COMPUTER SIMULATION OF THE ORDER FREQUENCIES AMPLITUDES EXCITATION ON RESPONSE DYNAMIC 1D MODELS

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Summary: *In this paper imposed on the 1D dynamic model of resistance substrate excitation modeling function with two frequency amplitude shift in the time domain. FFT transformations had been treated in the frequency domain response amplitudes displacement equations of motion which corresponds to the transfer function (I.M.Miličić, 2015). Two variants had been suggestions (when only the first or only the second amplitude in the resonance), and shows the comparative analysis of model behavior from the standpoint from the duration of the excitation. Two frequency response model with the proposed transfer function, the order of frequency amplitude excitation hadn't respected as an essential factor.*

Keywords: *FFT transformation, transfer function, amplitudes displacement.*

1. INTRODUCTION

Simulation as a scientific method of computer mechanics had treated knowledge from statics and dynamics of structures. The results of the impact in girders, due to the load depend on a number of factors. In this study considers the retention time of the facts, as in [1]. Observed the movement of 1D model, excited with two frequency amplitude – frequency displacement, where:

- The first amplitude in the resonance (Fig.2.a) – the first case,
- Second amplitude in the resonance (Fig.2.b) – the second case.

Expecting them individually, significant displacement response due to resonance, or in the same order as they imposed frequency amplitude excitation. Why?
Therefore, such an excitation in the testing system structure may be different, while the response has one condition proposed decision (1) that corresponds to the transfer function „excitation – response" (2).

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Therefore, the task of this research work is theoretically considered in [1] [2] and [3], while the verification conducted similar computer simulation.

2. COMPUTER SIMULATION

First, consider the movement of mathematically modeled equations of the form (1) where he served function of transfer (2)

$$x(t) = A_i \cdot P(\psi_i) \cdot \cos(\Omega_i \cdot t + \theta_i) \tag{1}$$

$$P(\psi) = \frac{x(t)}{\Delta(t)} = \frac{1}{\sqrt{(1-\psi^2)^2 + (2\cdot\xi\cdot\psi)^2}} \tag{2}$$

Second, impose a two frequency excitation system (3) according to the flow computer simulation (Fig. 1).

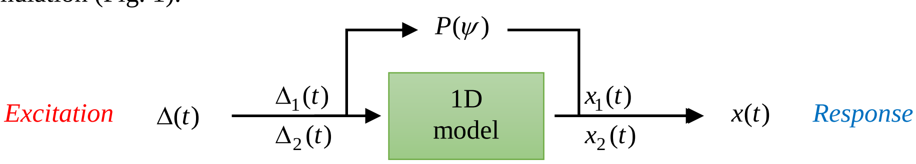


Figure 1 – Flowchart of simulation models with dual frequency excitation

The excitation is a 1D model input data superposition,

$$\Delta_1(t) = A_1 \cos(\Omega_1 t) \quad \text{and} \quad \Delta_2(t) = A_2 \sin(\Omega_2 t) \tag{3}$$

whereby the amplitude response superposition of modeled output amplitude as a function of excitation and transfer function „excitation – response“ (4)

$$x_1(t) = \underbrace{A_1 \cdot P(\psi_1)}_{X_1} \cos(\Omega_1 t + \theta_1) \quad \text{and} \quad x_2(t) = \underbrace{A_2 \cdot P(\psi_2)}_{X_2} \sin(\Omega_2 t + \theta_2) \tag{4}$$

where is:

- A_1, A_2 – amplitude excitation model
- X_1, X_2 – amplitude response model
- Ψ – disorder

The input data for the simulation model:

$m := 640\ kg$ $\qquad N := 256$

$\xi := 0.1$ $\qquad t_{max} := 5\ s$

$c := 1.0 \cdot 10^5\ \frac{N}{m}$ $\qquad i := 0..(N-1)$ $\qquad t_i := i \cdot \Delta t$ $\qquad \Delta t = 0.019531$

Calculating the natural frequencies and damping physical 1D models,

$$\omega := \sqrt{\frac{c}{m}} \qquad \omega = 12.5\ \frac{1}{s} \qquad f := \frac{\omega}{2\cdot\pi} \qquad f = 1.99\ \frac{1}{s}$$

$$b := 2\cdot m\cdot\omega\cdot\xi \qquad b = 1.6\times10^{3}\ \frac{kg}{s} \qquad \omega_d := \omega\cdot\sqrt{\left(1-\xi^2\right)} \qquad \omega_d = 12.44\ \frac{1}{s}$$

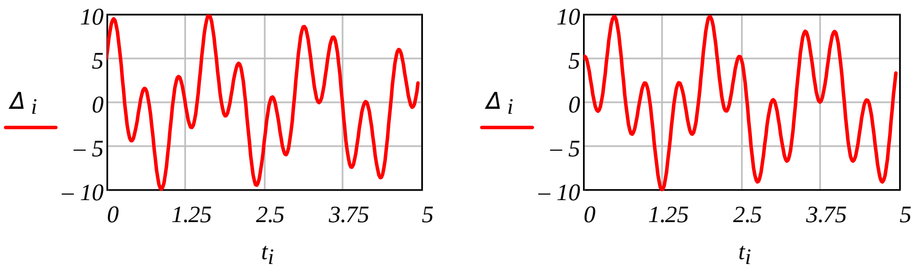
$$f_d := \frac{\omega_d}{2\cdot\pi} \qquad T_d := \frac{1}{f_d} \qquad T_d = 0.505 \qquad \frac{T_d}{10} = 0.0505$$

dual frequency excitation input:

• for the first case		• for the second case	
$A_1 := 5\ mm$	$A_2 := 5\ mm$	$A_1 := 5$	$A_2 := 5$
$\Omega_1 := \frac{3}{10}\cdot\omega$	$\Omega_2 := \frac{9.999}{10}\cdot\omega$	$\Omega_1 := \frac{9.999}{10}\cdot\omega$	$\Omega_2 := \frac{3}{10}\cdot\omega$

Excitation model:

$$\Delta_i := A_1\cdot cos\left(\Omega_1\cdot t_i\right) + A_2\cdot sin\left(\Omega_2\cdot t_i\right)$$



a) *b)*

Figure 2 – Dual frequency excitation with a retention time t = 5 s

The general form of the equation of motion model – response:

$$x(t) = X_1\cdot cos\left(\Omega_1\cdot t+\theta_1\right) + X_2\cdot sin\left(\Omega_2\cdot t+\theta_2\right)$$

Amplitude and phase angles response model,

amplitude: $$P(\xi,\psi) := \frac{1}{\sqrt{\left(1-\psi^2\right)^2 + (2\cdot\xi\cdot\psi)^2}}$$ scaling factor: $$\lambda := \frac{1}{A_1}$$

phase angle: $$\theta(\xi,\psi) := \left| \begin{array}{l} \theta \leftarrow -\mathrm{atan}\left(\dfrac{2\cdot\xi\cdot\psi}{1-\psi^2}\right) \\ \theta \leftarrow \theta - \pi \ \ \text{if} \ \ \psi > 1 \\ \text{return} \ \ \theta \end{array} \right.$$

$$\theta(\xi,\psi) := -\theta(\xi,\psi)\cdot\frac{180}{\pi}$$

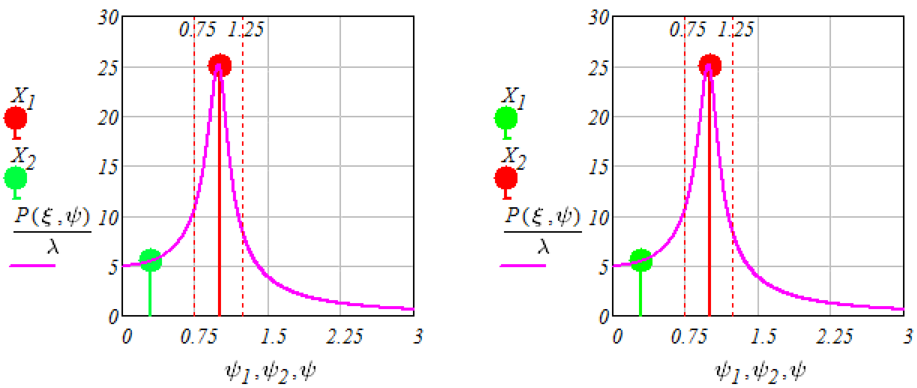


Figure 3 – Amplitude response for both cases

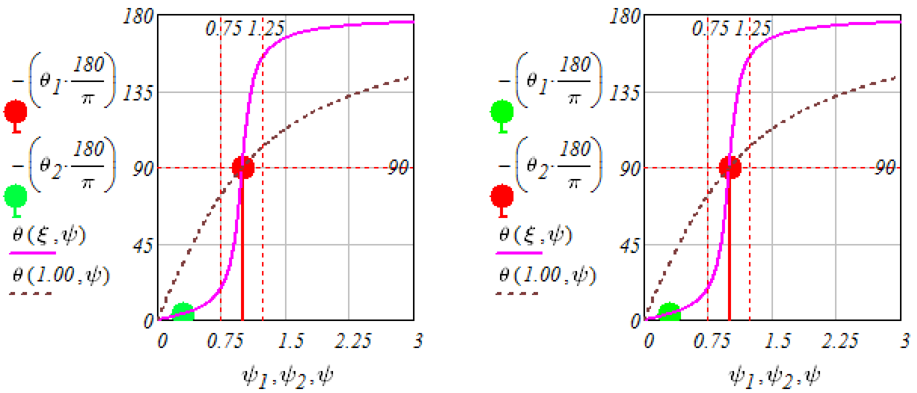


Figure 4 – The phase angles of the response for both cases

Note:
In this study, the ratio of natural frequencies had treated as a disorder.

3. RECONSTRUCTION RESPONSE 1D MODELS

Reconstruction response was conducted FFT algorithm sequentially with N = 256 points. FFT transformation to different retention times of external loads (both cases the excitation), are compared and displayed amplitude spectra (Fig. 5,7,9 and 11), and the spectra of the phase angles (Fig. 6,8,10 and 12) responds 1D model.

3.1 FFT transformation

Excitation: $U := FFT(\Delta)$

Response: $I := FFT(x)$

$$i := 0 .. \left(\frac{N}{2}\right) \qquad f_0 := \frac{1}{t_{max}} \qquad f_N := \frac{N}{2 \cdot t_{max}} \qquad fD_i := (i+1) \cdot f_0$$

Amplitude response:

first case $X_1 = 25$ $X_2 = 5.48$ $f_0 = 0.2$ $f_N = 25.6$

second case $X_1 = 5.48\ mm$ $X_2 = 25\ mm$ $f_0 = 0.2$ $f_N = 25.6$

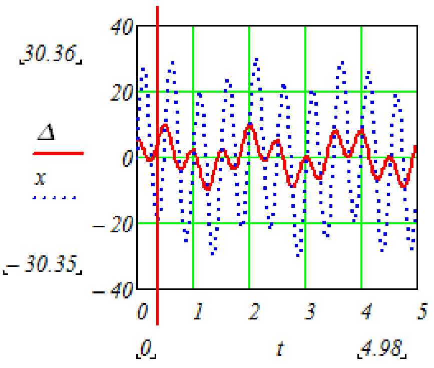
The phase angles response:

first case $-\theta_1 \cdot \frac{180}{\pi} = 89.943$ $-\theta_2 \cdot \frac{180}{\pi} = 3.772$

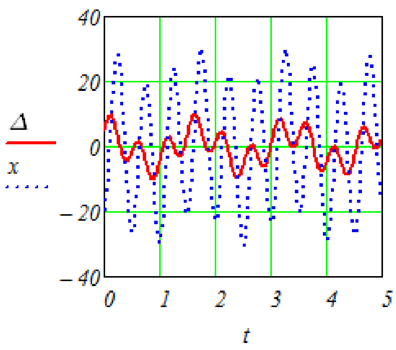
second case $-\theta_1 \cdot \frac{180}{\pi} = 3.772$ $-\theta_2 \cdot \frac{180}{\pi} = 89.943$

- **Time domain – t=5s**

first case



second case



- **The frequency domain**

first case second case

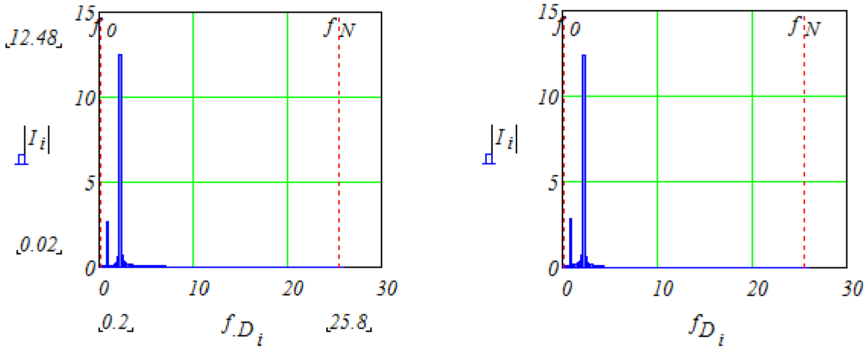


Figure 5 – Spectrum amplitude response for t = 5s

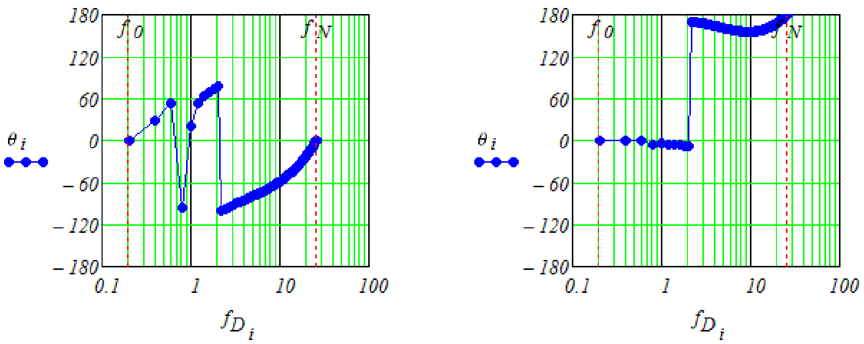
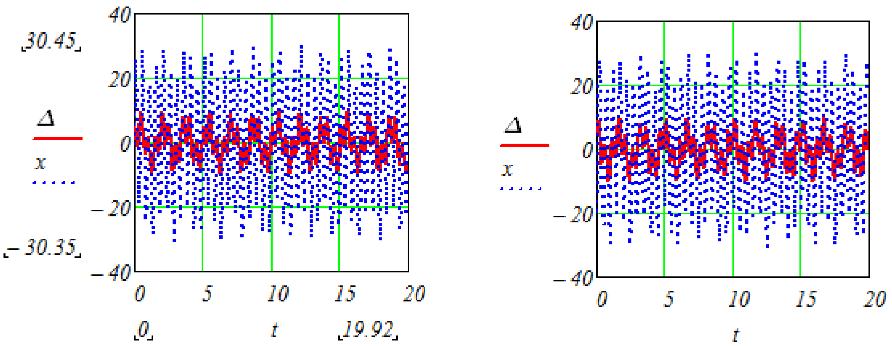


Figure 6 – The range of phase angle response for t = 5s

- **Time domain – t=20s**

first case second case



- **The frequency domain**

first case second case

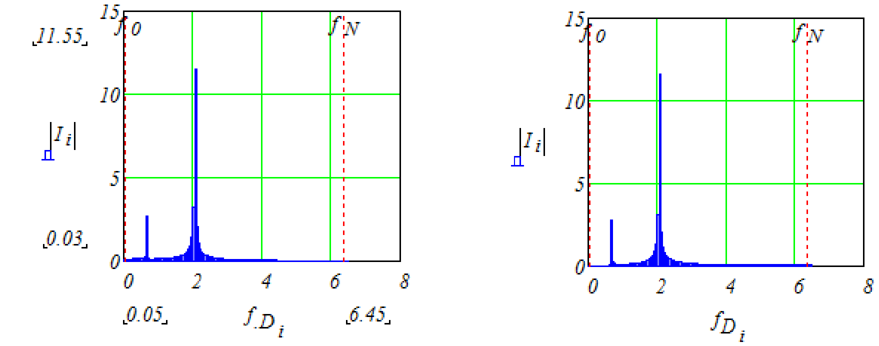


Figure 7 – The range of the amplitude response for t = 20s

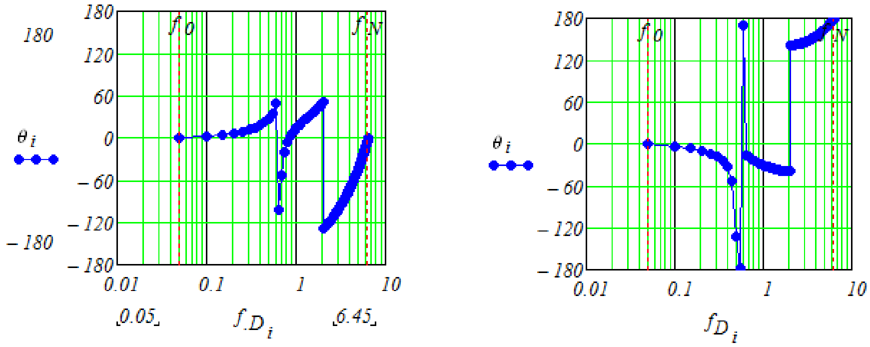
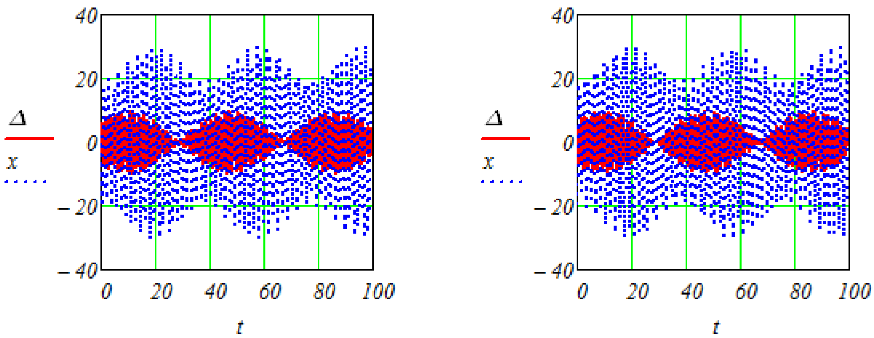


Figure 8 – The range of phase angle response for t = 20s

- **Time domain – t=100s**

first case second case



- **The frequency domain**

first case second case

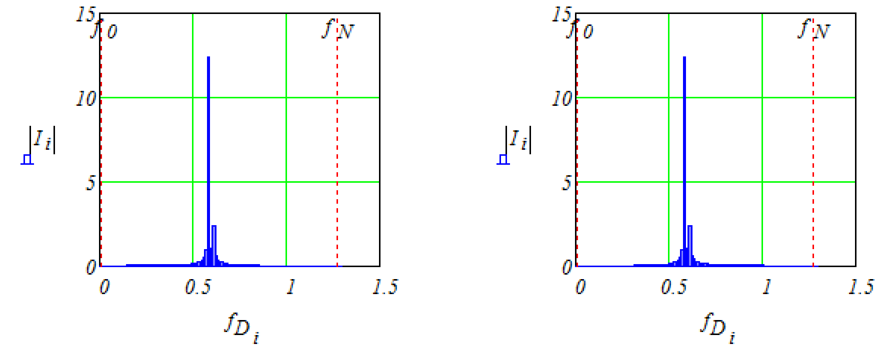


Figure 9 – Spectrum amplitude response for t = 100s

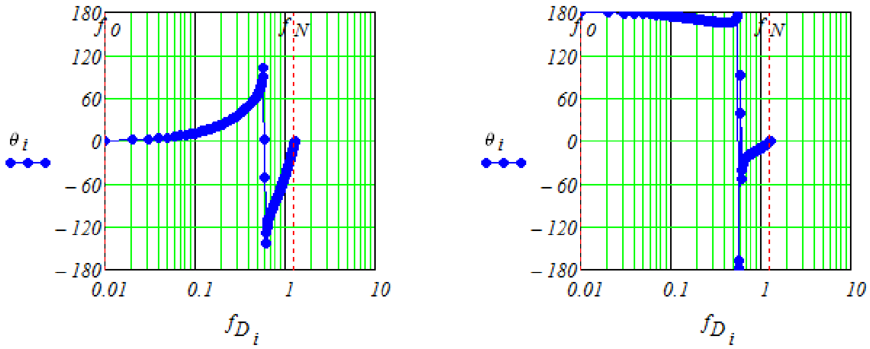
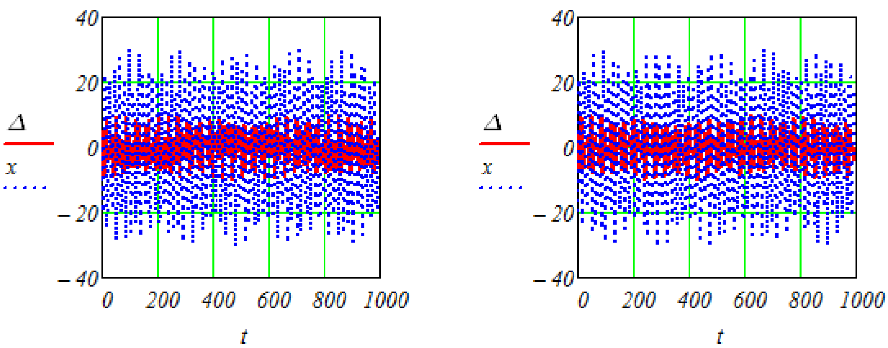


Figure 10 – Spectrum of phase angle response for t = 100s

- **Time domain – t=1000s**

first case second case



- **The frequency domain**

first case second case

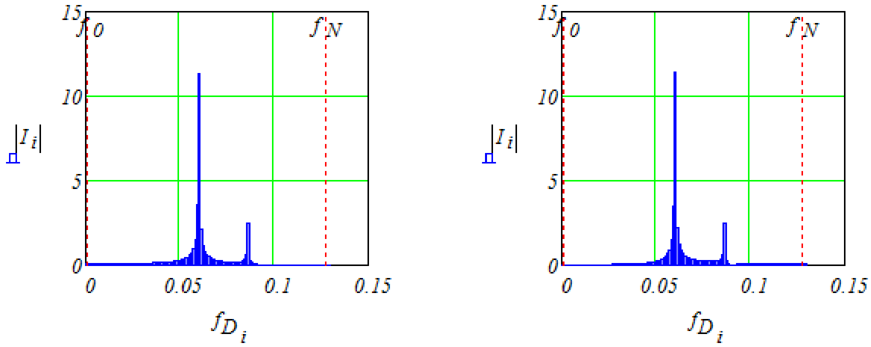


Figure 11 – Spectrum amplitude response for t = 1000s

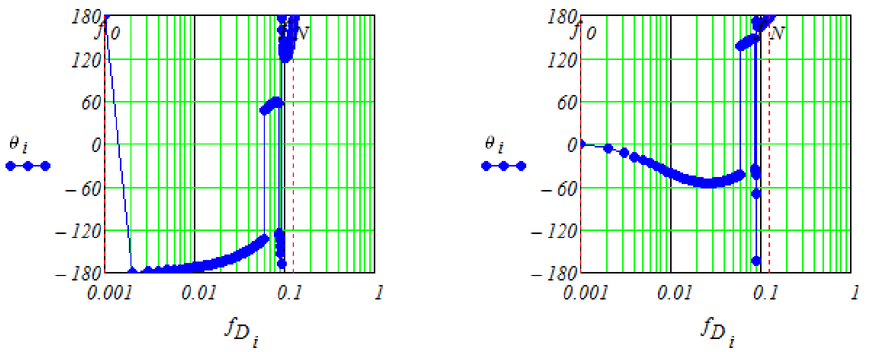


Figure 12 – Spectrum of phase angle response for t = 1000s

Note the results of the simulation for the duration of the excitation t = 100s (Fig. 9). We have two registered frequency response amplitudes close to each other. This indicates that, in the case of two frequency spectrum amplitude excitation, we are not always sure that the modeled response of the transfer function corresponded with two frequency amplitude displacement. Therefore, looking at the retention time workloads for both treated cases, we find the amplitude spectra shifts (two) variable sequence. Maximum amplitude response model for both cases arose during the first excitation input (Fig. 11).

4. CONCLUSION

Based on computer simulations had shown in this paper concludes that:

- sequence of the target amplitude frequency excitation imposed in the area of resonance in the response of the model shows a slight deviation,
- there is a difference in the spectra of phase angles of each simulation conducted,

- load retention time is an important factor,
- transfer function with two frequency excitation corresponds to the final solution of movement 1D models.

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REFERENCES

[1] Miličić, M.I, Lađinović, Đ.: Računarska simulacija odziva dvo frekventne pobude 1D dinamičkog modela primenom FFT i IFFT algoritma, Savremena dostignuća u građevinarstvu (4; Subotica; **2016**), ISBN 978-86-80297-63-7, str. 239-248

[2] Miličić, M.I., Prokić, A., Folić, R.: Matematičko modeliranje odziva 1D modela sa otporom podloge primenom Furijeve transformacije, Međunarodno naučno-stručno savetovanje Zemljotresno inženjerstvo i inženjerska seizmologija (5; Sremski Karlovci; **2016**), ISBN 978-86-88897-08-2, str. 273-282

[3] Miličić, M.I., Romanić, J.M.: Teorijska analiza dinamičkih uticaja 1D modela pobuđenog dejstvom spoljašnjih pomeranja, Savremena dostignuća u građevinarstvu (3; Subotica; **2015**), ISBN 978-86-80297-62-0, str. 341-350

[4] Tang, K.T.: Mathematical Methods for Engineers and Scientists 3, ISBN-10 3-540-44695-8 Springer Berlin Heidelberg New York, **2007**.

[5] PTC, Mathcad 14.0, User's Guide (pdf), February **2007**.

RAČUNARSKA SIMULACIJA REDOSLEDA UČESTANOSTI AMPLITUDA POBUDE U ODZIVU 1D DINAMIČKOG MODELA

Rezime: *U ovom radu nametnuta je 1D dinamičkom modelu sa otporom podloge pobuda modelirana funkcijom sa dve učestanosti amplituda pomeranja u vremenskom domenu. FFT transformacijama tretirane su u frekventnom domenu amplitude pomeranja odziva čija jednačina kretanja korespondira sa prenosnom funkcijom (I.M.Miličić, 2015). Razmatrane su dve varijante pobude (kada je samo prva, odnosno samo druga amplituda u području rezonancije) i prikazana je uporedna analiza odziva modela sa gledišta vremena trajanja pobude. Dvofrekventni odziv modela sa predloženom funkcijom prenosa, redosled učestanosti aplituda pobude ne respektuje kao bitan faktor.*

Ključne reči: *FFT transformacija, funkcija prenosa, amplituda pomeranja.*