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

Ilija M. Miličić¹
Aleksandar Prokić²
Đorđe Lađinović³

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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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¹ Ilija M. Miličić, PhD, CE, University of Novi Sad, Faculty of Civil Engineering Subotica, Kozaračka 2a, 24000 Subotica, Serbia, e – mail: milicic@gf.uns.ac.rs
² Aleksandar Prokić, PhD, CE, University of Novi Sad, Faculty of Civil Engineering Subotica, Kozaračka 2a, 24000 Subotica, Serbia, e – mail: aprokic@eunet.rs
³ Đorde Lađinović, PhD, CE, University of Novi Sad, Faculty of Technical Sciences, Dr Sime Miloševića 12, 21000 Novi Sad, Serbia, e – mail: ladinj@uns.ac.rs
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)

\[
x(t) = A_i \cdot P(\psi_i) \cdot \cos(\Omega_i \cdot t + \theta_i)
\]

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

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

\[
\Delta_1(t) = A_1 \cos(\Omega_1 t) \quad \text{and} \quad \Delta_2(t) = A_2 \sin(\Omega_2 t)
\]

The excitation is a 1D model input data superposition,

\[
\Delta_1(t) = A_1 \cos(\Omega_1 t) \quad \text{and} \quad \Delta_2(t) = A_2 \sin(\Omega_2 t)
\]

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

\[
x_1(t) = A_1 \cdot P(\psi_1) \cos(\Omega_1 t + \theta_1) \quad \text{and} \quad x_2(t) = A_2 \cdot P(\psi_2) \sin(\Omega_2 t + \theta_2)
\]

where is:
- \(A_i, A_2\) – amplitude excitation model
- \(X_i, X_2\) – amplitude response model
- \(\psi\) – disorder

The input data for the simulation model:

\[
m := 640 \, \text{kg} \quad \text{N}_\text{max} := 256
\]

\[
\xi := 0.1 \quad t_{\text{max}} := 5 \, \text{s}
\]

\[
C := 1.0 \cdot 10^5 \frac{N}{m} \quad i := 0 \ldots (N - 1) \quad \Delta t := i \cdot \Delta t \quad \Delta t = 0.019531
\]
Calculating the natural frequencies and damping physical 1D models,

\[
\begin{align*}
\omega &:= \sqrt{\frac{c}{m}} \quad \omega = 12.5 \ \frac{1}{s} \\
\omega &:= \frac{1}{2\pi} \quad f = 1.99 \ \frac{1}{s} \\
b &:= 2m\cdot\omega\cdot\xi \quad b = 1.6 \times 10^3 \ \frac{kg}{s} \\
\omega_d &:= \omega\cdot\sqrt{1 - \xi^2} \quad \omega_d = 12.44 \ \frac{1}{s} \\
f_{d} &:= \frac{\omega_d}{2\pi} \quad T_d = 0.505 \\
T_d &:= \frac{1}{f_{d}} \\
\frac{T_d}{10} &:= 0.0505
\end{align*}
\]

dual frequency excitation input:

- **for the first case**
  \[
  A_1 := 5 \ mm \\
  \Omega_1 := \frac{3}{10} \cdot \omega \\
  \Delta_1 := A_1 \cdot \cos(\Omega_1 \cdot t_i) + A_2 \cdot \sin(\Omega_2 \cdot t_i)
  \]

- **for the second case**
  \[
  A_1 := 5 \\
  \Omega_1 := \frac{9.999}{10} \cdot \omega \\
  \Omega_2 := \frac{3}{10} \cdot \omega \\
  A_2 := 5
  \]

Excitation model:

\[
\Delta_i := A_1 \cdot \cos(\Omega_1 \cdot t_i) + A_2 \cdot \sin(\Omega_2 \cdot t_i)
\]

![Figure 2](image)

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

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

\[
x(t) = X_1 \cdot \cos(\Omega_1 \cdot t + \theta_1) + X_2 \cdot \sin(\Omega_2 \cdot t + \theta_2)
\]
Amplitude and phase angles response model,

amplitude: \[ P(\xi, \psi) := \frac{1}{\sqrt{(1 - \psi^2)^2 + (2\cdot\xi \cdot \psi)^2}} \]
scaling factor: \[ \lambda := \frac{1}{A_f} \]

phase angle: \[ \theta(\xi, \psi) := \begin{cases} \theta & \text{if } \psi > 1 \\ \theta - \pi & \text{if } \psi < 1 \\ \text{return } \theta & \text{if } \psi = 1 \end{cases} \]

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

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: \( U := \text{FFT}(\Delta) \)

Response: \( I := \text{FFT}(x) \)

\[
i := 0..\left(\frac{N}{2}\right) \quad f_0 := \frac{i}{t_{\text{max}}} \quad f_N := \frac{N}{2\cdot t_{\text{max}}} \quad f_{D_{\text{t}}} := (i+1)f_0
\]

Amplitude response:

first case \( X_1 = 25 \quad X_2 = 5.48 \quad f_0 = 0.2 \quad f_N = 25.6 \)

second case \( X_1 = 5.48 \text{ mm} \quad X_2 = 25 \text{ mm} \quad f_0 = 0.2 \quad f_N = 25.6 \)

The phase angles response:

first case \( -\theta_1\frac{180}{\pi} = 89.943 \quad -\theta_2\frac{180}{\pi} = 3.772 \)

second case \( -\theta_1\frac{180}{\pi} = 3.772 \quad -\theta_2\frac{180}{\pi} = 89.943 \)

- Time domain – \( t=5s \)
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- The frequency domain

first case

second case

\[ |f(t)| \]

\[ \theta(t) \]

*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

\[ \Delta \]

*Zборник радова Међународне конференције (2017) |*
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
• **Time domain – t=1000s**

  first case  

  second case  

• **The frequency domain**
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,
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- 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

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 amplitude pomeranja u vremenskom domenu. FFT transformacijama tretirane su u frekventnom domenu amplitudne 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 amplitude pobude ne respektuje kao bitan faktor.

Ključne reči: FFT transformacija, funkcija prenosa, amplitude pomeranja.