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DYNAMICAL RESPONSE OF STRUCTURES TO MALICIOUS AND RANDOM ACTIONS

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Abstract

Irregular behaviour of cranes isespecially interesting in the practical world in order to protect them fromtheir collapse.The investigation was first performed experimentally and afterwards numerically.Vertical motions of the bridge cranecaused by swinging are mathematically modeled and demonstrated through numerical simulation.In this paper, some random and malicious actions on bridge cranes are shown that cause the extreme dynamical appearances and breakdowns. The theoretical-mechanical models were developed using the methods of modal dynamic structural analysis. These analyses provide answers for the actual risk frequencies of excitations that can cause serious damages to cranes.

Keywords*: Crane, vibration, misuse.*

1. INTRODUCTION

Random and malicious appearances are load sway,sudden discharge of load, load bumping into obstacle and blockade of load (jam) in manipulation.

The investigations of vibrations experimentally conducted on bridge cranes [1,3] at various work regimes, provided interesting results in terms of strain and the remaining carrying capacity of the structure. Irregular actions were particularly researched for the assessment of risk class. An understanding of risk provides an opportunity for electronic protection against adverse events.

On the basis of these experiments, the numerical models were developed in which the modal and other analyses had been performed.

The eigenfrequencies and mode shapes of the support structure were determined using modal analysis.The obtained eigenfrequency values were used subsequently in the dynamic FEM analysis of the structure at excitation of a malicious crane swinging.The analyses of risk class actions on cranes are a scientific topic of interest. They arebeing studied through research of meteorological and seismic phenomena as well as through malicious human actions [4].

2. EXPERIMENTAL RESEARCH

The testing results of a bridge crane with relatively low carrying capacity, a longer bridge span and middle structure elasticity in bending (Q=5t, L=30 m, H/L=0.03) [5] are presented in the frame of this paper. This crane structure of the mass of 17.2 t is characterized by elastic supports of medium stiffness (L/f=3000cm/7.07cm=424>250). The first excitation was accomplished with synchronous hopping of five people (the total mass of 350 kg) on the carrier. Thereby, the noticeable amplitudes of vibrations were caused only at the medium hopping effort of people. The acceleration of 16.2 m/s^{2}and the lowest (minimal) longitudinal stress of -3.65 kN/cm^2 in the middle of bridge span (on the upper box lamella) caused only by abovementioned action were measured. The longitudinalstress of 16kN/cm^2 is the allowable (limited) stress for crane structures in the first load case. Fig.1a,b shows the records of these experiments.

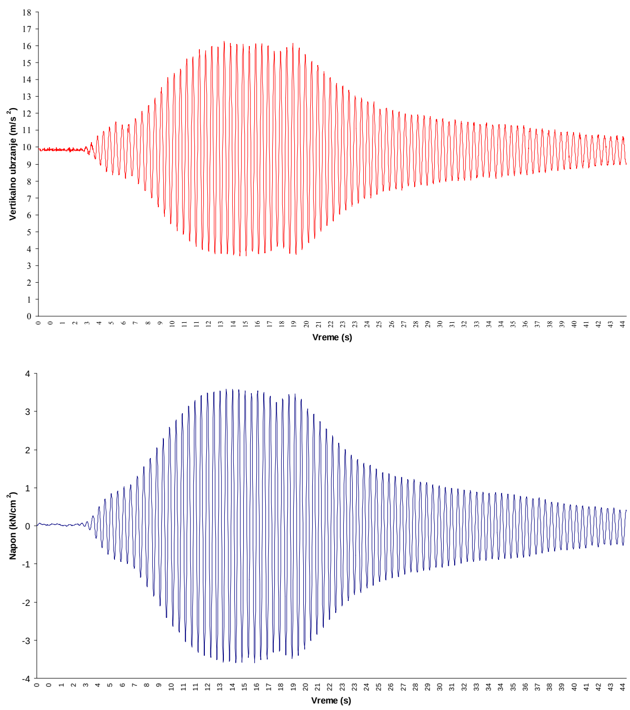

Fig. 1a,b. Acceleration diagram (a) and longitudinalstress diagram (b) for the carrier box of bridge crane MIN D800 (1977) at an intentional swinging

In the second experiment, vibrations caused by a rough hoisting of load of 4t off the ground were measured. It was done in order to compare the previously described effect of swinging with an action of regular exploitation, Fig. 2a,b.

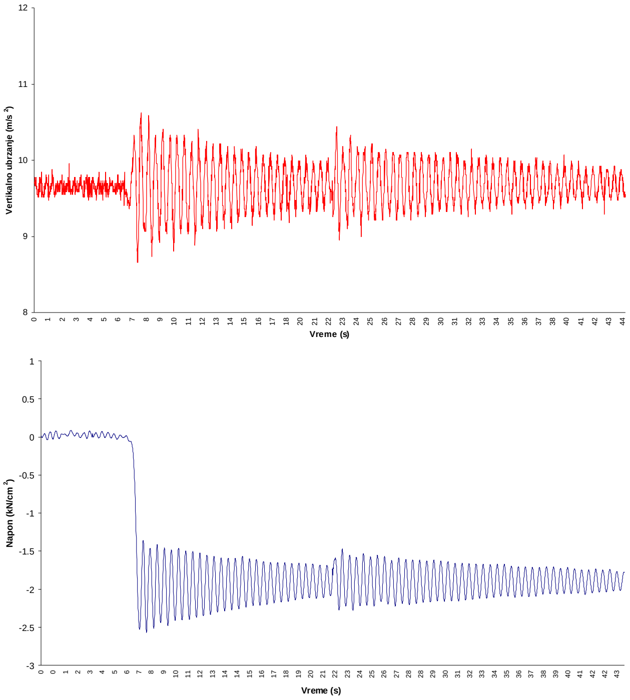

Fig. 2 a, b. Load of 4t hoisting – experimental records of accelerations (a) and longitudinal normal stresses (b) on the bridge

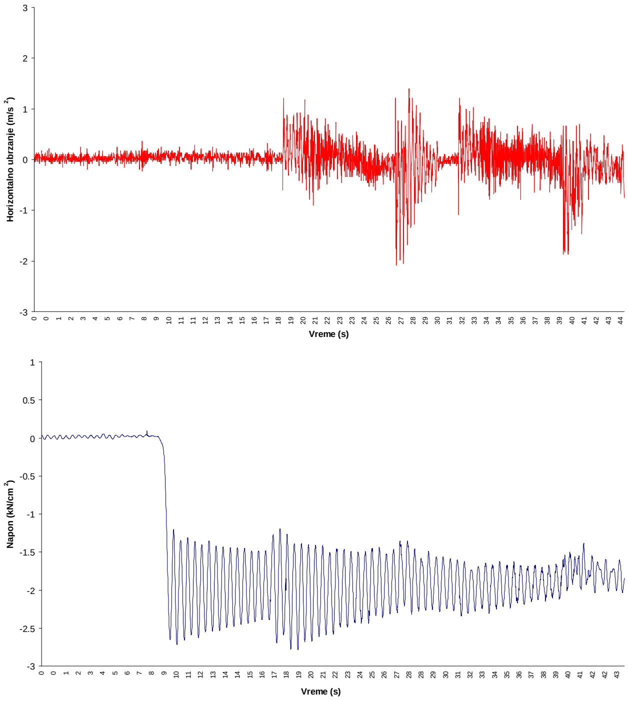

Fig. 3 a, b. Horizontal crane moving – experimental record of accelerations (a) and longitudinal normal stresses (b) on the bridge

In the second experiment, the accelerations of 10.6 m/s^2 in the middle on the bridge span and the largest stress rise of -2.65kN/cm^2 were obtained. The medium longitudinal stress was -2.0kN/cm^2 around which vibrations had occurred. The swinging period of bridge carrier was 0.525 s at 4 t of load.

The third experiment was performed by driving crane along track at velocity of 32 m/min together with the load mass of 4 t, Fig. 3a,b.During the experiment, the maximal horizontal acceleration of 2 m/s^2 was measured due to uneven resistances of movement. Thereby, the highest increase of stress of 2.8 kN/cm^2 was caused. A higher increase of the stress of driving in relation to the stress of hoisting was an unexpected increase as a result of a bad track on which the crane had been driven. The track was made at 8 m height, out of open steel girders and masts with 10 m range.

By analysing these three tests, it is easy to see that the bridge carrier swinging showed the greatest dynamic amplitude in the first test, both in terms of acceleration and stress increase.The increase of stress obtained by this random irregular action amounted 25% of the total allowable complex (comparative) stress.Increase in value of this stress would definitely damage the structure.For example, by an action of a few stronger heavy people.Wherein, these people must not be on the bridge carrier but on the ground. Such intention can be characterized as a misuse which was registered in the investigations of incidents with cranes in the world [4].Safety measures against similar actions are taken in the domain of security services.Nowadays, electronic equipment is very helpful for triggering of alarm against adverse actions.

3. NUMERICAL SIMULATION

The vibration properties check of selected structure was conducted by searching eigenfrequencies and mode shapes. These shown simulations were numerically performed using the program MSC NASTRAN 2005. The model of crane MIN D800 with 15902 elements and 89034 algebraic equations (DOF) was developed. Verification of the model was performed on the basis of comparison to stresses and deflections at operation with the load of 4 t as shown by the testing no.2, Fig. 2. A high convergence of results was obtained, for example: the longitudinal static stress numerically calculated only from load of 4 t took the value of 1.945kN/cm^2, while experimentally obtained medium stress took the value of 2.00kN/cm^2. Also, total deflection numerically calculated amounted 0.0704 m (D800.7) and the deflection only from load 0.0201 m. The deflection of 0.019 m was experimentally obtained from load of 4 t (D800.4).Such experimentally verified model served further for modelling of dynamic simulations. The dynamic simulation is related only to the modal frequency analysis in this paper.

The frequency polynomial solvingwas done using the Lanczos method for the first 50 frequencies. The frequencies at which were performed the forced malicious vibratory movements had been separated by using the mode shapes.These frequencies are the base for transient analysis in which the velocities of active damping are required.Certain limited frequencies of vibrating motion took values between 0.658 Hz and 4.148 Hz.Figures 4 and 5 show the eigenvalues (mode shapes) of vibrations for two selected frequencies. The extraction of the abovementioned frequencies was performed by observing the appearance of the first mode shape at the maximal amplitude (eigenvalue) in the middle of girder span. Table 1 provides an insight into the dynamic parameters from the numericalsimulation.

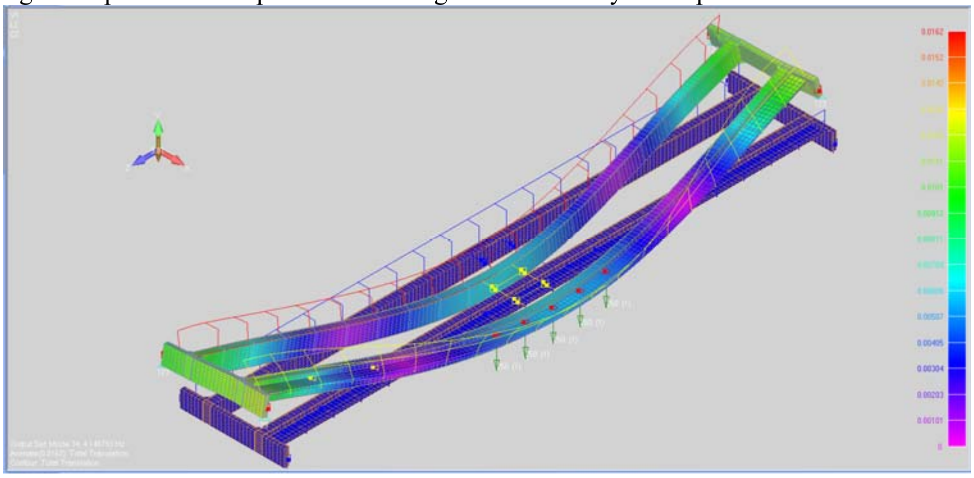

Fig.4. Mode-34 (4.148 Hz),crane D 800-9,vibration with hook load of 4 t, rigid pathway support

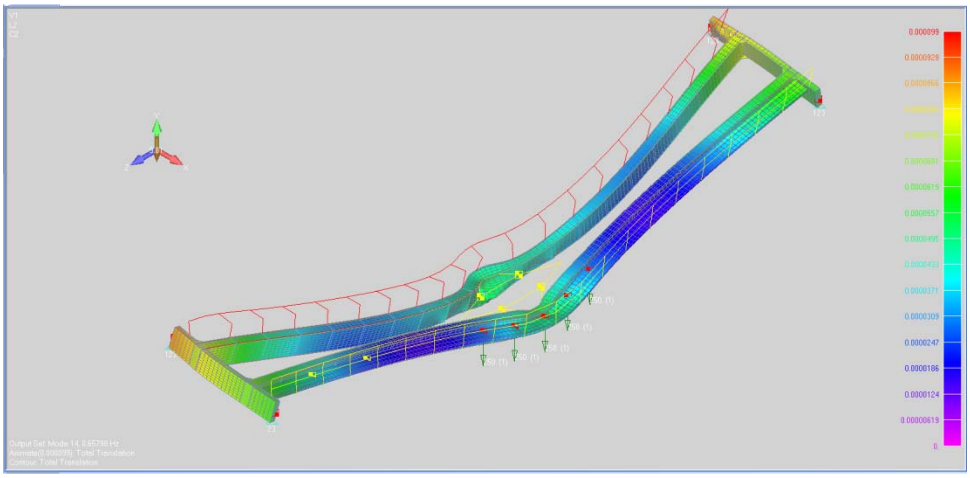

Fig.5. Mode-14 (0.658 Hz),crane D 800-9,vibration with hook load of 4 t, rigid pathway support

Table 1

	Eigenfrequencies of the crane structure D800.9 (Hz)				
Category of frequency	The lowest determined eigenfrequency f_1	The measured eigenfrequency f_{11}	The first significant eigenfrequency f_{14}	The second significant eigenfrequency f_{34}	The highest determined eigenfrequency f_{50}
Value (Hz)	3.051 E-6	0.460	0.658	4.148	10.874

CONCLUSION

1. A malicious action, according to the conducted analysis, can causehigher stress states than the regular actions. This fact raises the question of protection of all significant structures.
2. In terms of protection, technologies for remote control of cranes without access of man on the crane should be developed.
3. It should be expected that the development of system to detect high stresses in structures becomes justified and supported by development of universal electronic safety controllers.
4. The use of electronic safety controllers would protect expensive facilities against the working exceeding of limit states.
5. The limit parameters for adjustment of each structure with built-in protection can be identified by transient and modal analysis.
6. The controller could serve for determining the state of fatigue or amortization by registering all significant events in the exploitation of structure.
7. The proposed controller can be a commercial device, independent of the type of structure which is controlled. For proper installation of the controller, it is necessary to perform numerical analysis (simulation) for characteristic (dangerous) situations.
8. This controller is a type of black box and the data source for the judiciary in case of malicious events. By its presence on the structure, in the same time, the

controller is a mean of asset and people protection against adverse effects. Therefore, this device must be an autonomous and protected from the adverse effects.

9. By this analysis (simulation) based on the FEM technology, the procedure of basic conceptual model for protection of one type of structure (crane) is shown.

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