ISSN 1407-8015 TRANSPORT AND ENGINEERING 2007-24
MAŠĪNZINĀTNE UN TRANSPORTS

MECHANICS
MEHĀNIKA

THE ANALYSIS OF ACCURACY ESTIMATION OF EIGENFREQUENCY BY SPECTRAL METHOD AFTER IMPACT EXCITATION OF OSCILLATION

PAŠFREKVENČU NOTEIKŠANAS SPEKTRĀLĀS ANALĪZES PRECIZITĀTES NOVĒRTĒJUMS PĒC SVĀRSTĪBU IEROSINĀŠANAS AR TRIECIENU

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Keywords: spectral analysis, determination accuracy of eigenfrequency

1. Introduction

It is necessary to estimate and to control frequency characteristics of produced nods and details in real constructions. Nowadays, due to the development of manufacturability of materials earlier massive steel constructions are replaced by lighter steel and composite constructions as coverings. As a result, the estimation and analysis of eigenfrequency characteristics and prediction of behavior of the construction is particularly relevant [1].
Frequencies of curved steel plate, as a similarity of the covering element of the plane with one stringer of rigidity, with its following analysis of frequency spectrum, using Fourier transformation, are defined in this work.

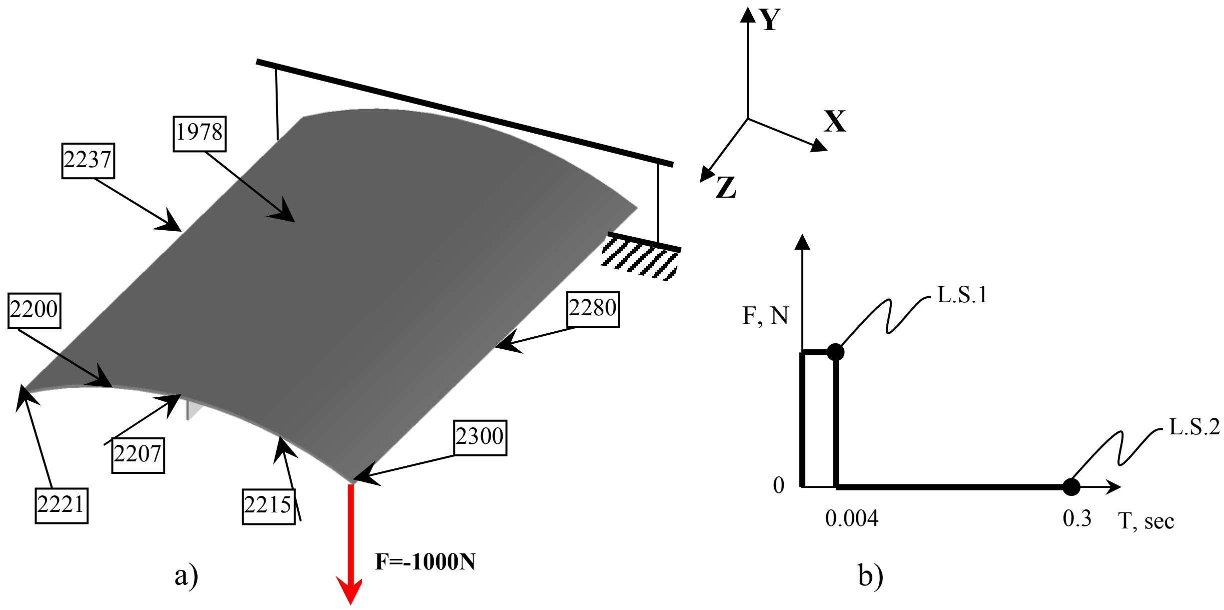


Figure 1. a) covering element – plate with checkpoints, (0.4x0.25x0.002 s-0.015),
b) stepped history of loading

2. Finite element model

The construction of curved plate was projected in SolidWorks 2004 program of parameter modeling. Then, finite element ANSYS model was built. The quantity of elements with oriented mesh is 1160. Solid-state element (a block with elastic characteristics E=2.1e11N/m, μ=0.3, corresponding to carbon steel) was chosen as a finite element [2]. Damping in calculation was not taken into consideration. The plate was considered to be with one fixed end.

3. Simulation data by Ansys

The first thirty eigenfrequences were determined at the first stage of calculation (Table #1, Fig.3).

Table 1

№	Frequency	-
1	71.179	
2	141.28	
3	242.71	
4	295.24	
5	321.39	
6	559.80	
7	560.19	
8	572.17	
9	738.88	
10	855.30	
11	864.29	
12	869.55	
13	1032.9	
14	1069.4	
15	1165.3	
16	1181.4	
17	1207.7	
18	1230.2	
19	1516.1	
20	1584.7	
21	1601.3	
22	1731.5	
23	1766.3	
24	1856.7	
25	1885.4	
26	1981.2	
27	2031.5	
28	2047.5	
29	2133.6	*
30	2269.1	

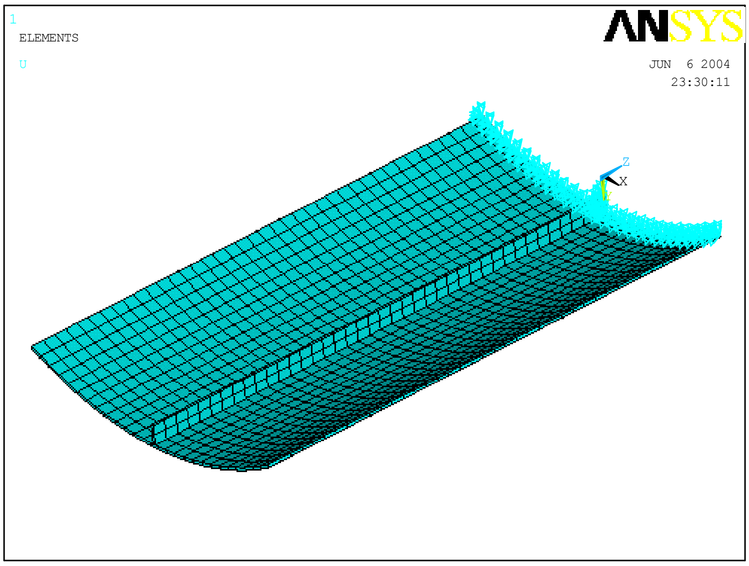


Figure 2. Finite-element model of the plate

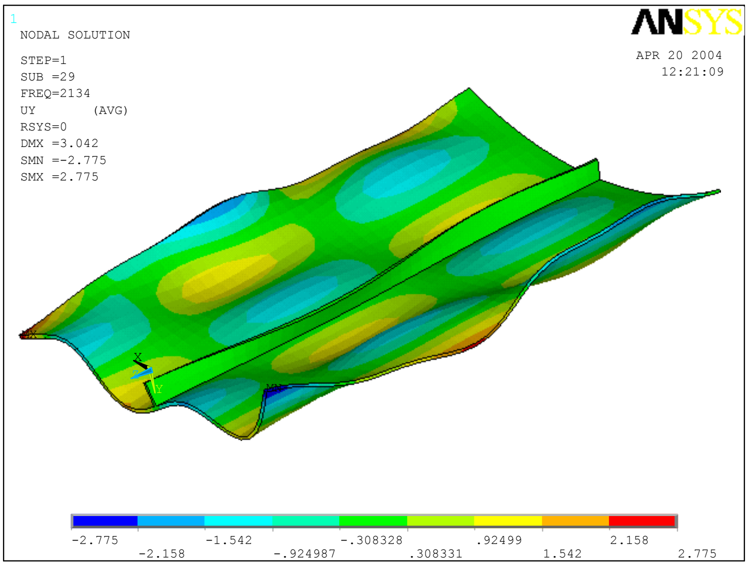


Figure 3. State of strain of a plate along axis Y on 29-th frequency (Table 1), is turned

Then more effective collision excitation for excitation of the much more frequencies according to height and location was sorted out. The character of collision excitation is shown at 1b figure. The state of strain of a plate along axis Y on 29-th frequency is revealed at the figure 3. To disclose the existing frequencies in plate, the time integration was made by small step – 0.0001 sec. The steps amount was reaching 2000 and 3000 at the time period 0.3 sec. Such calculations require a significant resource of personal computer. That’s why those calculations were made on P4 class computer with processor Intel – 3000 Hz and operating system Windows XP.
During modeling, it was clarified, that it is necessary to apply dissymmetrical pulse load for the construction for excitation of the greatest number of frequencies.

4. Spectral analysis

The program of Fourier transformation (Polyharmonic) was created for carrying out spectral analysis, based on the data arrays received by ANSYS program (with displacements vs. time), for researched points of plate. The calculations results are shown at the figure 4 – the displacement of the point № 1978 (Fig.1a.) of investigated plate along Y-axis. The spectral analysis by Polyharmonic program was made according listed displacement graph that shows on figure 5. This figure shows that the lowest frequencies are displayed with exactness in the third number f_1=71,2Hz, f_2=141,27 Hz. Nevertheless the frequencies upper than the 15^{th} one attenuates and it is impossible to identify them. At the figure 6 the frequency f_3=242,71 Hz is not presented. More upper frequencies in the range 500 – 900 – 1300 Hz with some closest meanings are reflected during spectral analysis as a one frequency and with a little less meanings of frequencies (Fig.7, 8).

№	Ferquency
1	71.179
2	141.28
3	242.71
4	295.24
5	321.39
6	559.80
7	560.19
8	572.17
9	738.88
10	855.30
11	864.29
12	869.55
13	1032.9
14	1069.4
15	1165.3
16	1181.4
17	1207.7
18	1230.2
19	1516.1
20	1584.7
21	1601.3
22	1731.5
23	1766.3
24	1856.7
25	1885.4
26	1981.2
27	2031.5
28	2047.5
29	2133.6
30	2269.1

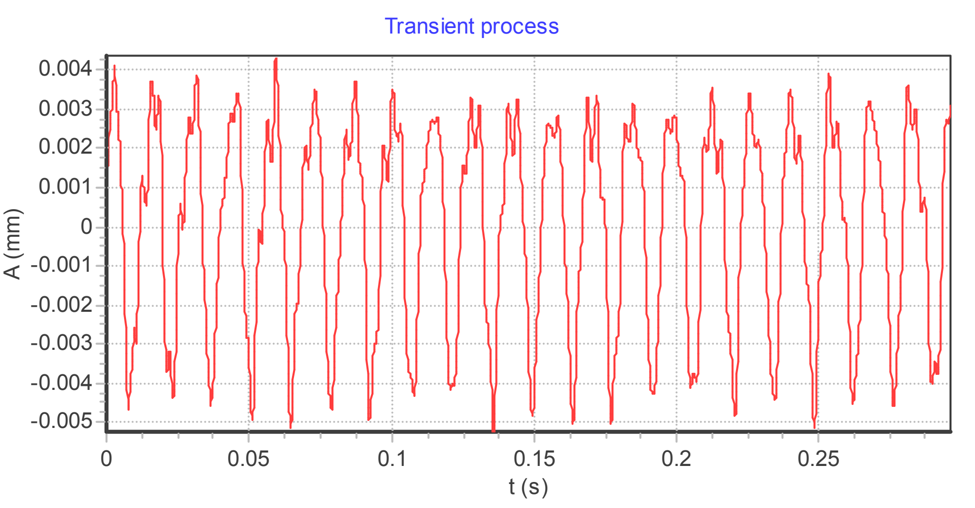


Figure 4. Calculation by ANSYS – displacement of the point №1978 at time along Y-axis (Fig.1.)

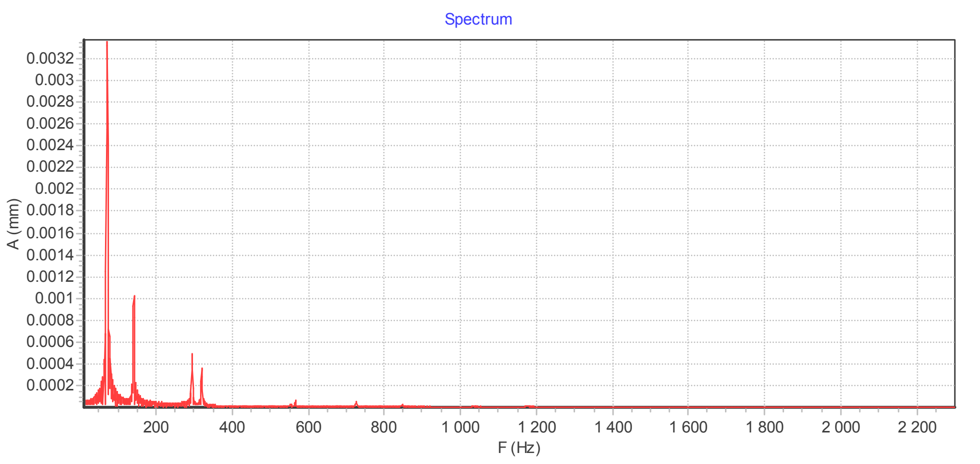


Figure 5. Frequency spectrum of 10 – 2300 Hz created by Polyharmonic program

№	Frequency
1	71.179
2	141.28
3	242.71
4	295.24
5	321.39

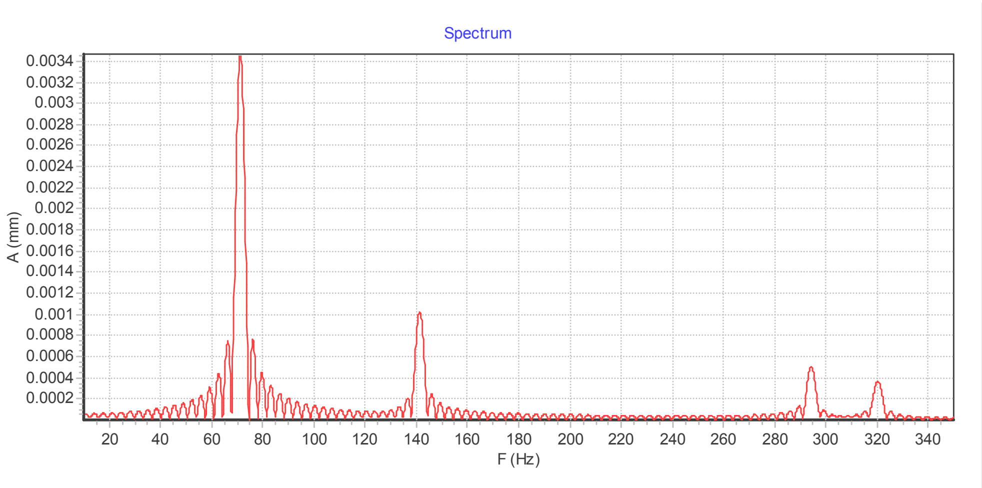


Figure 6. Frequency spectrum in the range 10 – 350 Hz

№	Frequency
6	559.80
7	560.19
8	572.17
9	738.88
10	855.30
11	864.29
12	869.55

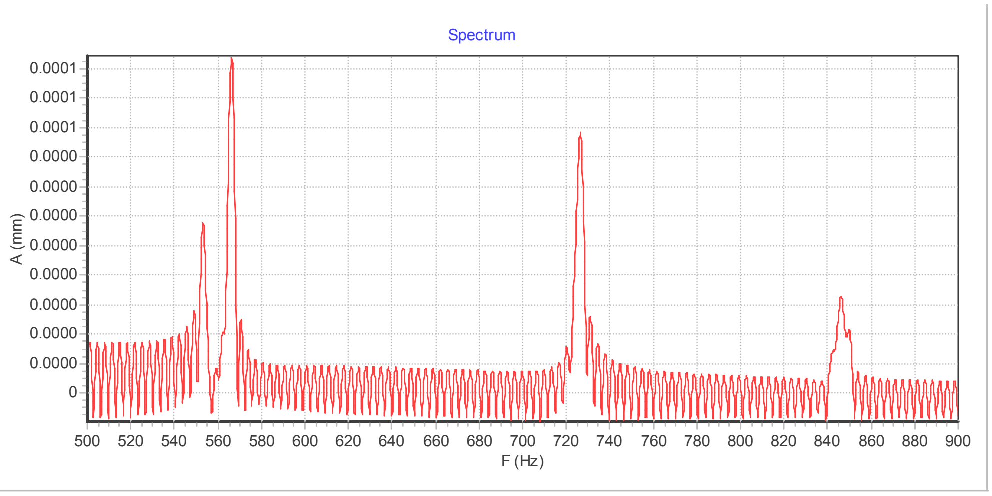


Figure 7. Frequency spectrum in the range 500 – 900 Hz

№	Ferquency
13	1032.9
14	1069.4
15	1165.3
16	1181.4
17	1207.7
18	1230.2

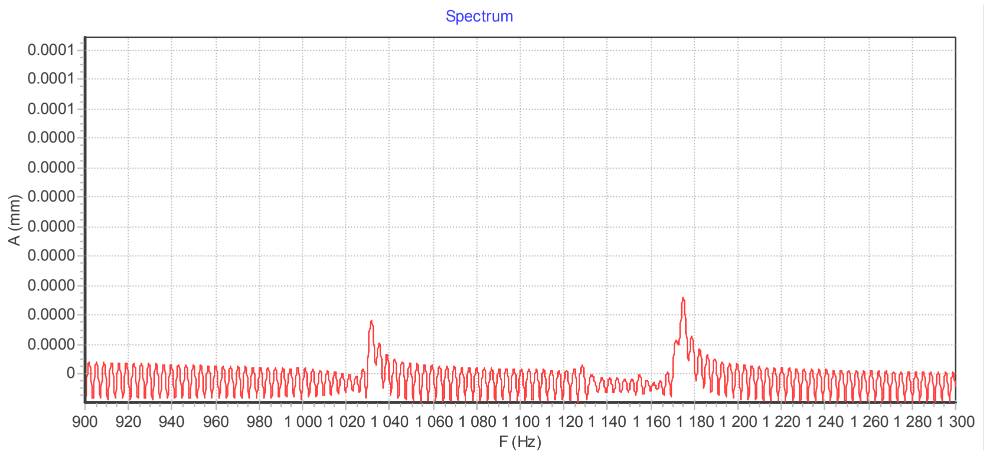


Figure 8. Frequency spectrum in the range 900 – 1300 Hz

To complete analysis of the facts (Fig.5–8), established during spectral analysis based on the calculated data of ANSYS program, we will carry out the frequency-amplitude processes synthesis by the created Polyharmonic program.

The Polyharmonic program can generate the transitional frequency-amplitude processes (Fig.10, 11, 12) by the first 28th frequencies (Fig.9). It also can copy and save the received data for the following processing.

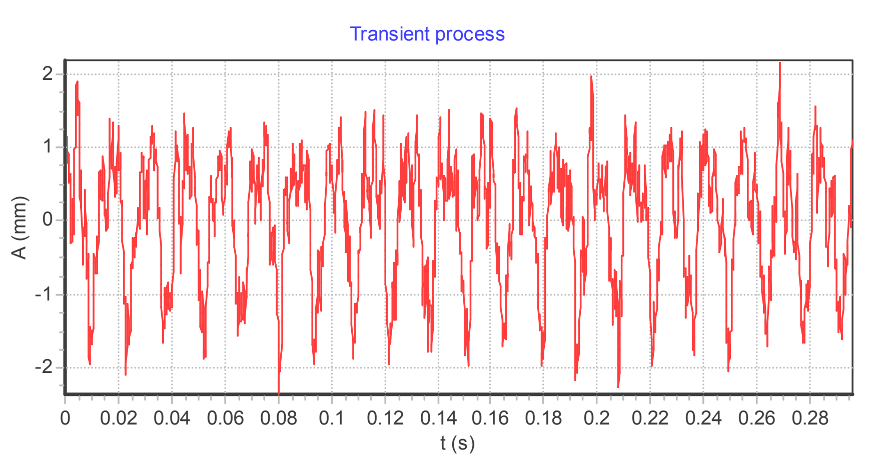
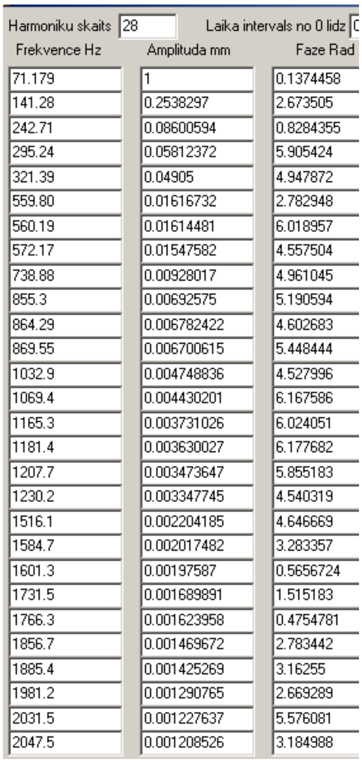


Figure 10. Synthesized displacement process *u* vs. time *t*. Amplitude *A* is inversely proportional to eigenfrequency *w*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Frekvence Hz	Amplituda mm	Faze Rad
71.179	1	0.1374458
141.28	0.2538297	2.673505
242.71	0.08600594	0.8284355
295.24	0.05812372	5.905424
321.39	0.04905	4.947872
559.80	0.01616732	2.782948
560.19	0.01614481	6.018957
572.17	0.01547582	4.557504
738.88	0.00928017	4.961045
855.3	0.00692575	5.190594
864.29	0.006782422	4.602683
869.55	0.006700615	5.448444
1032.9	0.004748836	4.527996
1069.4	0.004430201	6.167586
1165.3	0.003731026	6.024051
1181.4	0.003630027	6.177682
1207.7	0.003473647	5.855183
1230.2	0.003347745	4.540319
1516.1	0.002204185	4.646669
1584.7	0.002017482	3.283357
1601.3	0.00197587	0.5656724
1731.5	0.001689891	1.515183
1766.3	0.001623958	0.4754781
1856.7	0.001469672	2.783442
1885.4	0.001425269	3.16255
1981.2	0.001290765	2.669289
2031.5	0.001227637	5.576081
2047.5	0.001208526	3.184988

Fig.9. Input window of the calculated frequencies, synthesis of the amplitudes and phases

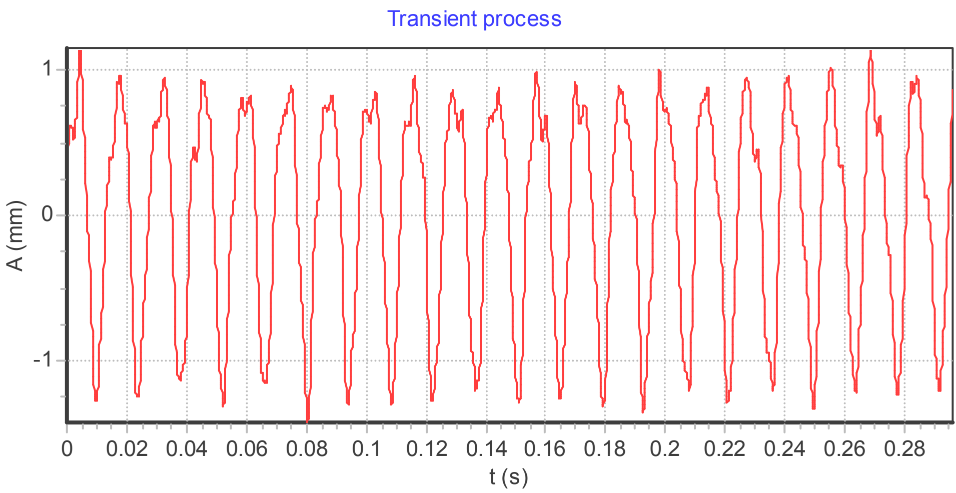


Figure 11. Synthesized displacement process of *u* vs.time *t* – amplitude $A=1/w^2$

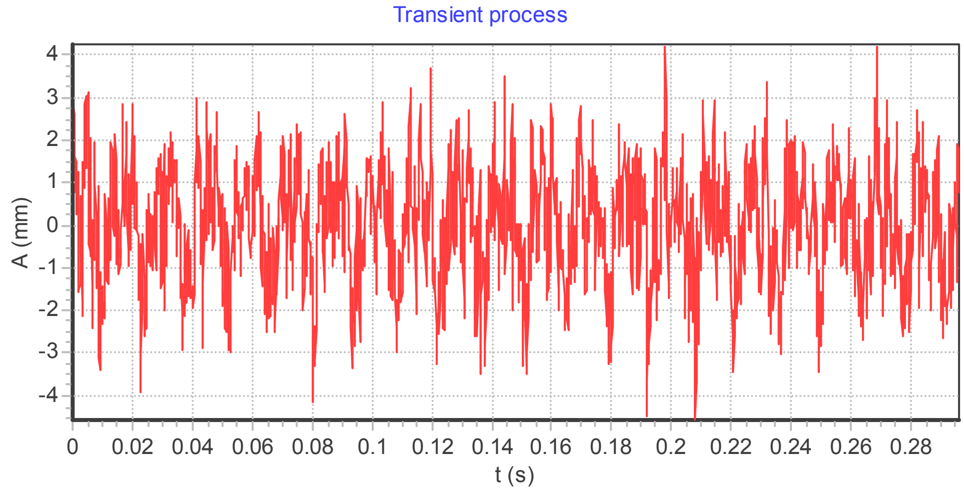


Figure 12. Synthesized displacement process of u from time t – amplitude $A = \sqrt{1/w^2}$

Synthesized (Fig.11) and calculated process by ANSYS (Fig.4) aligns well with each other. Hence the amplitudes of the processes are inversely proportional to the squared eigenfrequency.

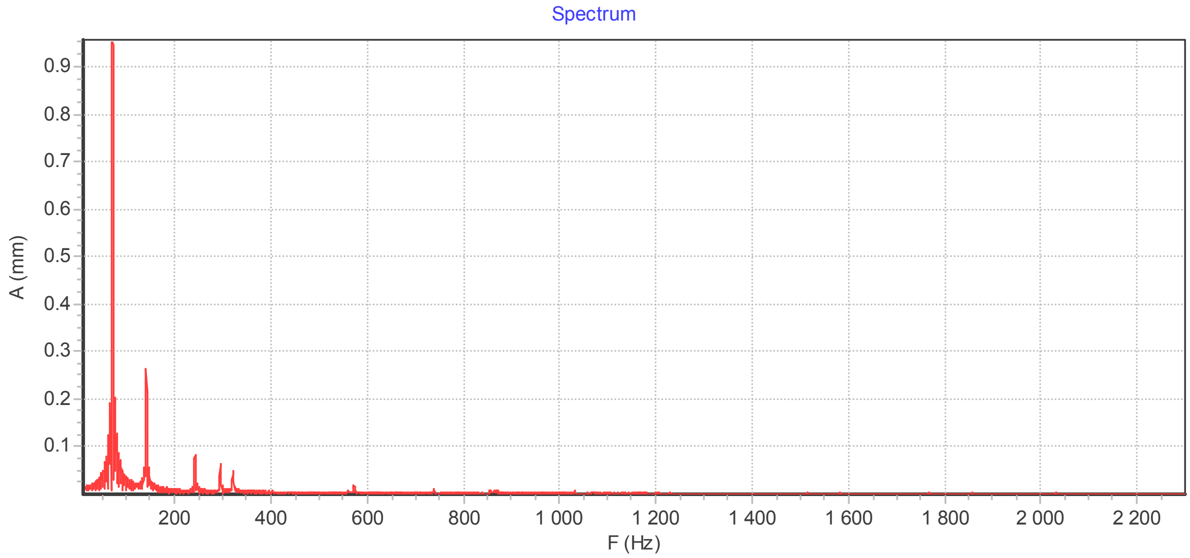


Figure 13. Frequency spectrum 10-2300 Hz of the process synthesized by Polyharmonic program.

Their amplitude is inversely proportional to the squared frequency $A = \sqrt{1/w^2}$. The phases are accidental.

№	Frequency
1	71.179
2	141.28
3	242.71
4	295.24
5	321.39

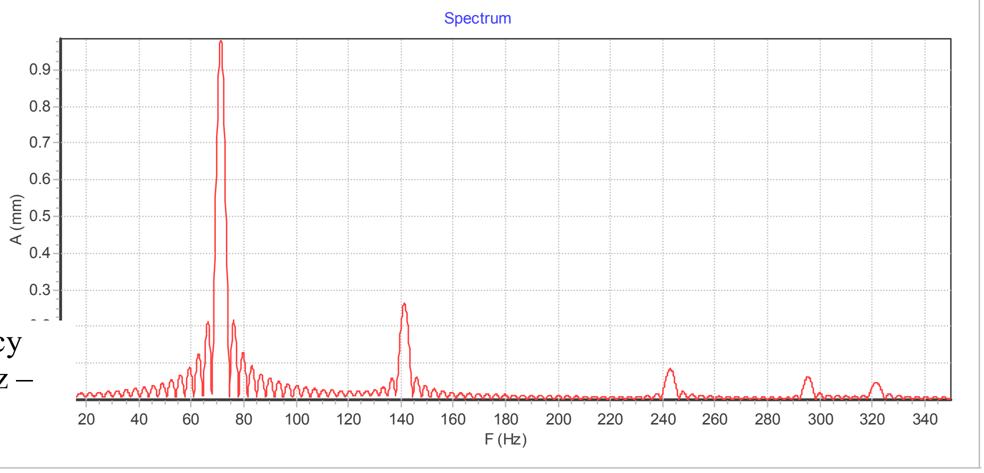


Figure 14. Frequency spectrum 10-350 Hz – synthesis.

№	Frequency
6	559.80
7	560.19
8	572.17
9	738.88
10	855.30
11	864.29
12	869.55

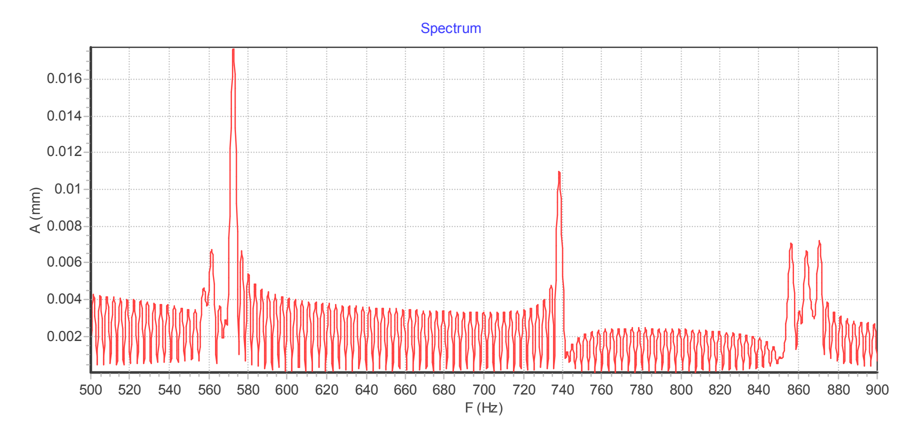


Figure 15. Frequency spectrum 500-900 Hz - synthesis

№	Frequency
13	1032.9
14	1069.4
15	1165.3
16	1181.4
17	1207.7
18	1230.2
19	1516.1
20	1584.7
21	1601.3
22	1731.5
23	1766.3
24	1856.7
25	1885.4
26	1981.2
27	2031.5
28	2047.5

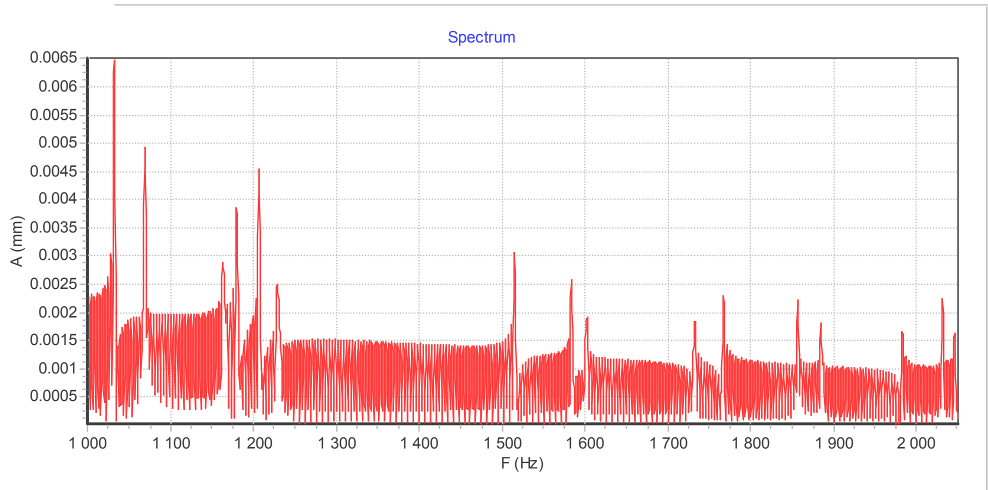


Figure 16. Frequency spectrum for 1000-2100 Hz - synthesis

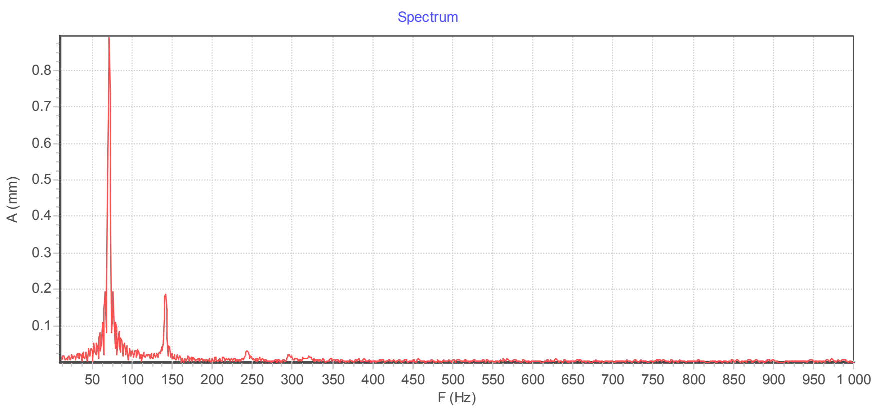
The verification of spectra of received frequencies from calculating by ANSYS and from synthesizing by Polyharmonic program shows that the eigenfrequencies are found by ANSYS program only up to the 15th eigenfrequency. The frequencies upper than the 15th one are not precisely identified and the process attenuates quickly. Perhaps, it has a bearing on the numerical integration algorithm and on influence of the boundary conditions on the results of identification of the eigenfrequency.

At the figure 6 the frequency f_3=242,71 Hz is not visible. However at the figure 14 the frequency f_3=242,71 Hz is clearly seen. Hence, the mentioned frequency has not been excited in the current experiment, but it can be dispayed when you add another loading or loading's combination.

It has to be admitted, that if some eigenfrequencies are nearly situated during processing, the peaks are converges and we'll see one frequency. This phenomenon intensifies at the rising of frequency, which we can see both in calculating (Fig.7, 8) and synthesizing figures (Fig.15) of the frequency spectrums.

Also the noise level, attenuation, number and quantity of the discretization's steps of the Fourier transformation on the frequencies calculation's accuracy was analyzed. It was defined, that at noise level 20% eigenfrequencies up to 10th are precisely calculated with exactness in second number. It is possible to precisely define the eigenfrequencies up to 6th – 8th (Fig.17) at the simultaneous applying of the quantity of attenuation about 0.000001 - 0.000006.

Figure 17. Frequency spectrum 10-2000 Hz – synthesis.
Noise level- 20%
Dissipation coefficient - 0.000006



The analysis of number and quantity of the discretization's steps of the Fourier transformation reveals that the decreasing of the step's number from 3000 to 2000 leads to the significant loss of the accuracy of the determination of eigenfrequencies above 10th as it is shown at the figure 18, 19.

№	Frequency
10	855.30
11	864.29
12	869.55
13	1032.9
14	1069.4
15	1165.3
16	1181.4

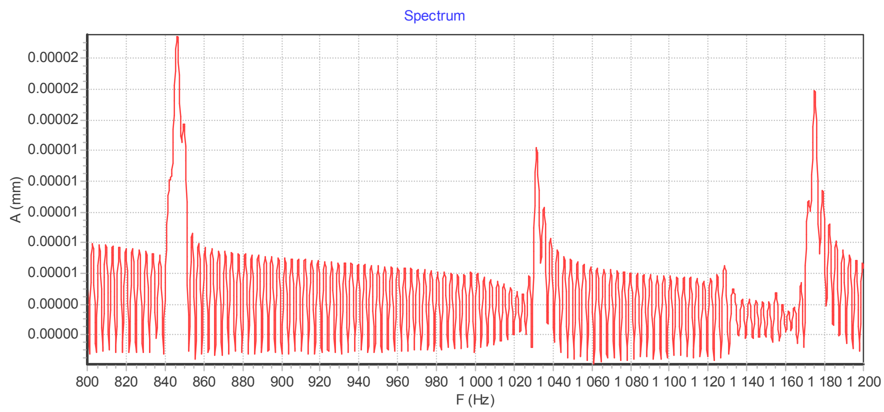


Figure 18. Frequency spectrum 800-1200 Hz of calculated process, 2000 steps

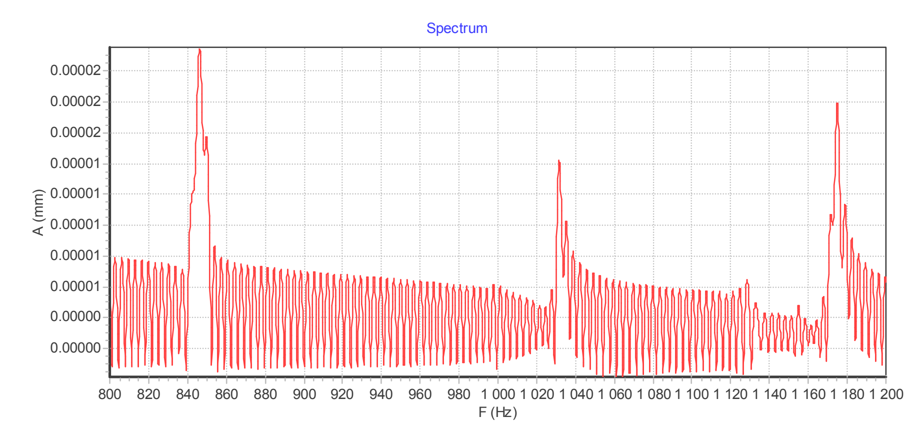


Figure 19. Frequency spectrum 800-1200 Hz of calculated process, 3000 steps

5. Conclusions

1. Highest frequencies do not exist or attenuates during modeling. That's why it is impossible to identify frequencies upper than the 15th one.
2. Several frequencies are not presented as they were not excided by this loading.
3. In the system the close frequencies exist, which are reflected as one frequency with their less meanings in the spectral analysis.
4. During modeling it was clarified, that amplitudes are inversely proportional to the squared eigenfrequency.
5. The noise level and attenuation influence on the accuracy of the determination of frequencies not significantly.
6. The number and quantity of the discretization's steps of the Fourier transformation have a great influence on the accuracy of the determination of frequencies upper than the 10th one.
7. It is necessary to execute the experimental measurements for verification of the results of numerical modeling.

References

1. Technical Report. POSICOSS. Task 3.2. Identification of realized material properties, May 5, 2002.
2. The ANSYS User's Manual, Theory, release 8.0, 2003.

Boiko A. Pašfrekvenču noteikšanas spektrālās analīzes precizitātes novērtējums pēc svārstību ierosināšanas ar triecienu

Rakstā tika veikta pašfrekvenču noteikšanas spektrālās analīzes precizitātes novērtējums pēc svārstību ierosināšanas ar izliektas tērauda plāksnītes triecienu (līdzīgi lidmašīnas apšuves elementam ar vienu stingruma ribu). Pēc tam tika analizēts trokšņu, rimšanas un Furjē soļu skaita diskretizācijas metodes iespaids uz frekvences noteikšanas precizitāti.

Boyko A. The analysis of accuracy estimation of eigenfrequency by spectral method after impact excitation of oscillation

The analysis of accuracy estimation of eigenfrequency by spectral method after impact excitation of oscillation of curved steel plate, as a similarity of the covering element of the plane with one stringer of rigidity was executed in this work. Also influence of the noise level, attenuation, number and quantity of the discretization's steps of the

Fourier transformation on the frequencies calculation's accuracy was analyzed.

Бойко А. Анализ точности определения собственных частот спектральным методом после ударного возмущения колебаний

В данной работе выполнен анализ точности определения собственных частот спектральным методом после ударного возмущения колебаний изогнутой стальной пластинки – подобие элемента обшивки самолета с одним ребром жесткости. Затем анализировалось влияние шума, затухания и числа шагов дискретизации метода Фурье на точность определения частот.