Experimental verification of the dynamic numerical model of a fire engine structural part

Vesna Milošević Mitić
Associated Professor
University of Belgrade
Faculty of Mechanical Engineering
Kraljice Marije 16

Nina Andjelić
Assistant Professor
University of Belgrade
Faculty of Mechanical Engineering
Kraljice Marije 16

An aluminium superstructure of a fire engine was created and mounted on the chassis. Some dynamic characteristics were obtained in laboratory conditions (Lab. CIAH - Faculty of Mechanical Engineering in Belgrade). An aproppriate numerical model was formed using beam and thin plate finite elements. Calculations were done using the finite element method, Program package KOMIPS, as it is presented in this paper. At first, comparative analisy of the experimental and numerical results verified the numerical model. Further dynamic analysis of the behaviour of one structural part of fire engine were done only numericaly. Stiffnesses of the supports variated and appropriate dynamic behaviour was obtained. Eigen-frequencies were calculated and presented together with the amplitudes. Forced damped vibrations in frequent domain were calculated. Dynamic method in analysing is a very reliable method if the reconstruction of a structures is needed.

Keywords: *vibrations, amplitude, verificatin, fire engine, dynamic, stiffness, eigen-frequency*

1. INTRODUCTION

Dynamic analysis presented in paper was done for an aluminium superstructure mounted on the immobile chassis of a fire engine by using finite element method [1], [2]. Numerical model was formed and verified with the experimental results obtained in laboratory conditions. The model for calculation was created using beam finite elements and thin plate finite elements. The stiffness of the supports variated from 10 dN/mm to 100 dN/mm. Eigen frequencies were obtained in all cases of the supports. For any calculated mode of oscillation, appropriate amplitude field was obtained and presented. Forced damped vibrations in frequent domain were calculated.

2. EXPERIMENTAL RESULTS

Considered aluminium structure, global dimensions 2120×1420×1010 mm was created and installed in Laboratory CIAH at Faculty of Mechanical Engineering University in Belgrade. The construction, together with the equipment for loading simulation, is presented in Figure 1.

Correspondence to: Vesna Milošević Mitić
Faculty of Mechanical Engineering,
Kraljice Marije 16, 11120 Belgrade 35, Serbia
E-mail: vmilosevic@mas.bg.ac.rs

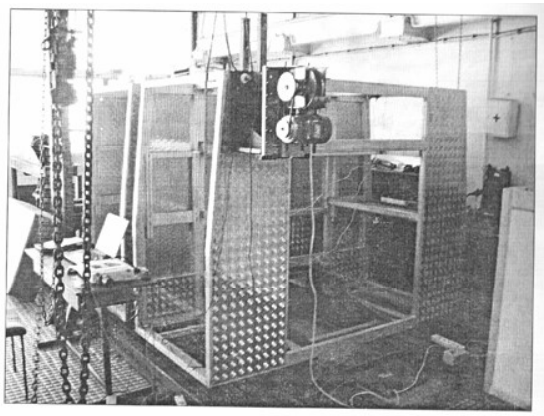

Figure 1. Aluminium structure of fire engine

The structure was hammer-pulsed and appropriate eigen-frequencies were measured. Obtained results are presented in Table 1 and on the diagram (Figure 2).

Table 1. Eigen-frequencies

Experimental model	Frequency [Hz]			
	1.	2.	3.	4.
	6.22	11.56	15.56	21.778

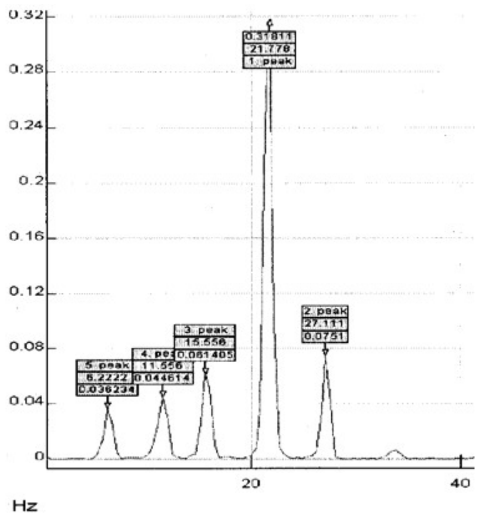

Figure 2. Eigen-frequencies of the aluminium fire engine structure

Experimental obtained amplitudes as a function of frequency are presented in Figure 2.

3. NUMERICAL ANALYSIS

3.1 Validation

Considered type of the superstructure for the fire engine was modeled with 1034 nodal points, 509 beam finite elements and 820 plate finite elements. Material of all elements was aluminum with module of elasticity of $E=10^5$ N/mm^2, Poisson's ratio of $\nu=0.3$ and density of $\rho=2.7\ 10^{-6}$ N/mm^3. Beam finite elements had four cases of cross-sections, mostly boxes dimensions 80×40×4 mm and 40×40×4 mm. The thickness of the plates was 2 mm [6].

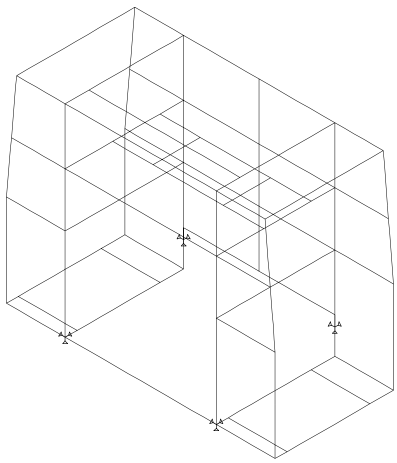

Figure 3. Beam finite elements with the supports

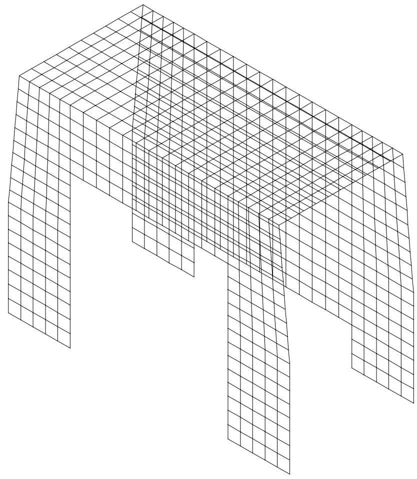

Figure 4. Plate finite elements

The model of the superstructure is presented in previous pictures. The beam finite elements with the supports are shown in the Figure 3 and the plate finite elements in the Figure 4.

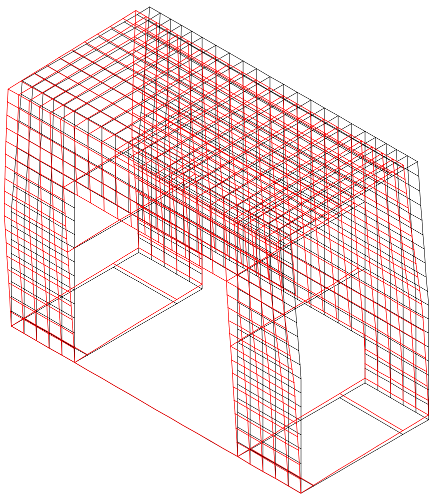

Figure 5. Amplitude field in the first mode of oscillations

Eigen-frequences depend of the stiffnesses of the supports. In presented calculation both lower supports were rigid. For the stiffness of the 40 dN/mm of the upper supports, amplitude fields were calculated and presented in Figures 5 and 6. Figure 5 represents the first and Figure 6 the second mode of oscilation.

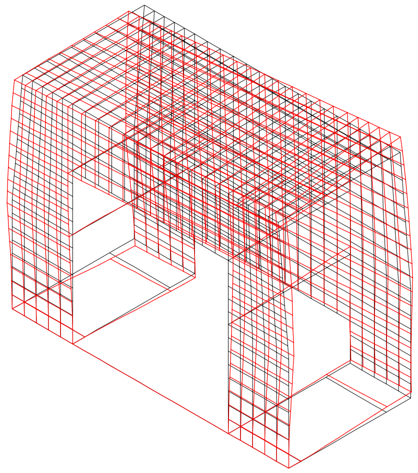

Figure 6. Amplitude field in the second mode of oscillations

Distribution of the eigen-frequencies and appropriate maximal amplitudes are presented in diagram from the Figure 7.

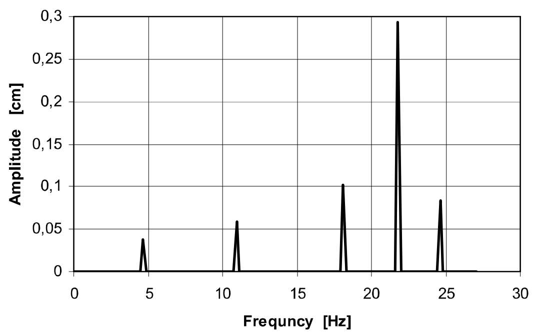

Figure 7. Numerical results

Comparasion of the experimental and numerical results from the Figures 2 and 7 gives that the shape of the diagrams as the same. Values of the amplitudes are very similar and a small difference in the frequencies are the consequence of the stiffness of the supports and the number of laid aluminium plates. So, we can conclude that the numerical model is correct for the further dynamic analysis.

3.2 Dynamic analysis of the structure

At first, eigen-frequencies for the numerical model consisted only of beam finite elements (presented in figure 3) and with the rigid supports were calculated and shown in Table 2.

Table 2. Eigen-frequencies of the beam model

	Frequency [Hz]			
Beam model	1.	2.	3.	4.
	7.15	8.67	13.96	28.38

The stiffness of the supports varied from 10 dN/mm to 100 dN/mm and calculated frequencies for the first four modes are presented in Table 3. These calculation was done for the compete model, beam and plate elements together.

Table 3. Eigen-frequencies for the complete model

Stiffness of the supports	Frequency [Hz]			
	1.	2.	3.	4.
10 daN/mm	4.16	9.39	11.71	21.58
20 daN/mm	4.34	9.90	14.33	21.62
40 daN/mm	4.64	10.92	18.09	21.78
60 daN/mm	4.76	11.81	20.33	22.27
80 daN/mm	5.19	12.64	21.01	23.01
100 daN/mm	5.10	13.35	21.19	23.39
rigid	5.70	/	21.42	23.41

As we can notice from the presented table, for the rigid supports the shape of the second mode of oscillations disappearing.

Variation of the frequencies as a function of the support stiffness is presented in diagram from Figure 8.

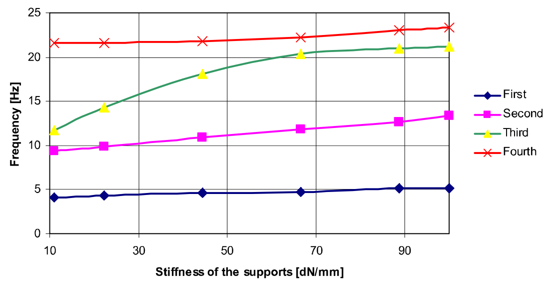

Figure 8. Frequency as a function of the support stiffness

Eigen-frequencies increase with the increasing of the stiffness of the supports.

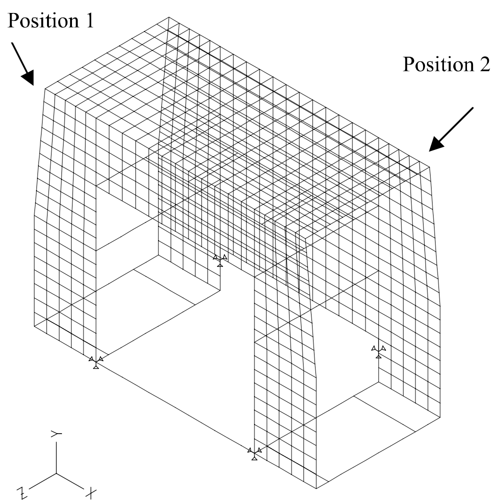

Figure 9. Numerical model with the coordinate system

Following diagram is a result of the calculation of a damped vibrations in frequent domain. Sinusoidal force was placed on position 1 and response was obtained on position 2 from the Figure 9.

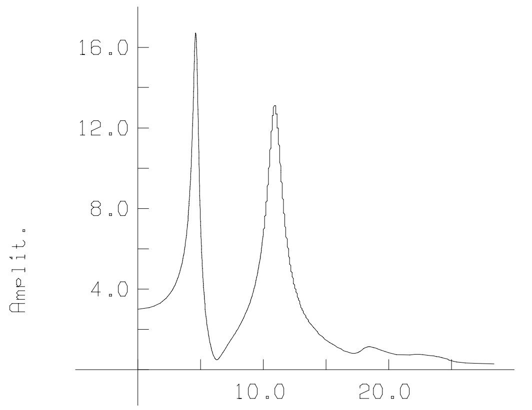

Figure 10. Vibrations in frequent domain

4. CONCLUSION

An aluminum-superstructure was formed in the Laboratory CIAH from Faculty of Mechanical Engineering in Belgrade. Structure was interconnected and mounted on the chassis of a fire engine. Some dynamic characteristics were measured throw the experiment and appropriate results were presented. At the same time, numerical model was formed and an appropriate calculation was done using the finite element method, Program package KOMIPS [3]. The model of the superstructure was done using beam finite elements and thin plate finite elements. For variations of the stiffness of the supports from 10 dN/mm to 100 dN/mm, the dynamic behavior was obtained. Eigen-frequencies were calculated and presented together with the appropriate amplitudes.

Comparasion of the experimental and numerical results verified the numerical-finite element model. As the numerical model is valid, it can be used for more complex calculations.

For this considered type of the superstructure all eigen-frequencies increase with the support stiffness. The values of the appropriate amplitudes are satisfied. But, the first and the second frequencies are too law and they are almost independent of the support stiffness. The calculation of a damped vibrations in frequent domain was done. Distribution of the difference of potential and kinetic energy can present critical places in the construction. So, dynamic behavior of this type of the superstructure is not quite satisfied and some interconnections have to be involved. Dynamic method in analysing is a very reliable method which is indicated the requirement of the reconstruction of a structures.

ACKNOWLEDGMENT

"Numeričko-eksperimentalno proaktivno projektovanje modularnih struktura nadgradnje vatrogasnih vozila", 2008 (rukovodilac projekta prof. dr T. Maneski, Mašinski fakultet Beograd). Projekat je finansiralo Ministarstvo za nauku i razvoj. TR 14023

REFERENCES

[1] T. Maneski, Program Package “KOMIPS”, Belgrade, 2009.

[2] T. Maneski, V. Milošević-Mitić, D. Ostrić, Postavke čvrstoće konstrukcija, Monografija, Belgrade, 2002.

[3] T. Maneski, Kompjutersko modeliranje I proračun struktura, Monografija, Mašinski fakultet, Belgrade, 1998.

[4] T. Maneski, D. Ignjatović, Dijagnostika čvrstoće konstrukcija, *Integritet i vek konstrukcija*, Vol. 4, No. 1, Belgrade, 2004.

[5] T. Maneski, V. Milošević Mitić, N. Andjelić, Numerical and experimental diagnostics of the behavior of the palette-pack machine, Section in Monograph Machine Design, ADECO, Faculty of Technical Sciences, Novi Sad, pp. 133-138, 2008.

[6] T. Maneski, V. Milošević Mitić, N. Andjelić, Numerical dynamic analysis of the influence of the supports and interconnections of fire engine structural parts, in: *Proceedings of the 2nd IConSSM* Palić, C22 1-7, 2009.

