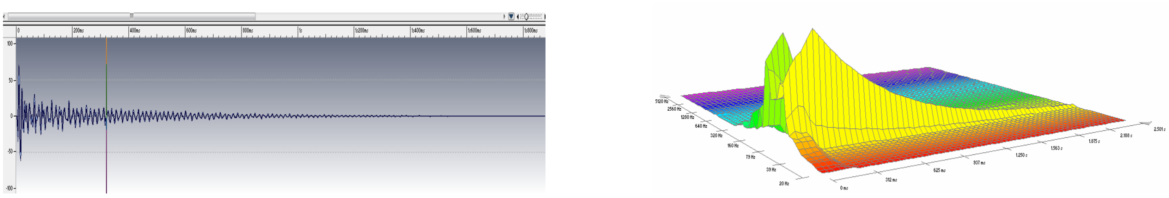

Fig.9 Two and Three Dimentional Signal Graphics Obtained From The Leather Number 6

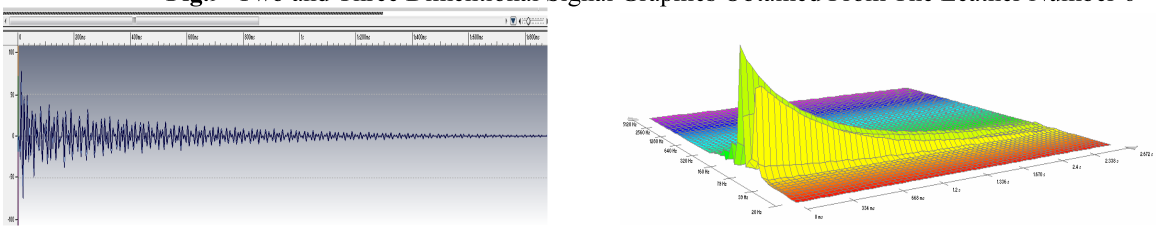

Fig.10 Two and Three Dimentional Signal Graphics Obtained From The Leather Number 7

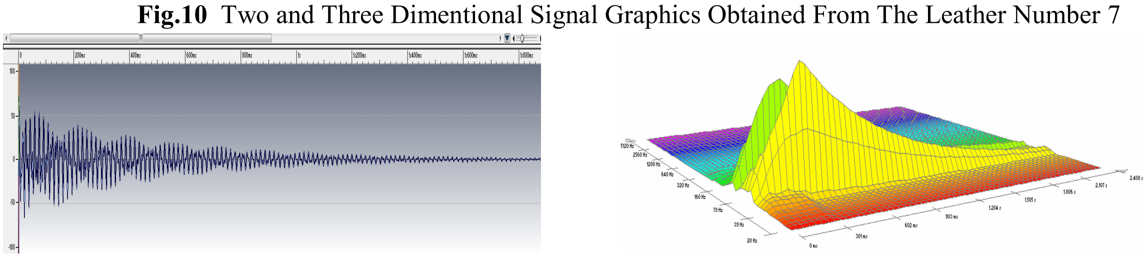

Fig.11 Two and Three Dimentional Signal Graphics Obtained From The Leather Number 8

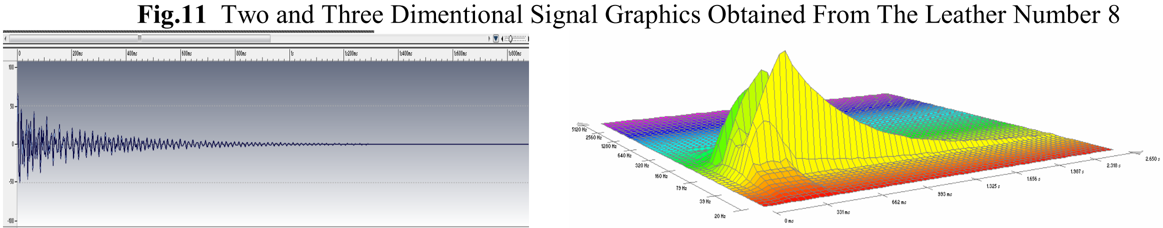

Fig.12 Two and Three Dimentional Signal Graphics Obtained From The Leather Number 9

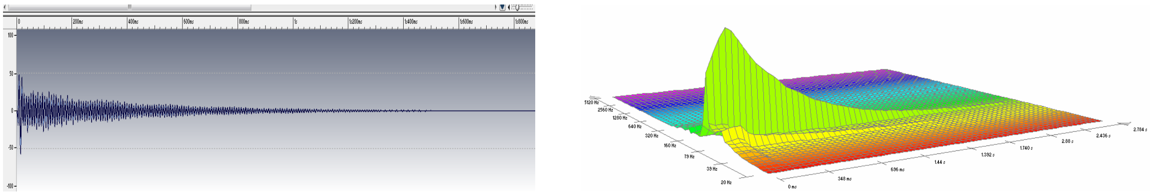

Fig.13 Two and Three Dimentional Signal Graphics Obtained From The Leather Number 10

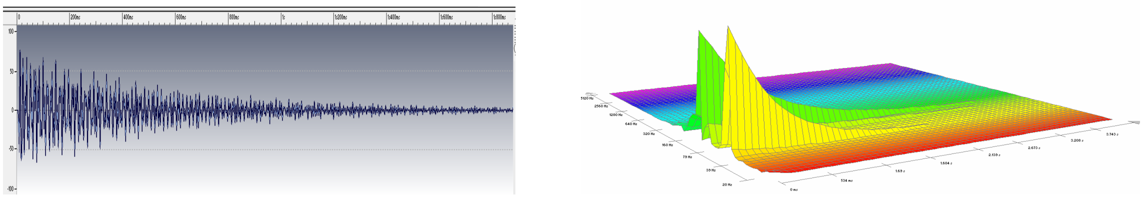

Fig.14 Two and Three Dimentional Signal Graphics Obtained From The Leather Number 11

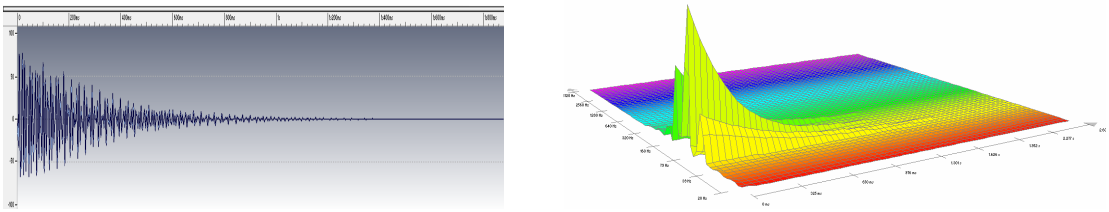

Fig.15 Two and Three Dimentional Signal Graphics Obtained From The Leather Number 12

To the best of our knowledge, there are only a few studies on vibroacoustic caracterization for drum heads in the literature. However; all the studies are only related to the characterization of a sound obtained from a musical instrument and not from any sound source. No matter how musical quality is, it is obtainable from a whole instrument. In fact, the pure tone emitted from main sound source is very important for the musical quality. So, it is aimed to keep under control the efective factors of sound quality over pure tone obtained from sound source (hide membrane).

In this study, the analysing of pure tone quality was studied and the heads were strecthed over MSA for simulation of a percussion instrument. Tensile strength and vibroacoustic analysis graphics obtained with the hides characterised structurally by Tensile strength device and SEM, the relationship between structural regularity, mechanical property and sound quality evaluated by graphical order was proved. Althoug the ideal hide structures were not obviously distinctive in analysis, hides with tight, compact and elastic structures as well as homogeneous surfaces gave acoustically high ordered graphics. Graphical order is considered to be uniform and harmonic progression in appearence during attack, sustain and decay.

Conclusions

The sound of drum heads made of hides is the dynamic response of the structure during beating, which is composed of congragating many harmonics. Timbre character and sound quality in vibroacoustic characterization is assesed by harmonic order in spectral graphic and the correspondence between fundamental frequency and its wave envelopes. In our study, the correspondance and harmonicity of spectral range obtained from hides as drum heads were evaluated during atack, sustain and decay period of time.

In brief, we conclude that sound emission and propagation in drum heads from hides are strictly affected by tight, compact and elastic structures as well as homogeneous surfaces giving acoustically high ordered graphics. Total sound quality is based on the pure tone obtained from sound source and in our study, the use of MSA for our objective with the available references was proved to be possible based on our final evaluation.

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