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ANALYSIS OF OVERHEAD TRAVELLING CRANE'S MOTION IN HORIZONTAL PLANE

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Abstract: Nonstationary translatory motion of an overhead travelling crane is analysed in the paper. The crane consists of two main girders with box shaped profiles and has carrying capacity of 32 tons. Original dynamic model of carrying structure is formed by the use of the finite element method. Modelling of the carrying structure is performed with the shell and beam finite elements. All significant dynamic parameters are considered, dynamic loads are defined and dynamic equations of motion are formed and solved. Diagrams of carrying structure bevelling and of side forces depending on the position of the trolley on the main girders are presented as the results of the analysis. Variations of mentioned dynamic parameters in time are considered in the period of acceleration, as well as in the period of breaking of the crane.
Keywords: overhead travelling crane, Finite element method, translatory motion

1. INTRODUCTION

Overhead travelling crane is a machine for lifting and moving loads. It consists of a crane bridge travelling on wheels along runway rails, a trolley, which travels across the bridge and a hoist for lifting the loads. The trolley hoists or lowers the loads and carries them on the bridge structure. The bridges carry the loads on a rail. As a result, overhead crane performs three perpendicular movements.

Proper functioning of overhead crane depends on proper crane runway girder design and detailing. The runway girders should be viewed as a part of a system comprised of the crane rails, rail attachments and electrification support. Each runway is designed to support a specific crane or group of cranes. The weight of the crane and trolley and the wheel spacing for the specific crane should be obtained from the crane manufacturer [1].

In exploitation of overhead crane during its translatory motion, the basic problem is its bevelling – difference between the distances travelled by the left and the right side of the crane. This problem is especially pronounced in non-stationary regimes of motion or in periods of acceleration and braking of the crane. Appearance of crane bevelling introduces significant lateral loads at the contact area between the wheel rim and rail head. In severe cases, there may be some undesired effects like: crane jam, emergency drive failure, unpermitted deformations of elements and, even, fractures of individual assemblies [2].

Lateral crane loads are perpendicular to the crane runway and are caused by:

» acceleration and deceleration of the trolley and loads,
» non-vertical lifting,
» unbalanced drive mechanism,
» irregular travel of the carrying structure.

The maximum dynamic lateral loads depend on many factors – the height of the load, the position of the loaded trolley relative to the bridge, the gaps between the trolley wheels and rails.

To improve the efficiency of cranes, it is necessary to control the crane in order to minimize the swing angle, the transferring time of heavy loads and crane bevelling.

In this paper, non-stationary translatory motion of overhead travelling crane's carrying structure is analysed. As a result, it is possible to determine time variations of individual dynamic values like: bevelling travel, deformations of the main girders, stress states and lateral loads, which are the most important dynamic indicators of crane behaviour during translatory motion.

2. FINITE ELEMENT MODEL OF OVERHEAD TRAVELLING CRANE'S CARRYING STRUCTURE

In order to analyse dynamic behaviour of the crane's carrying structure, a geometrical model of the crane based on real construction (span of 22,5 m, load capacity of 32 t) is formed using the "FEMAP" software package. The model of overhead travelling crane's carrying structure consists of four-node shell elements. The total number of elements is 1952 and the number of nodes is 1610.

In Figure 1, the geometrical model of the crane is shown. The model enables the simple way of taking into account the current position of the loaded trolley at the bridge. It is also possible to analyse the influence of the trolley's speed on dynamic behaviour of the whole system. The static and dynamic analyses were conducted using the "PAK" software package [3, 4].

In formulation of the mathematical model, only the first and the second vibration modes of the main girder were considered, because the amplitudes of higher modes are less noticeable. Dynamic equations of motion are also based on the following assumptions [5]:

- The overhead travelling crane is represented by a beam with a constant cross-section;
- Load transfer between the trolley and the bridge is achieved with concentrated forces;
- Wheeled trolley is considered as a rigid body;
- The rope has linear elastic characteristic during loading, determined by static measurements;
- The vibration damping of the main girder is viscous and linear;
- The main girders have box-shaped cross-sections, while the control is carried out from the bridge cabin or from the ground.

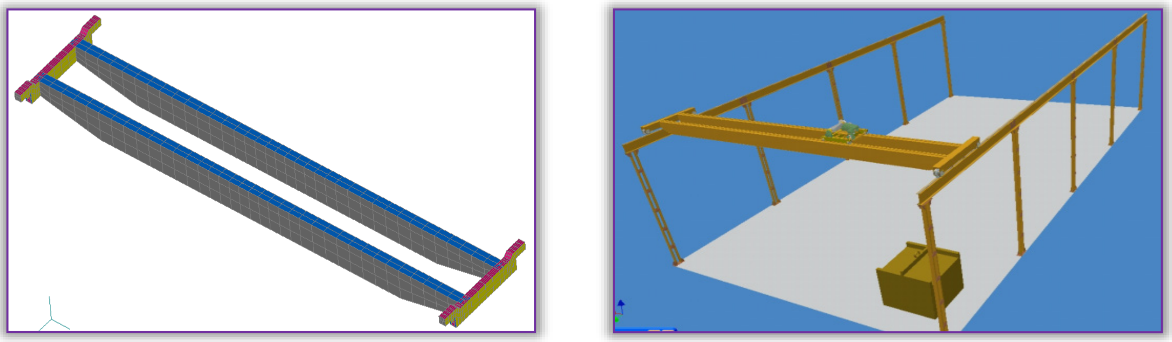
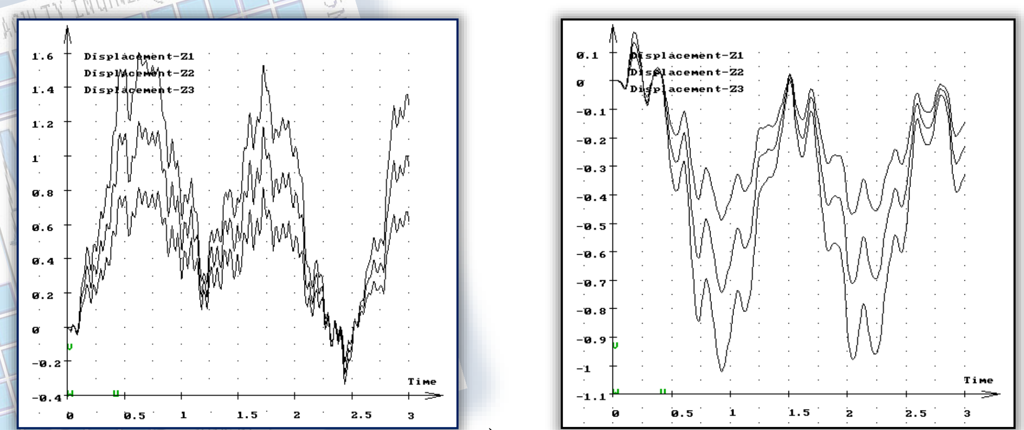


Figure 1. The geometrical model of the crane's carrying structure [6]

3. REVIEW AND ANALYSIS OF THE RESULTS

Three possible positions of the trolley with a hanging load were analyzed, whereby the distance between the trolley and the left frontal girder was defined by coordinate, x_k (2.5 m, 4.2 m and 5.6 m). Corresponding values of resistive forces, drive forces and brake forces were calculated for the mentioned positions of the trolley.



a) b)

Figure 2. Bevelling in the period of: (a) acceleration and (b) braking

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At the beginning of the crane's motion i.e. at the beginning of period of acceleration, the crane stands still and the load is lifted from the ground. At the beginning of period of braking, it is

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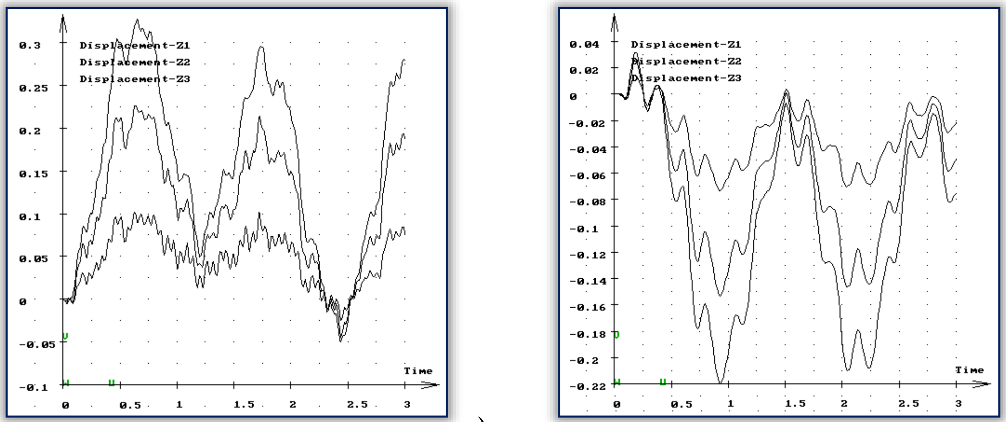
assumed that the overhead crane conducts stationary motion with its nominal travelling speed, v_m.

Figure 2 shows dependence between time variations of the bevelling paths of the crane wheels and the position of the trolley. Figure 2a) refers to crane's period of acceleration and Figure 2b) refers to the period of braking. In given cases, the crane's drive mechanism and hoisting mechanism are active. The load is already lifted off the ground and hangs on the ropes, while crane's motion occurs (acceleration or braking of the crane's carrying structure). It may be seen that the bevelling path is the greatest when the trolley is in its ultimate (left) position.

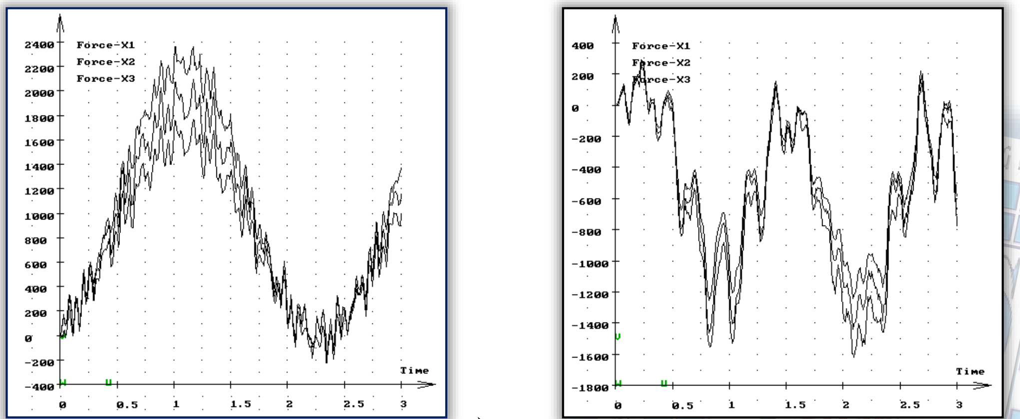


a) b)

Figure 3. Relative displacements of the nodes at the centre of the girder:
(a) during acceleration, (b) during braking

Values of relative displacements of the central nodes of the girders in the period of acceleration and braking are shown in Figures 3a) and 3b). During dynamic analysis of the braking period, the most unfavourable case was assumed – the crane was not bevelled at the beginning of the braking period and it travels with the greatest possible speed. Real time of braking in exploitation of the crane is certainly smaller, considering the appearance of real bevelling. Variations of the observed dynamic values are followed until the period of 3 s has passed, because it is considered that during this period, the highest peaks of dynamic values occur, as well as that the influence of damping is not sufficiently intensive.

Figure 4 shows variations of horizontal lateral reactions (side forces) at the contact area between the wheel rim and rail. Time variations are given depending on the trolley's position, during acceleration, Figure 4a) and during braking, Figure 4b). It may be seen that lateral forces are bigger when the trolley is at its ultimate left position than when the trolley is more distant from that position.



a) b)

Figure 4. Lateral forces at the wheel – rail contact: a) during acceleration, b) during braking

Comparison between bevelling paths during acceleration and braking is presented in Figure 5 for the first position of the trolley which is the most critical.

The results show that the dynamic values are greater during acceleration than during braking, including the bevelling path and values of lateral forces. In any case, in order to determine dynamic values in periods of nonstationary motion, braking process must be studied besides acceleration.

In all positions of the trolley, the maximal bevelling path is greater in period of acceleration then in period of braking. The greatest bevelling path during both nonstationary motions occurs when the trolley with the load is at ultimate left position. By removing the trolley away from the frontal girders, the bevelling path decreases, so in the observed third position, it has the smallest value. Values of lateral forces decrease with removing the trolley away of the frontal girders.

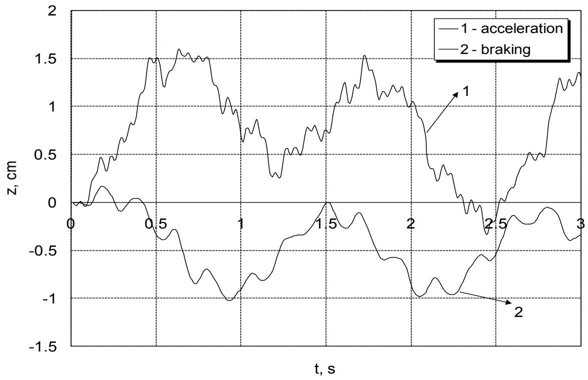


Figure 5. Comparison between bevelling paths during acceleration and braking

4. CONCLUSION

The formed geometrical model enables the analysis of time variations of selected quantities, both during operations of the hoisting mechanism and during horizontal motion of the crane. By taking into account the variation of the drive force, and by variation of the input parameters (stiffness, speed, damping), a quick insight on the influence of individual quantities on dynamic behaviour of the crane is possible. It is also possible to analyse the appearance of the carrying construction's material fatigue at the points with significant stress concentration. Stochastic character of dynamic effects during overhead travelling crane's operation can also be taken into consideration by the use of available software.

With the application of ready-to-use modules of "PAK" software and some minor model modifications, it would be possible to compare the dynamic behaviour of similar crane types. It is possible to analyse other cases, not mentioned here, like: simultaneous motion of the hoisting mechanism and one of the drive mechanisms (of the trolley or of the bridge), variation of trolley's position at the bridge, etc.

Analysis of the overhead travelling crane's motion in horizontal plane has shown that the bevelling path of the crane carrying structure is the greatest when the crane trolley is in its ultimate (left) position. It is also noticed that lateral forces are the highest when the trolley is at its ultimate left position and that they decrease with removing the trolley away of the frontal girders. In all positions of the trolley, the maximal bevelling path is greater in period of acceleration then in period of braking.

Note: This paper is based on the paper presented at The 12th International Conference on Accomplishments in Electrical and Mechanical Engineering and Information Technology – DEMI 2015, organized by the University of Banja Luka, Faculty of Mechanical Engineering and Faculty of Electrical Engineering, in Banja Luka, BOSNIA & HERZEGOVINA (29th – 30th of May, 2015), referred here as[7].

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