COMPUTER SIMULATION 1D MODEL EXCITED OF TWO FREQUENT BY THE ACTION OF EXTERNAL DISPLACEMENT – PART 1

Ilija M. Miličić[1]
Đorđe Lađinović[2]
Ivana I. Miličić[3]

UDK: 531.1:519.87
DOI: 10.14415/konferencijaGFS2018.016

Summary:. *In this paper is simulated motion of the 1D model at low frequencies of moving an external excitation. The external excitation is imposed by two equal amplitudes of displacement ($\Omega_1=\Omega_2=0$) which is particularity of this research. Using the FFT and IFFT transformation algorithms, the amplitude of displacement are treated in the frequency and time domain, which in the final response solution correspond with the transmission function (I.M.Miličić, 2015). On the basis of the simulated simulations for a possible "motion" case, there is a displacement in the system controlled by the stiffness of the model – the structure.*

Keywords: *Simulation, dynamic model, FFT and IFFT algorithm, transfer function, displacement.*

1. INTRODUCTION

Computer mechanics is supported to treat some theoretical problems with simulation by softwares. That is reason for continue some reaserch [2] [4], which problems are how the movement of 1D dynamic model correspond with suggested transfer function “excitation – response”.
We use two frequency external excitation and suggested that expected movement only will control by stiffness of girder.
In this paper [4] we present the solution which will normalize movement of model by coefficient of disorder. Equation (12) is design to control movement of 1D model with low frequency of external excitation by stiffness of girder.
In this paper we consider how external excitation is:

- continual function of time,
- simulated by dynamical periodical load with two frequency with same amplitudes

[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] Đorđe Lađinović, PhD, CE, University of Novi Sad, Faculty of Technical Sciences, Dr Sime Miloševića 12, 21000 Novi Sad, Serbia, e – mail: ladjin@uns.ac.rs
[3] Ivana I. Miličić, Gymnasium „Dušan Vasiljev“, Dr Zorana Đinđića 7, 23300 Kikinda, Serbia, e – mail: i_milicic@hotmail.com

2. COMPUTER SIMULATION

Simulation 1D model – calculating the natural frequencies and damping

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

$$b := 2\cdot m\cdot\omega\cdot\xi \qquad b = 1.6\times 10^{3} \qquad \omega_d := \omega\cdot\sqrt{\left(1-\xi^{2}\right)} \qquad \omega_d = 12.44$$

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

Two frequency excitation input,

$$A_1 := 5 \qquad A_2 := 5$$

$$\Omega_1 := \frac{0}{10}\cdot\omega \qquad \Omega_2 := \frac{0}{10}\cdot\omega$$

excitation model:

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

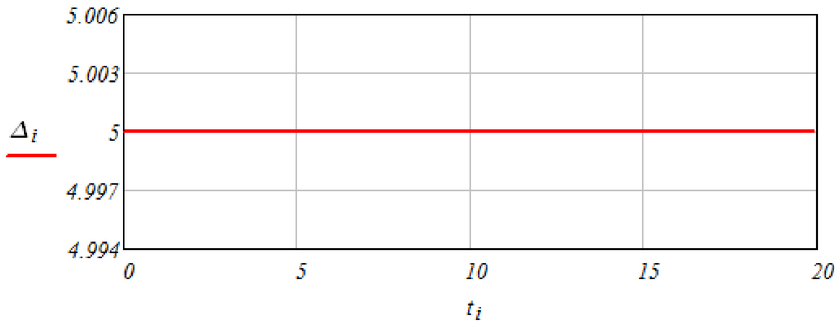


Figure 1 – Two frequency excitation with a retention time t=20s

The general form of the equation of the movement of the model,

$$x(t) = A_i\cdot P\left(\psi_i\right)\cdot\cos\left(\Omega_i\cdot t + \theta_i\right)$$

superposition of individual responses

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

Where:

- amplitude response $$X_i = \frac{c}{c}\cdot A_i\cdot P\left(\psi_i\right)$$
- coefficient of disorder $$\psi_i = \frac{\Omega_i}{\omega} \qquad i = 1, 2$$

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: $$\lambda := \frac{1}{A_2}$$

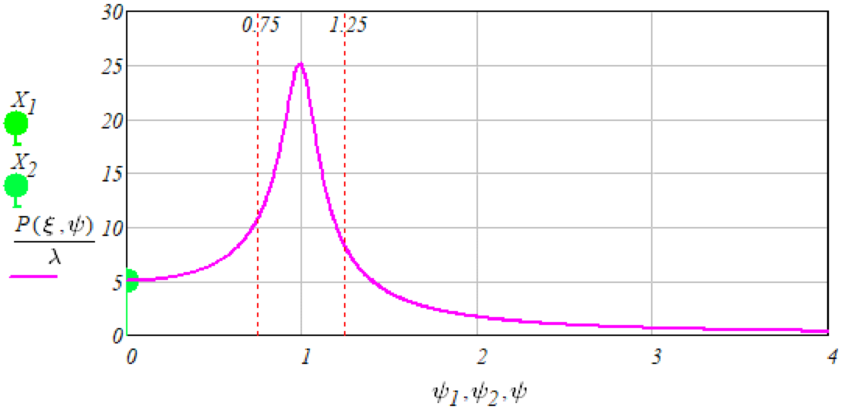


Figure 2 – Amplitude response

phase angle: $$\theta(\xi,\psi) := \left| \begin{array}{l} \theta \leftarrow -atan\left(\frac{2\cdot\xi\cdot\psi}{1-\psi^2}\right) \\ \theta \leftarrow \theta - \pi \ \ \text{if} \ \ \psi > 1 \\ \text{return} \ \ \theta \end{array} \right.$$ $$\theta(\xi,\psi) := -\theta(\xi,\psi)\cdot\frac{180}{\pi}$$

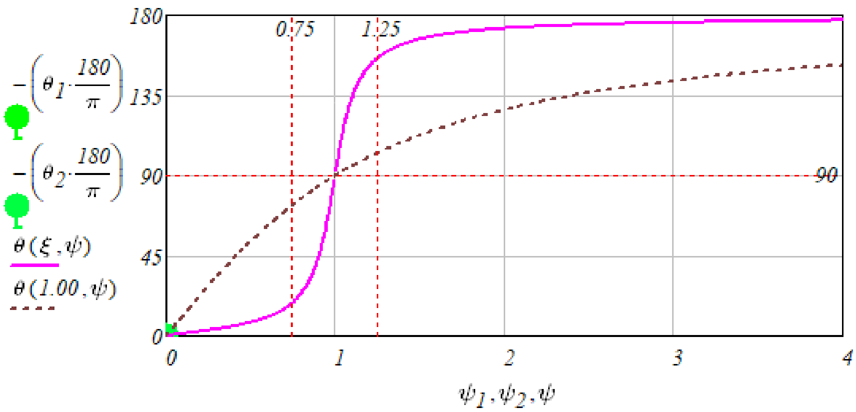


Figure 3 – The phase angles of the response

First response:

$$\psi_1 := \frac{\Omega_1}{\omega} \qquad \psi_1 = 0$$

$$P(\psi_1) = 1 \qquad \theta_1 := \theta(\psi_1)$$

$$X_1 := \frac{c}{c} \cdot A_1 \cdot P(\psi_1) \qquad X_1 = 5.0000 \qquad \theta_1 \cdot \frac{180}{\pi} = 0$$

Second response:

$$\psi_2 := \frac{\Omega_2}{\omega} \qquad \psi_2 = 0$$

$$P(\psi_2) = 1 \qquad \theta_2 := \theta(\psi_2)$$

$$X_2 := A_2 \cdot P(\psi_2) \qquad X_2 = 5.0000 \qquad \theta_2 \cdot \frac{180}{\pi} = 0$$

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

$$x_i := X_1 \cdot \cos(\Omega_1 \cdot t_i + \theta_1) + X_2 \cdot \sin(\Omega_2 \cdot t_i + \theta_2)$$

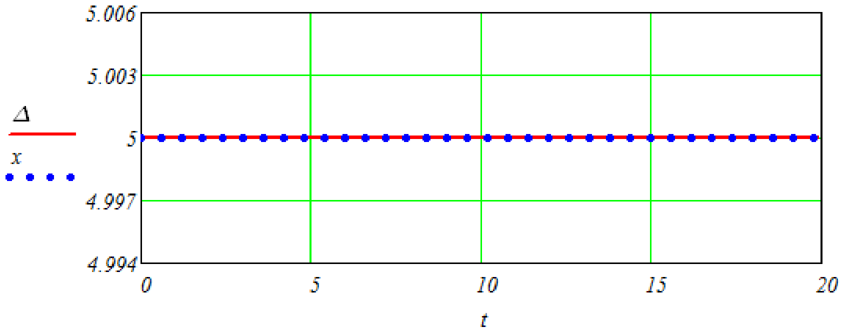
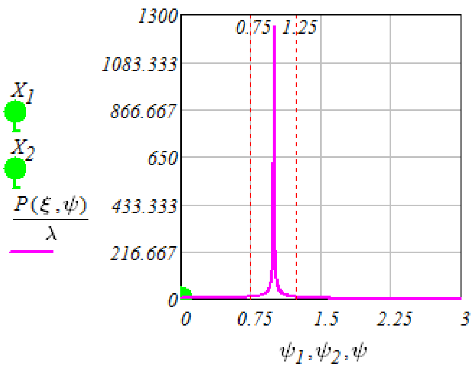


Figure 4 – Displacement 1D dynamic model for t=20s (excitation – response)

Comment: Based on one part of simulation, we are noticed movement of model with constant amplitude in time, which present statics displacement stiffness of girder.

We are monitor variety of stiffness (column 1) simulated by constant coefficient of damping (column 2). The according to equation (9) from [4], amplitudes moving respons are calculated by each excitation (column 3 and 4) and comparing relationship between normal and compulsive frequency of excitation (column 7), see Table 1, 2 and 3.

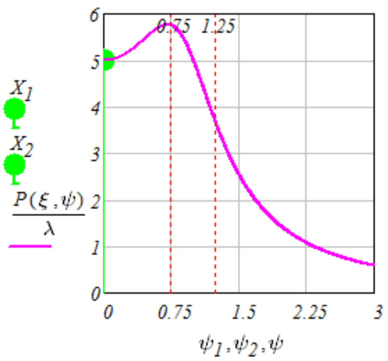
Table 1 – The first case



c (N/m)	ξ (-)	X_1 (mm)	X_2 (mm)	Ω_1 (1/s)	Ω_2 (1/s)	f/ω_d (-)
1	2	3	4	5	6	7
10^2	0.0	5.000	5.000	0	0	0.159
10^4						
10^5						
10^7						
10^8						

Comment: We noticed oscillatory movement of model with constant amplitude model response.

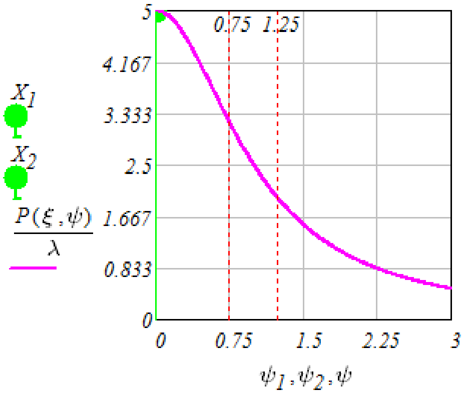
Table 2 – The second case



c (N/m)	ξ (-)	X_1 (mm)	X_2 (mm)	Ω_1 (1/s)	Ω_2 (1/s)	f/ω_d (-)
1	2	3	4	5	6	7
10^2	0.5	5.000	5.000	0	0	0.184
10^4						
10^5						
10^7						
10^8						

Comment: We noticed partially oscillatory movement with constant amplitude model response and coefficient of system damping by 50 %.

Table 3 – The third case



c (N/m)	ξ (-)	X_1 (mm)	X_2 (mm)	Ω_1 (1/s)	Ω_2 (1/s)	f/ω_d (-)
1	2	3	4	5	6	7
10^2	1.0	5.000	5.000	0	0	∞
10^4						
10^5						
10^7						
10^8						

Comment: We noticed border case, with who isn't exist oscillatory movement because of coefficient of system damping which is 100 %.

Accordingly, priority is consideration of first case in which we have oscillatory movement 1D dynamics model. We are changing coefficient damping of system at constant stiffness (Table 4) and we have values of amplitudes which corespond with transfer function "excitation – response".

Table 4 – Results of simulation for one system stiffness value

c	**ξ**	**X_1**	**X_2**	**Ω_1**	**Ω_2**	**f/ω_d**
(N/m)	(-)	(mm	(mm	(1/s)	(1/s)	(-)
10^5	0.0	5.000	5.000	0	0	0.159
	0.1					0.160
	0.2					0.162
	0.3					0.167
	0.4					0.174
	0.5					0.184
	0.6					0.199
	0.7					0.223
	0.8					0.265
	0.9					0.365
	1.0					∞

We will first calculated three amplitudes of model response with their amplitudes of external excitation at frequency of changing coefficient of damping.
Different values of coefficient of damping, amplitudes of model response are the same value. So, movement of 1D model control exclusively stiffness of girder.
We consider how values amplitude of external excitation and which equation we have to use for movement of model (9) [4] ?

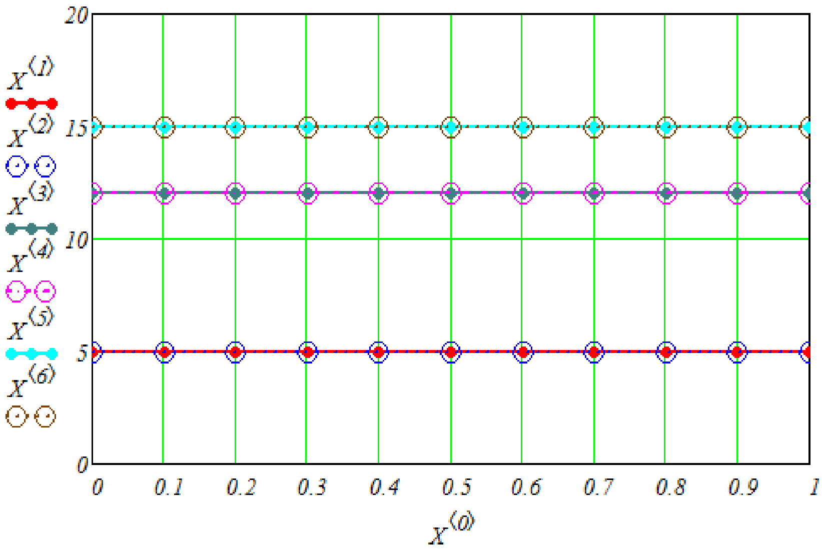


Figure 5 – Graphic representation of simulation results displacement 1D model (excitation – response)

Where:

- $X^{\langle 0 \rangle}$ - coefficient of system damping
- $X^{\langle 1 \rangle}$ – first amplitude of moving excitation
- $X^{\langle 2 \rangle}$ – first amplitude of moving response
- $X^{\langle 3 \rangle}$ – second amplitude of moving excitation
- $X^{\langle 4 \rangle}$ – second amplitude of moving response
- $X^{\langle 5 \rangle}$ – third amplitude of moving excitation
- $X^{\langle 6 \rangle}$ – third amplitude of moving reponse

Comment: Values amplitude of moving excitation in 1D dinamic model isn’t depend, because, according to transfer function, have same values amplitude of movement external excitation by response displacement for three case.

3. RECONSTRUCTION RESPONSE 1D MODELS

3.1. FFT transformation

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

Response: $I := FFT(x)$

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

First response,

$$\Delta 1_i := A_1 \cdot \cos(\Omega_1 \cdot t_i)$$

$$x1_i := X_1 \cdot \cos\left[\Omega_1 \cdot t_i + \left(\theta_1 \frac{\pi}{180} + \varphi\right)\right]$$

Second response,

$$\Delta 2_i := A_2 \cdot \sin(\Omega_2 \cdot t_i)$$

$$x2_i := X_2 \cdot \sin\left[\Omega_2 \cdot t_i + \left(\theta_2 \cdot \frac{\pi}{180} + \varphi\right)\right]$$

where:

- excitation: $\Delta_i := \Delta 1_i + \Delta 2_i$
- response: $x_i := x1_i + x2_i$

The calculation values of the phase differences of the model response are:

$$-\theta_1 \cdot \frac{180}{\pi} = 0 \qquad -\theta_2 \cdot \frac{180}{\pi} = 0$$

The calculation values of the amplitudes with the limits of the frequency of the response of the model are:

$$X_1 = 5 \qquad X_2 = 5 \qquad f_0 = 0.05 \qquad f_N = 6.4$$

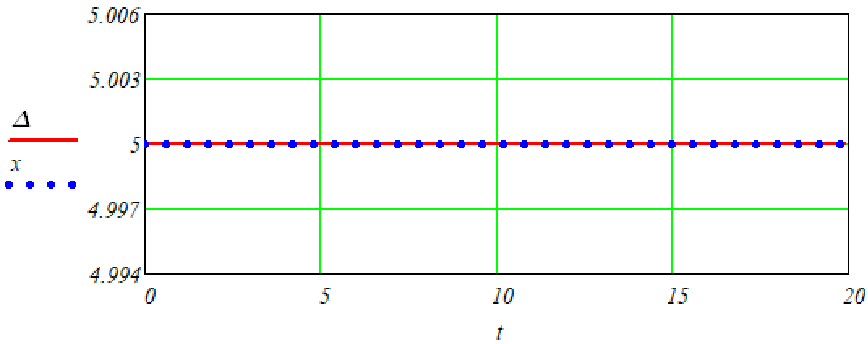


Figure 6 – Time domain – displacement 1D model (excitation-response) for t = 20s

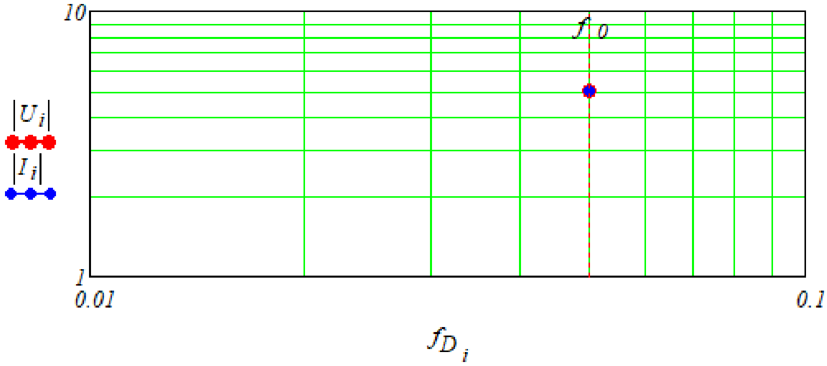


Figure 7 – The frequency domain – spectrum amplitude response for t = 20s

4. CONCLUSION

Based on this computer simulation for quaetly external dynamic load – “quasi” statics effects we have:

- for frequency of excitation $(\Omega_1=\Omega_2=0)$ movement model in time;
- statics verification values of displacement point of observed on girder;
- precision transfer function “excitation – response” using FFT and IFFT, Furie’s transformations.

Acknowledgements
The results presented in this paper are the result of work of this project No. 142-451-3768 / 2016-02 funded by the Provincial Secretariat for higher education and scientific research AP Vojvodina.

REFERENCES

[1] Miličić, M.I, Prokić, A, Lađinović, Đ.: Computer simulation of the order frequencies amplitudes excitation on response dynamic 1D models, Conference proceedings 5th international conference contemporary achievements in civil engineering 2017, DOI:10.14415/konferencijaGFS2017.032, ISBN 978-86-80297-68-2, pp. 311-320

[2] 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

[3] 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

[4] 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

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

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

РАЧУНАРСКА СИМУЛАЦИЈА 1Д МОДЕЛА ПОБУЂЕНОГ ДВО ФРЕКВЕНТНИМ ДЕЈСТВОМ СПОЉАШЊИХ ПОМЕРАЊА – ДЕО 1

Rезиме: *У овом раду симулира се стање кретања 1Д модела при ниским учестаностима померања спољашње побуде. Спољашња побуда наметнута је са две једнаке амплитуде померања ($\Omega_1=\Omega_2=0$) што представља посебност овог истраживања. Применом FFT и IFFT алгоритама трансформација третирају се амплитуде померања у фреквентном и временском домену које у коначном решењу одзива кореспондирају са функцијом преноса (И.М.Миличић, 2015). На основу спроведених симулација за могући случај „кретања“ показује да постоји померање система којег контролише крутост модела – конструкције.*

Кључне речи: *Симулација, динамички модел, FFT и IFFT алгоритам, функција преноса, померања.*