Top plate vibration analysis of the kanun

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Abstract
This study is focused on the vibration analysis of the top plate of a stringed instrument, Kanun. The aim is to identify and predict the spruce and the plane tree top plate's natural frequencies by studying an experimental method and verify those experimental results with the physical model results which are obtained by the finite element method. The method is to measure the resonant frequencies with an impact hammer test experiment and then verify those results with a 3D physical model of the plates computed with a PC in free modes of vibration. This verification is achieved only for the free modes of vibrational behaviour at this stage. Achieving this goal may lead the model to the next level to identify the fixed modes of vibration behaviour of the top plates. Finally, the results are evaluated within the range of the fundamental frequencies of the instrument. The plane tree has much more natural frequency harmonic component within the frequency range of the instrument than the spruce as one of an example.

Keywords
finite elements method, physical modelling, experimental modal analysis, natural frequency, kanun, top plate

This study is focused on the top plate vibration analysis of the Kanun instrument. The aim is to identify and predict the top plate's natural frequencies by using an experimental study and verify those experimental results with the physical model results which are obtained by the finite element method (Değirmenli, 2018). By doing so; the frequency spectrum of the instrument is going to be analyzed and evaluated with the model results for two top plates of different woods called spruce and plane tree.

The tendency to pick up particularly the top plate of the entire instrument is highly related with the study as presented by (Lee et al., 2016) briefly mentioning the top plate as a potential in future research to increase the loudness of the instrument. According to Lee, (2016) ''The soundboard is the most important part of the good quality guitars. Research has proven that the top plate plays an increasingly important role compared to sound hole, back plate and the bridge at high frequencies''.

As a plugged string instruments family member, Kanun has 22 to 27 plastic made strings with three strings on each course approximately providing three and a half musical octaves (Karadoğan, 2010).

It has a half trapezoid shape with dimensions of 95 to 100 cm length, 38 to 40 cm width and 5 cm depth (See Fig. 1). This small composite chamber which is called the instrument's body is constructed mostly with wood and a membrane surface making it also a small reverb chamber. The body

Fig. 1: Kanun instrument

of the instrument also acts as a Helmholtz resonator with its drilled ornaments placed on top of the top plate, letting the air to flow in and out from the instrument's small air chamber.

Apart from its delicate form, ornamented texture and its complex view, the instrument may be categorized as a simple acoustic model like; a trapezoid box-shaped body and strings attached to it. String and body connectors are called bridges and these are the energy transmitters in the solid environment beside the air movement around the instrument. The box is formed with the main carcass and it is covered with the back and the top plates. The back plate is made of MDF and the top plate is made of wood. In this case, the spruce and the plane tree top plates are studied. The main carcass is also supported with various wood elements to increase reflection and therefore reverberation inside the instrument body.

Reverberant energy is also supported and radiated with the help of the composite material design, a membrane or skin is located beside the top plate under the bridge. The plastic grouping made up of three strings is also subject to sympathetic vibration due to mechanical coupling and sound energy radiation field apart from their chorus effect on the timbre. Other mechanical tuning parts and switches on the instrument make it possible to fine-tune in cents for micro tunings.

Even though only the top plate component of the entire instrument construction is analyzed and studied throughout this work, the results may likely to be evaluated by considering that narrowed research concept in terms of Kanun's complex structure and form.

Method and procedure

The method is; to start with an experimental study which measures the resonant frequencies of the top plates with an impact hammer test experiment. The article of Akbulut M., Erol H. (2019) could be given as an example of this kind of an experiment practice. Roving hammer test is performed; top plates are tapped with an impact hammer from several points and the impact responses are recorded to a PC software via an accelerometer which is fixed on the plates. Several individual points on the plates are researched so those data are stored and kept for the further stage of the study; physical model verification. So the experimental study stands for a reference point of the study to confirm that the model is truly and efficiently working and close enough to the experimental results.

Finite element method (FEM) is used for the physical modelling study to identify the Eigen frequencies. By physically modelling the different top plates and defining their characteristic material properties in the computer environment, the results were computed with a PC software in free modes of vibration for the 3D physical model of the plates. After the verification is made, by comparing the free modes of vibrational behaviour; the model is approved that it can be used for further computations safely. Then the fixed modes of vibration are studied and the results are evaluated within the frequency range and of the instrument.

Hammer test environment and equipment

At this stage, two identical geometries of spruce and plane tree top plates are studied with hammer test experiments. The experiment results are listed below and they are used as a reference point for validating the truly working physical model of the top plates. This is done by comparing the free modes of vibration. After achieving the experiment and model equality close enough with free modes of vibration; it is confirmed that the physical model is working close enough to experimental study conditions. So this may lead to calculate the fixed modes of vibration for the physical model; which may behave more likely to the real instrument behaviour.

Experiments are performed on both plates, as spruce can be seen in Fig. 2; the numbers indicate the hammer impact positions on the top plate. The hammer is Dytran Dynapulse with a built-in Dytran 5800b3 force transducer (See Fig. 3 and 4). A steel tip was used to get proper excitation in the range of interest, which was from 20 Hz to 1500 Hz, a range that starts from the human audible extreme low frequency to Kanun's highest pitches of fundamental frequencies. The plates are freely suspended and therefore extremely lightly damped. The green highlighted region in the figure below is covered with an accelerometer. The plates were drilled tiny enough to be hanged from their corners. The plates were suspended from their corners using soft rubber bands. Thus, the damping effects due to boundary conditions were kept small enough to be neglected.

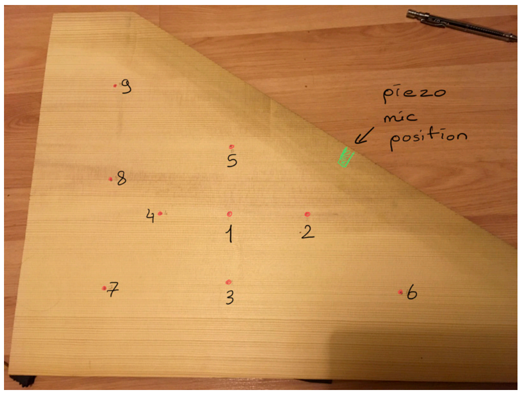

Fig. 2: Hammer test impact points and the accelerometer position (spruce).

The output signal was measured using a small light-weight DJB Instruments Accelerometer Type A/123/e. The force and vibration signals were analyzed using the 01 Db multichannel analysis system type Db4. Post-processing of the data was carried out using the NetdB software. Using a signal analyzer, the resonant frequency of the plates could be monitored. Following figures are covered with the results of the hammer test experiments with spruce plane tree and spruce and plane tree together respectively.; as frequency response functions (FRFs) obtained from the measurements.

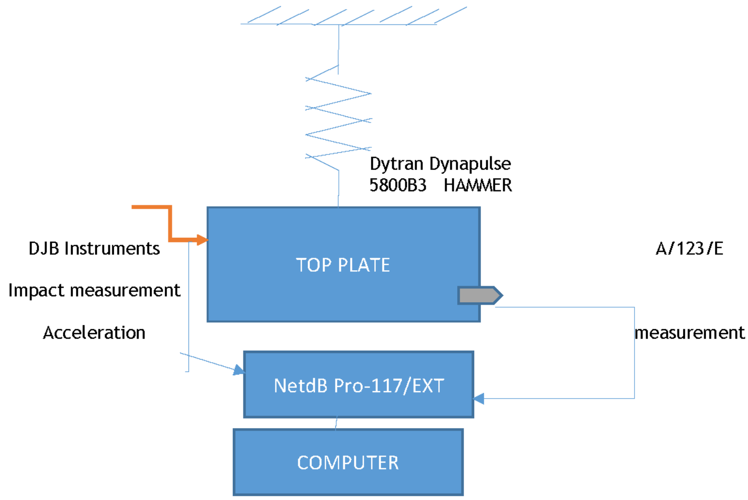

Fig. 3: Schematic model description of the hammer test experiment.

Method for computer analysis

Finite Element Method (FEM) is used to identify the top plate resonant modes with the COMSOL software running on a PC Macintosh computer. Basically a computer is used to obtain information about top plate vibration mode calculations. Therefore, aiming to verify the results with the hammer test experiments. By modelling the geometry, defining the material properties and determining the physical conditions; modal patterns and their overtone frequencies may be seen after the computation of the related software.

Software Modelling and Associated Parameters

Geometry, material density, Young module (including 3 axes ;), Shear Module (including 3 axes; x, y, z) and the Poisson's ratio (3 planes; xy, yz, xz) are the variable parameters of the software calculations to identify top plate resonant modes. At first the instrument top plate is 3D modeled with CAD module of the software and then the material properties like density, Shear and Young Modules and Poisson's ratio are defined for spruce and plane tree respectively.

Free modes are calculated first to approve the truly working 3D physical model. The goal is to get the hammer test experiment results as close as possible which are naturally present in the real world as a reference. And then the workflow order comes to fixed boundary mode calculations with the verified physical model. By doing this we ideally like to get the model much closer to real world conditions. Normally, the top plate is fixed with the instrument's structural carcass. So at this stage the model's four boundaries are fixed, letting the top plate's top and bottom surface for displacement.

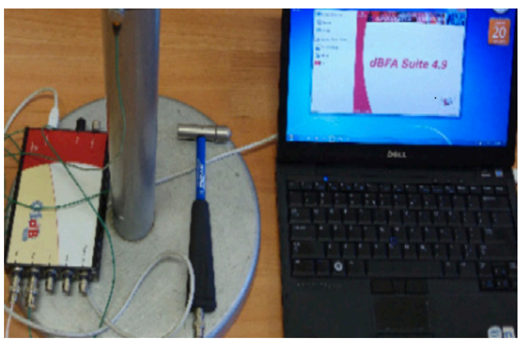

Fig. 4: Equipment used for the hammer test experiment.

Geometry;
Spruce Dimensions:

Fig. 5: Spruce top plate view.

Length bottom: 75 cm
Length top: 10,5 cm
Width: 44 cm
Height: 0,4 cm

Plane Tree Dimensions:

Fig. 6: Plane tree top plate view.

Length bottom: 74 cm
Length top: 12 cm
Width: 43,5 cm
Height: 0,4 cm

Material properties:
Density SPRUCE: 355,6 kg/m3
Density PLANE TREE: 365 kg/m3

Young Module Values:

Elasticity implies that deformations produced by low stress are completely recoverable after loads are removed. Elastic ratios, as well as the elastic constants themselves, vary within and between species and with moisture content and specific gravity.

Table 1: Young Module values are listed and compared in Mega Pascals for Spruce and Plane Tree

Young Module (MPa)	SPRUCE	PLANE TREE
E_X	2100	2500,2
E_Y	21000	12430
E_Z	1400	830,8

Woods are classified as an orthotropic material simply which behaves non-uniform in different axis. Basically, length (longitudinal) (y), width (radial) (x) and height tangential (z) axis presents different material properties within specific conditions. Below are the related material properties listed which may be required to be used for further computations.

Poisson's Ratio Values:

Table 2: Poisson's ratio values are listed and compared for Spruce and Plane Tree

Poisson's Ratios	SPRUCE	PLANE TREE
μ_{XY}	0,030	0,033
μ_{XZ}	0,467	0,604
μ_{YZ}	0,530	0,641

Shear Module Values:

Table 3: Shear Module values are listed and compared in mega Pascals for Spruce and Plane Tree

Shear Module (MPa)	SPRUCE	PLANE TREE
G_{XY}	850	1653,2
G_{YZ}	726	919,82
G_{XZ}	35	12,43

Both material property values are taken from Wood Handbook (Ross, R. J., 2010) at first as a starting point and then the physical model property values are approximated to experiment results by changing density and Young Modulus values during the physical modelling study.

Results and analysis

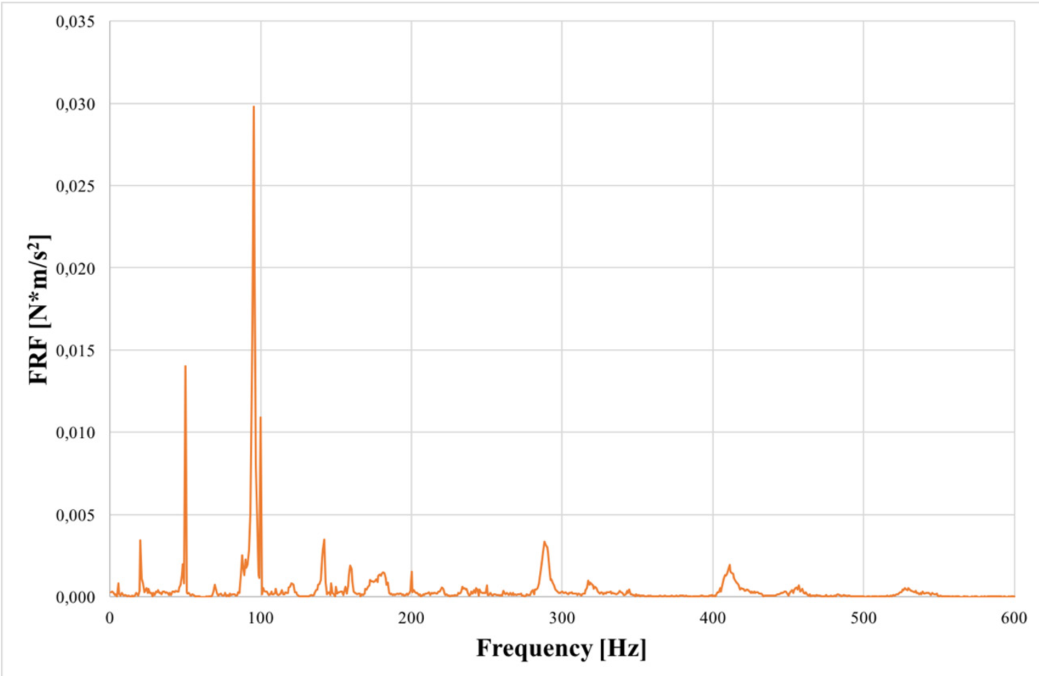

Fig. 7: Spruce natural frequencies detected by the experiment on point 1.

On spruce, point 1 excites at; 20,31 Hz – 50 Hz – 95,31 Hz – 142,19 Hz – 288,28 Hz – 410,94 Hz - … (See Fig. 7).

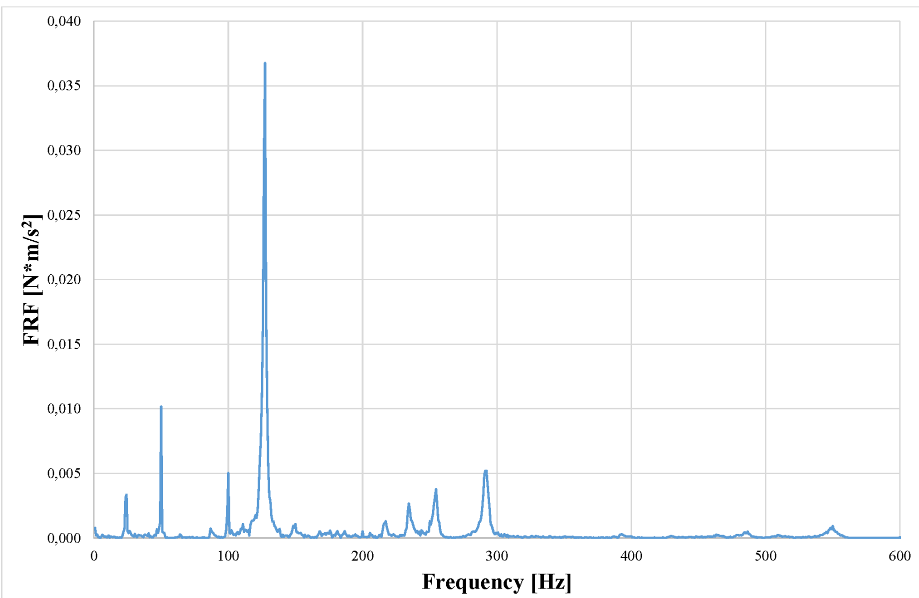

Fig. 8: Plane tree natural frequencies detected by the experiment on point 1.

On the plane tree, point 1 resonates at;23,44 Hz – 50 Hz – 100 Hz – 125 Hz – 217,19 Hz – 235,59 Hz – 253,91 Hz – 292, 97 Hz - … (See Fig. 8).

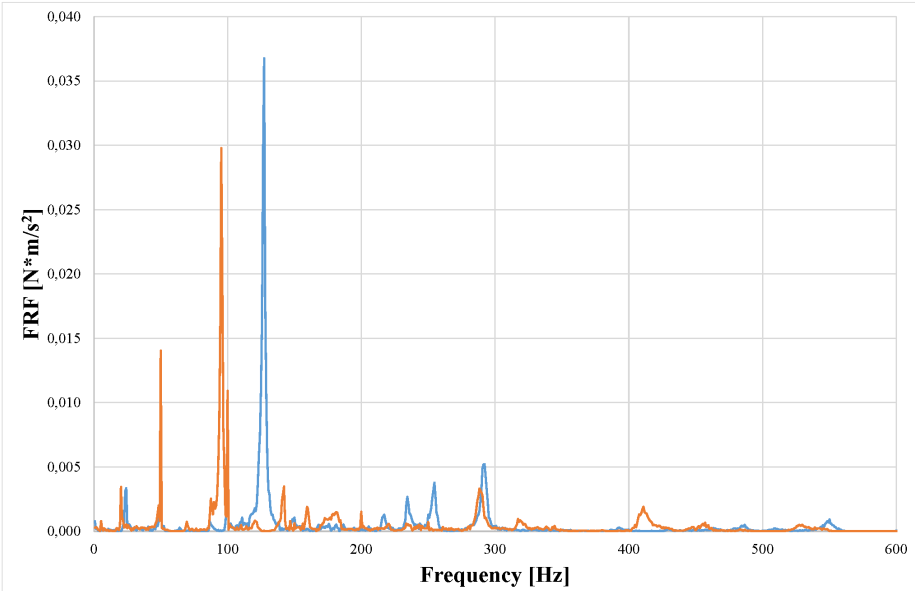

Fig. 9: Natural frequencies viewed together detected by the experiment on point 1 for the spruce and the plane tree.

As the experiments are carried through with nine individual points on the top plate (see Fig. 2), only a one-point analysis will be described as an example for the graphics. All points resonant frequencies for two kinds of wood can be seen from Table 4 and 5. These data for nine points are collected and kept (See Fig. 10 and 11). Therefore, that would be a reference point from the real world parameters to compare and verify with the following 3D Physical Modelling stage.

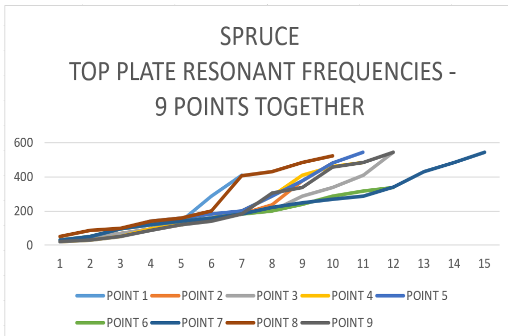

Fig. 10: Spruce natural frequencies viewed together for nine impact points detected by the experiment on point 1. Below 200 Hz the impact locations behave more like together.

Table 4: Spruce top plate natural frequencies viewed together for nine points in Hz. the results are read and listed for spruce on all points.

Frequency No	POINT 1	POINT 2	POINT 3	POINT 4	POINT 5	POINT 6	POINT 7	POINT 8	POINT 9
1	20,31	20,31	20,31	20,31	20,31	30,47	31,25	50	20,31
2	50	50	50	30	48,44	50	50	87,5	30,47
3		69	69,53	50	95,31	95	96	100	50
4	95,31	95,31	94,53	95,31	141,41	120	120	141	87,5
5	142,19	120	121	121	159,38	141	141	159	120,31
6	288,28	158	158	159	182,81	159	159	200	141
7	410,94	182	182	200	200	182	182	408	184
8		236	200	288	289	200	223	431	305
9		378	289	409	378	239	250	485	339
10		483	340	460	482	289	271	525	459
11			410	484	546	319	289		484
12			544			339	341		545
13							432		
14							485		
15							546		

Table 5: Plane tree top plate natural frequencies viewed together for nine points in Hz.

Frequency No	POINT 1	POINT 2	POINT 3	POINT 4	POINT 5	POINT 6	POINT 7	POINT 8	POINT 9
1	23,44	23,44	23,44	24,22	24,22	50,78	50	50	23,44
2	50	50	50	50	50,78	100	64,84	100	50
3	100	99,22	99,22	99,22	64,05	125	98,44	127	64,84
4	125	125,78	117	116,41	99,25	290	126,56	168	99,22
5	217	250	166	125	125,78	353	167,97	200	115
6	235	340	219	149	200	507	210,94	250	126
7	253,91		250	167	253,91	547	234,38	291	291
8	292,97		293	197,66	291,41		254,69	355	507
9			339	254,69	255,47		289,84	464	
10			355	290,63	392,19		339,84	489	
11			507	339,84	506,25		390,63	504	
12				355,47			507,81	547	
13				506,25			549,22		

The natural frequencies of the top plates are listed for two kinds of wood (See Table 4 and 5). Below 200 Hz the impact locations behave more like together.

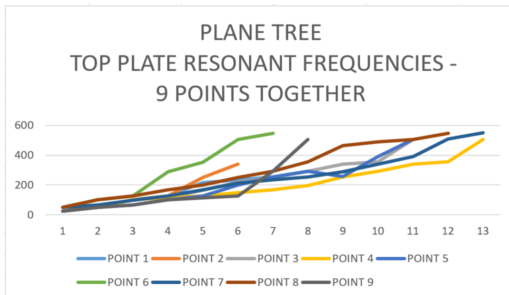

Fig. 11: Plane tree natural frequencies viewed together detected by the experiment on point 1.

Free modes of vibration modal analysis

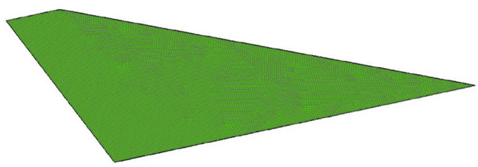

Fig. 12: Top plate static view without vibration

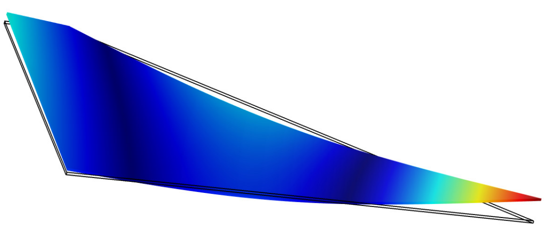

Fig. 13: Free mode first harmonic frequency view for the spruce – 20,31 Hz.

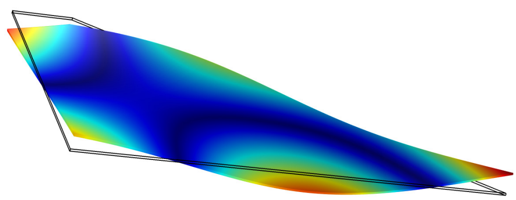

Fig. 14: Free mode second harmonic frequency view for the spruce– 43,88 Hz.

Above and below the modal shape of the natural frequencies can be seen in Fig 13 and 14; displacement from the equilibrium position is shown through colours. Starting from the low values from deep blue, blue, green, yellow and finally the highest values to the red.

This harmonic series can be seen individually like Fig 13 and 14 and so forth. The natural frequencies are listed below with the hammer test results for comparison to verify the physical model is efficiently working.

20,31 – 43,88 - 54,94 – 87,50 – 106,18 – 144,57 – 171,46 – 178,29 – 214,72 Hz ... and so on.

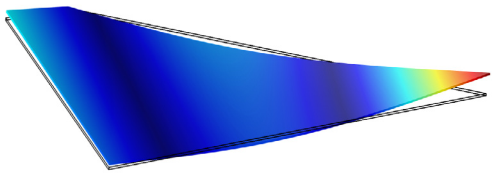

Fig. 15: Free mode first harmonic frequency view for the plane tree – 23,44 Hz.

Above and below the modal shape of the natural frequencies can be seen in Fig 15 and 16; displacement from the equilibrium position is shown through colours. Starting from the low values from deep blue, blue, green, yellow and finally the highest values to the red.

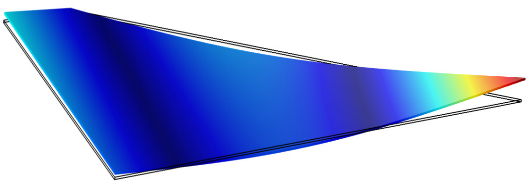

Fig. 16: Free mode second harmonic frequency view for the plane tree – 55,23 Hz.

As it is performed before, this harmonic series can be seen individually like Fig 15 and 16 and so forth. The natural frequencies are listed below with the hammer test results for comparison to verify the physical model is efficiently working.

23,44 – 55,23 – 62,33 – 104,04 – 106,18 – 120,07 – 142,03 – 166,73 – 191,44 Hz … and so on.

Free Modes Comparison

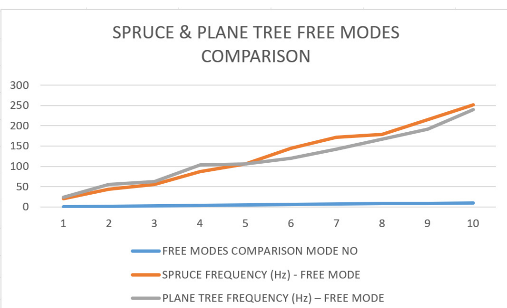

Fig. 17: Free modes comparison of the spruce and the plane tree; the orange line indicates spruce and the gray line indicates plane tree.

Table 6: Free modes comparison for Spruce and Plane Tree in Hz.

FREE MODES COMPARISON	SPRUCE	PLANE TREE
MODE NO	FREQUENCY (Hz) - FREE MODE	FREQUENCY (Hz) – FREE MODE
1	20.31	23.44
2	43.88	55.23
3	54.94	62.33
4	87.50	104.04
5	106.18	106.18
6	144.57	120.07
7	171.46	142.03
8	178.29	166.73
9	214.72	191.44
10	251.26	239.76

As we see in Fig. 13, 14, 15, and 16, the harmonic series of the natural freqencies are listed in Table 6. Apart from the first two harmonics, ten individual natural frequencies can be compared for two kinds of wood from Table 6.

Table 7: Spruce experiment and model results comparison

SPRUCE EXPERIMENT	SPRUCE MODEL
FREQUENCY MEASURED (Hz)	FREQUENCY CALCULATED (Hz)
20.31	20.31
50	54.94
95.31	87.50
100	106.18
142	144.57
181.25	178.29
200	214.72
288.28	297.74
342.97	345.41
410.94	400.2
457.03	450.69
527.34	521.32

The graphical representation of Table 6 can be seen in Fig. 17 which compares first ten harmonics of the natural frequencies for two kinds of wood.

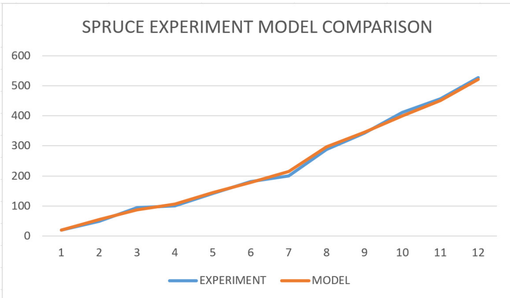

Fig. 18: Spruce experiment results compared with the model results. The orange line indicates the model; the blue line indicates the experiment.

At this stage, the physical model for the spruce top plate can be seen as approved and verified (See Fig. 18).

Table 8: Plane Tree experiment and model results comparison

PLANE TREE EXPERIMENT	PLANE TREE MODEL
FREQUENCY MEASURED (Hz)	FREQUENCY CALCULATED (Hz)
23.44	23.44
50	55
100	104
125	120
166	166
217	214
253	239
292	297
342	356
410	421
457	466
527	521
547	579

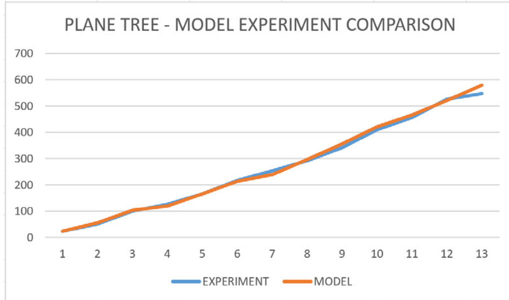

Fig. 19: Plane Tree experiment results compared with the model results. The orange line indicates the model; the blue line indicates the experiment.

Both Fig. 18 and 19 look like the experiment and physical model result graphics match. Therefore, we may assume that the model is working close enough to experimental conditions. And also the model is ready for further computations considering the fix boundary conditions.

Fixed modes of vibration modal analysis

Spruce fixed modes of vibration;

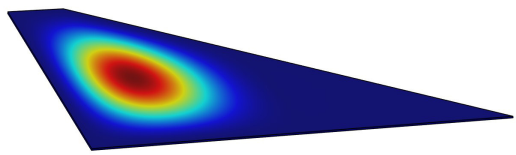

Fig. 20: Spruce fixed mode first harmonic frequency view – 186,64 Hz.

Above and below the modal shape of the natural frequencies can be seen in Fig. 20 and 21; displacement from the equilibrium position is shown through colours. Starting from the low values from deep blue, blue, green, yellow and finally the highest values to the red.

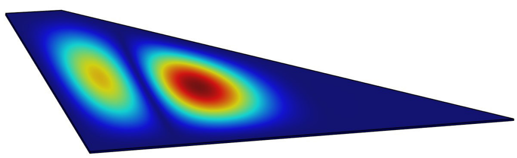

Fig. 21: Spruce fixed mode second harmonic frequency view – 268,21 Hz.

This harmonic series can be seen individually like Fig 20 and 21 and so forth. The natural frequencies are listed below with the hammer test results for comparison to verify the model is truly and efficiently working. 186,64 Hz – 268,21 – 358,95– 431,38 – 106,18 – 460,94 – 171,46 – 554,52 Hz … and so on.

Plane tree fixed modes of vibration;

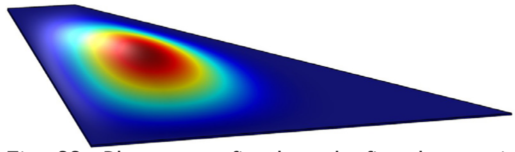

Fig. 22: Plane tree fixed mode first harmonic frequency view – 155,6 Hz.

Table 9: Kanun's pitch and frequency values for equal temperament tuning and their corresponding Turkish music names.

String Group No	PITCH	FREQUENCY (Hz) (EQUAL TEMPERAMENT)	PITCH (TURKISH MUSIC)
1	B2	123,5	E - Kaba Hüseyni Aşiran
2	C3	130,8	F - Kaba Acem Aşiran
3	D3	146,8	G - Kaba Rast
4	E3	164,8	A - Kaba Dugah
5	F#3	185	B - Kaba Buselik
6	G3	196	C - Kaba Çargah
7	A3	220	D - YEGAH
8	B3	247	E - Hüseyni Aşiran
9	C4	261,6	F - Acem Aşiran
10	D4	293,7	G - Rast
11	E4	329,6	A - Dugah
12	F#4	370	B - Buselik
13	G4	392	C - Çargah
14	A4	440	D - Neva
15	B4	493,9	E - Hüseyni
16	C5	523,3	F - Acem
17	D5	587,3	G - Gerdaniye
18	E5	659,3	A - Muhayyer
19	F5	698,5	B - Tiz Buselik
20	G5	784	C - Tiz Çargah
21	A5	880	D - Tiz Neva
22	B5	987,7	E - Tiz Hüseyni
23	C6	1047	F - Tiz Acem
24	D6	1175	G - Tiz Gerdaniye

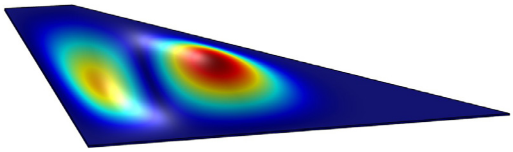

Fig. 23: Plane tree fixed mode second harmonic frequency view – 233,42Hz.

The modal shape of the natural frequencies can be seen in Fig. 22 and 23; displacement from the equilibrium position is shown through colours. Starting from the low values from deep blue, blue, green, yellow and finally the highest values to the red.

As it is performed before, this harmonic series can be seen individually like Fig 22 and 23 and so forth. The natural frequencies are listed below with the hammer test results for comparison to verify the model is truly and efficiently working. 155,6 Hz – 233,42– 318,69 – 352,44 – 413,46 – 473,63 – 516,9 Hz … and so on.

Actual sounding instrument frequency and the pitch relation are listed above in Table 9 (Yılmaz, 2002). These data would stand as a reference for the final results of the physical model.

Spruce fix modes vs pitch:

Table 10: Nine different pitches such as F# / C / F / A / A# / C# / D / G / G# are naturally produced on spruce top plate in the frequency range of the instrument; due to boundary fixed conditions as well as material properties.

FIX MODE COMPARISON	SPRUCE	PITCH-FREQUENCY
MODE NO	FREQUENCY (Hz) FIX MODE	PITCH, OCTAVE REGISTER and FRE-QUENCY
1	186.64	F# 3 (185 Hz)
2	268.21	C 4 (261.6 Hz)
3	358.95	F 4 (349.2 Hz)
4	431.38	A 4 (440 Hz)
5	460.94	A# 4 (466.2 Hz)
6	554.52	C# 5 (554.4 Hz)
7	577.78	D 5 (587.3 Hz)
8	677.86	F 5 (698.5 Hz)
9	708.62	F 5 (698.5 Hz)
10	780.97	G 5 (784 Hz)
11	807.13	G# 5 (830.6 Hz)
12	848.69	A 5 (880 Hz)
13	942.59	A# 5 (932.3 Hz)
14	955.81	A# 5 (932.3 Hz)
15	999.07	B 5 (987.7 Hz)
16	1089.3	C# 6 (1109 Hz)
17	1124.2	C# 6 (1109 Hz)
18	1162.5	D 6 (1175 Hz)
19	1230.3	

Plane tree fix modes vs pitch:

Table 11: Twelve different pitches such as D# / A# / F / G# / C / D / F# / G / A / B / C# / D are naturally produced on plane tree top plate in the frequency range of the instrument; due to boundary fixed conditions as well as material properties

FIX MODE COMPARISON	PLANE TREE	PITCH&OCTAVE - FREQUENCY
MODE NO	FREQUENCY (Hz) FIX MODE	
1	155.6	D# 3 (155.6 Hz)
2	233.42	A# 3 (233.1 Hz)
3	318.69	D# 4 (311.1 Hz)
4	352.44	F 4 (349.2 Hz)
5	413.46	G# 4 (415.3 Hz)
6	516.9	C 5 (523.3 Hz)
7	594.19	D 5 (587.3 Hz)
8	623.29	D# 5 (622.3 Hz)
9	631.73	D# 5 (622.3 Hz
10	715.26	F 5 (698.5 Hz)
11	749.88	F # 5 (740 Hz)
12	789.67	G 5 (784 Hz)
13	839.15	G# 5 (830.6 Hz)
14	878.38	A 5 (880 Hz)
15	944.24	A#5 (932.3 Hz)
16	967.33	B 5 (987.7 Hz)
17	982.08	B 5 (987.7 Hz)
18	1013.8	B 5 (987.7 Hz)
19	1092.9	C# 6 (1109 Hz)
20	1109.4	C# 6 (1109 Hz)
21	1152.4	D 6 (1175 Hz)
22	1173.4	D 6 (1175 Hz)
23	1230.4	

Fixed mode comparison:

Table 12: Spruce and plane tree fixed mode comparison; 23 individual overtones for plane tree versus 19 individual overtones for spruce.

FIX MODES COMPARISON	PLANE TREE	SPRUCE
MODE NO	FREQUENCY (Hz) FIX MODE	FREQUENCY (Hz) FIX MODE
1	155.6	186.64
2	233.42	268.21
3	318.69	358.95
4	352.44	431.38
5	413.46	460.94
6	516.9	554.52
7	594.19	577.78
8	623.29	677.86
9	631.73	708.62
10	715.26	780.97
11	749.88	807.13
12	789.67	848.69
13	839.15	942.59
14	878.38	955.81
15	944.24	999.07
16	967.33	1089.3
17	982.08	1124.2
18	1013.8	1162.5
19	1092.9	1230.3
20	1109.4	
21	1152.4	
22	1173.4	
23	1230.4	

Conclusions

- Even a cm change in any dimension of the geometry affects the natural frequency results of the top plates. Therefore, the sound's emphasized harmonic content and radiation intensity in terms of frequency and the corresponding amplitudes may be expected to be changed in the perceived sound field. Dimensions determine the wavelengths. Thus, the natural frequency changes may be expected while the dimensions change when the speed of sound is constant.
- After handling several top plates during the manufacturing process, even though all plates have the same form and geometry and identical dimensions, the weights are variable in practice. Briefly; the density and the relative humidity of the wood strongly affect the natural frequency. The speed of sound in solids is related to the Young's Modulus and the density. So, when only the density parameter decreases; the natural frequencies tend to go higher inversely.
- Plane and spruce woods resonate around different parts of the frequency spectrum. In this case, again the geometries are very closely identical. Additional to the density, Young's Modulus, Shear Modulus and Poisson's ratios together determine these differences.
- While we check the fixed mode results comparison of two kinds of wood for the natural frequencies; the plane tree has much more overtones (24) placed in the actual sounding frequency range of the instrument than the spruce (19).
- Intervals and chords may be researched and analyzed for free and fixed natural mode series of two kinds of wood.
- Composite materials may be seen more often than before, which may behave free of direction unlike the orthotropic nature of the wood.
- Formulas, algorithms and further modifications of the finite element method model parameters may also be used as a specific source data for digital sound synthesis subject like physical modelling digital sound synthesis.

Hopefully, this study could stand as a meaningful and useful practical step for instrument designers and luthiers. During the design stage or before manufacturing any change of ideas may be previewed, analyzed and evaluated using the physical model. Density, Young Module, Shear Module, Poisson's Ratio and finally the dimensions and geometry may be changed according to this study. So, any effect on the natural frequencies coming from the material properties or form and geometry changes may be previewed and analyzed. Another following alternative and a complete step for this particular study would be; analyzing the whole kanun body construction with the same method and the study model. As far as we confirm one particular component like the top plate vibration; the Helmholtz resonators on top of the top plates, the air inside the body, the skin membrane attached to the bridges and finally the whole body may be modelled and studied via the same method.

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Kanun göğüs tahtasının titreşim analizi

Özet

Bu çalışma kanun enstrümanının göğüs tahtasının titreşim analizine yoğunlaşmıştır. Çalışmanın amacı, göğüs tahtasının doğal titreşim frekanslarını üç boyutlu fiziksel modelleme yardımıyla tanımlamak ve tasarım sürecinde olası değişiklikleri öngörebilmektir. Yöntem, başlangıç olarak çekiç testi ile doğal titreşim frekanslarını ölçen deneysel çalışmayı kullanmıştır. Böylece deney, fiziksel modellemenin doğru ve tutarlı bir şekilde çalıştığını sağlamak ve enstrümanın asıl şartlarına mümkün olduğunca yakınlığını sağladığını göstermek amacı ile bir referans noktası olarak kullanılmıştır. Ardından her iki farklı ağaç türü için sabitlenmiş titreşim modları çalışılmış ve plakaların doğal titreşim frekanslarının, enstrümanın ses sahasına farklı etkileri gözlemlenmiş ve ilişkili parametreler belirtilmiştir.

Anahtar kelimeler

sonlu elemanlar metodu, fiziksel modelleme, deneysel modal analiz, doğal frekans, kanun göğüs tahtası