Vibroacoustics of Oud

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Introduction

Oud is a plucked musical instrument played in many regions, especially in Greece, Turkey and Arabic countries. Its origin, with the earliest depictions found, is dating back to 700 AD. Two main oud types that commonly used today are the Arabian and Turkish ouds. Arabian ouds have larger body than their Turkish counterparts where they have a scale length of 610 - 620 mm in comparison to the 585 mm scale length for Turkish ones. The scope of this study involves only the Turkish ouds from the acoustical point of view. Commonly, this instrument has 11 strings grouped in 6 courses. It has a short neck, fretless keyboard and lute-like body. There are three sound holes on the soundboard arranged in triangular position. Its soundboard has a thickness varying between 1.5-2.0 mm and seven fan braces are placed on the inner side parallel to each other and perpendicular to the string alignment to withstand the force created by the string tension. Walnut, mahogany, maple, rosewood family and wenge are some of the most common hard woods used in the body of the instrument whereas spruce and cedar are the tone woods used to construct the soundboard. A Turkish oud and its soundboard (traditionally with seven fan-braces) are shown in Figure 1.

This study aims at giving insight into the vibration characteristics of an oud soundboard. FRF (frequency response function) measurements were performed by experimental modal analysis technique for an oud soundboard. Resonance frequencies and mode shapes were obtained for free-free boundary conditions.

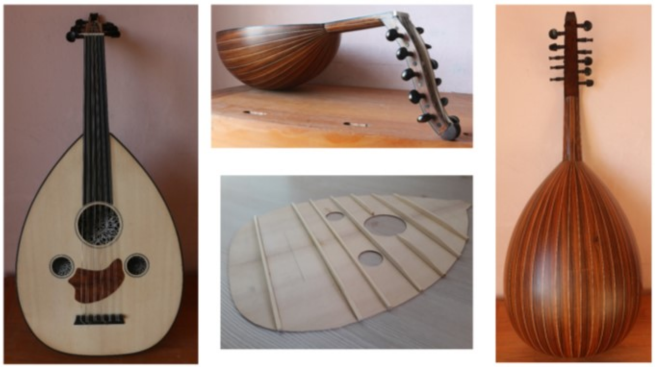

Figure 1: A Turkish Oud and Its Soundboard

Motivation

This historical musical instrument involves many structural parts effecting its vibration characteristics and sound quality. Similar to many plucked instruments, soundboard of the oud is the most crucial part to get the desired sound quality. Since the material properties of the wood can vary in a large range, there is no standard geometric dimensional set that oud makers can use for every instrument they build, instead they adjust the thickness of the soundboard and the fan brace dimensions to tune it inherently.

There are many studies on acoustics of musical instruments in the literature. Their main focus is the determination of the resonance frequencies of the soundboard, the body air cavity and the coupled modes of both. Experimental studies [1]-[4] are mainly based on the modal testing and the finite element method (FEM) has been widely used in numerical studies [5]-[8]. This study is one of the initials with [9] to reveal the vibroacoustic behaviour of oud.

Experimental Set-up

Experimental modal analysis technique was used to determine the dynamic behaviour of the soundboard. The experimental set-up consists of a DEWESoft SIRIUSm 4xACC four-channel data acquisition unit together with a PCB 352A21 one-axis accelerometer (miniature & lightweight with frequency range of 1Hz to10 kHz, sensitivity of 1 mV/(m/s2) and a weight of 0.6 g) and a Dytran 5800 SL impact hammer (50 lbf range and 100 mV/lbf sensitivity). Two channels of DAQ unit were allocated for impact hammer and accelerometer during the measurements. The soundboard was put into vibration at 317 excitation points by the impact hammer and the responses were measured by one-axis accelerometer at a fixed point which is called revolving hammer method. The excitations and the measured responses were perpendicular to the soundboard which is the most important direction in terms of radiated sound from the final instrument. The accelerometer was attached to the surface by a thin wax layer. The frequency range considered was between 0 to 350 Hz with a resolution of 1.22 Hz. Resonance frequencies, coherence factors and mode shapes were obtained by means of FRF technique. The postprocess of the data was performed by DEWESoftx3 software.

The soundboard and fan braces were manufactured from Borçka spruce (from North-eastern of Turkey). The soundboard has a uniform thickness of 2.0 mm. Depending on the mechanical properties of the wood, the thickness can decrease around to 1.5 mm. Decreasing thickness profile may also be applicable from bridge location to the edge of soundboard. The geometric details are presented in Figure 2. The soundboard has a length of 490 mm and width of 360 mm. The geometric parameters defining the fan-braces are given in Figure 3 and their values are presented in Table 1. Most of the oud makers use seven parallel fan brace arrangement but they have some minor variations in the inter distance and the geometric dimensions.

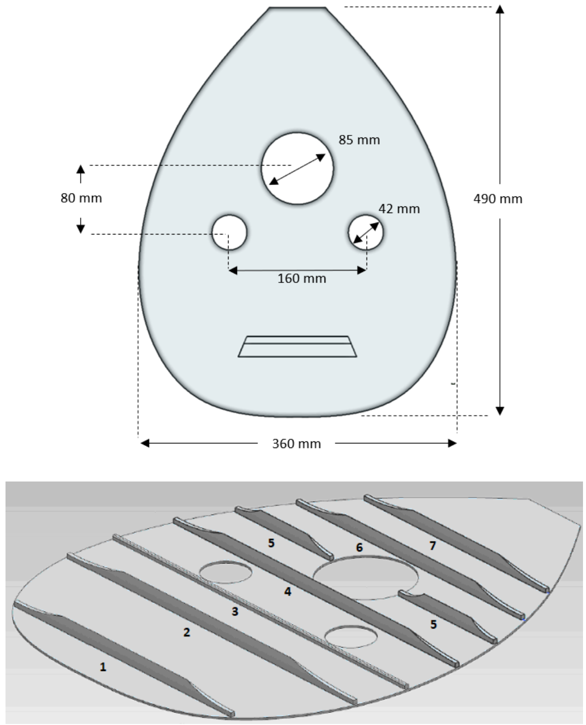

Figure 2: Conventional Oud Soundboard

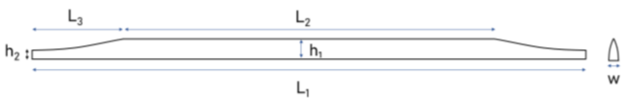

Figure 3: Fan Brace Geometric Parameters

Table 1: Fan-Brace Dimensions

	L_1 (mm)	L_2 (mm)	L_3 (mm)	h_1 (mm)	h_2 (mm)	w (mm)
1	300	200	50	12	6	5
2	355	255	50	12	6	6
3	355	255	50	5	6	5
4	344	244	50	12	6	5
5	118	48	35	12	6	5
6	278	178	50	12	6	6
7	222	122	50	12	6	6

The soundboard was supposed to be in free boundary conditions during the measurements. It was supported by three soft foam elements underside. The excitation points and the response point are presented in Figure 4. The distance between each excitation point is 20 mm in both direction and they are distributed all over the soundboard surface. The response point was placed at the coordinate of -40 mm (x), +180 mm (y). Prior to the experiments, simulations were carried out by FEM to ensure the adequacy and suitability of the excitation points.

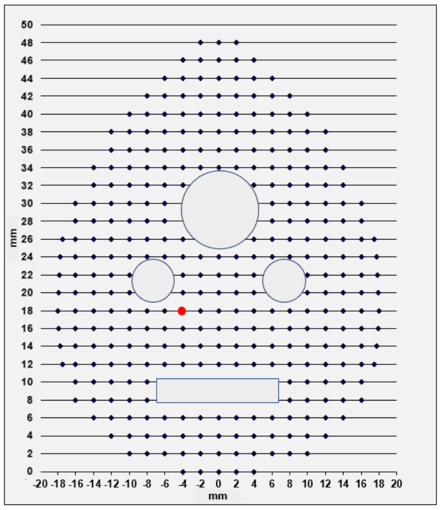

Figure 4: Excitation Points

Results and Discussions

Results of the measurements are presented as resonance frequencies and vibration modes. Frequency response functions were calculated by average of three taps. Figure 5 shows the normalized FRFs for the frequency range of 0-350 Hz. This frequency range is considered to make the strongest contribution to the sound radiation of the instrument. Totally eight peaks were observed corresponding to different resonance frequencies; 31 Hz, 51 Hz, 69 Hz, 115 Hz, 123 Hz, 198 Hz, 292 Hz and 347 Hz. Coherence is presented in Figure 6 for the frequency range of measurement to quantify the quality of measurement.

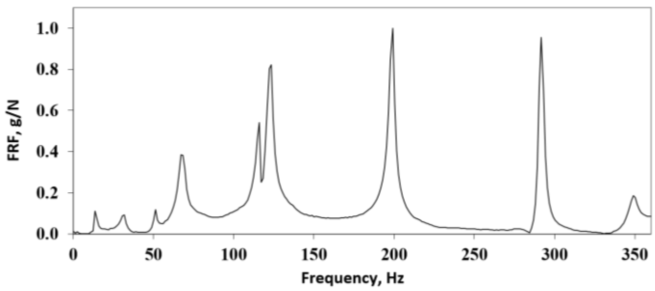

Figure 5: FRF

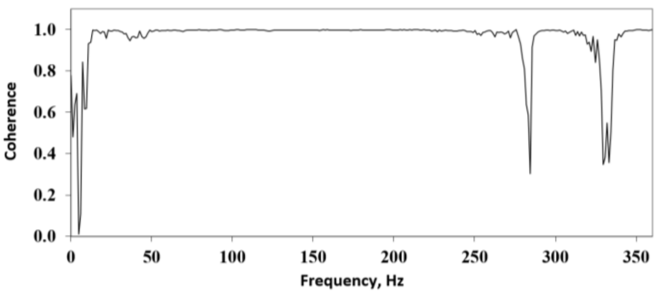

Figure 6: Coherence

The modes were denoted as (m, n), where “m” is the number of transverse half-waves and “n” is the number of longitudinal half-waves on the soundboard. Figure 7 shows the lowest eight mode shapes corresponding to each resonance frequency.

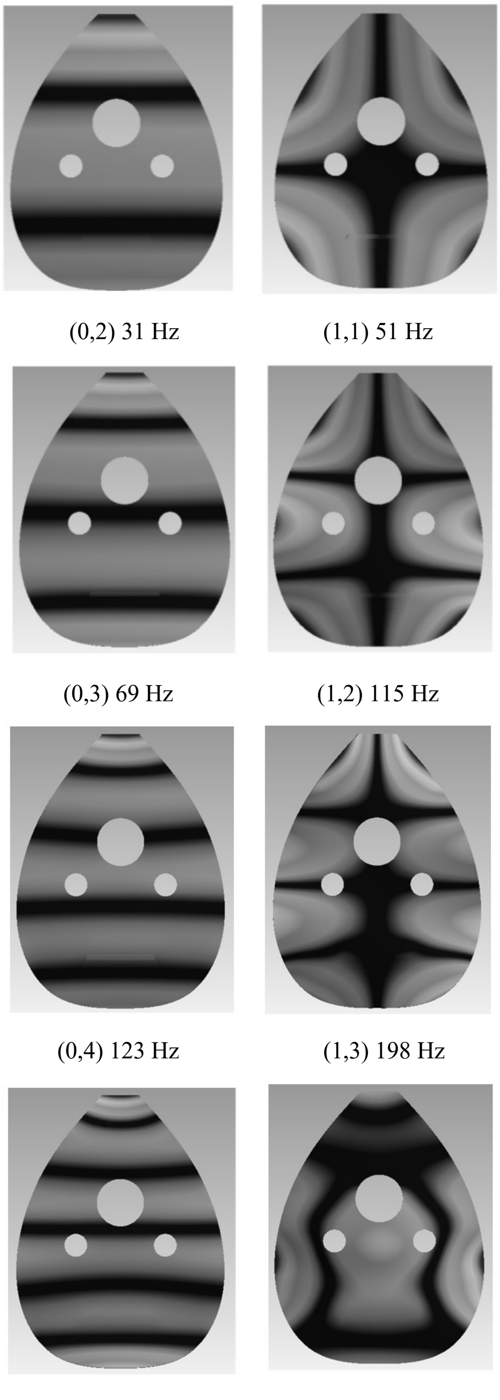

Figure 7: Mode Shapes Corresponding to Each Resonance Frequency

Conclusion

Dynamic behaviour of an oud soundboard was investigated by experimental modal analysis technique. Resonance frequencies and mode shapes were obtained by FRF measurements. The content of this study involves only the vibrational behaviour of the soundboard itself. Next step will be the investigation of the coupled modes of the soundboard and the air cavity of body after completing the instrument assembly. Further step is the correlation of the resonance frequencies of the soundboard with the sound quality of the final instrument by defining and measuring some psychoacoustic parameters.

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