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Dynamical Model for Calculation Transverse Forces between Overhead Bridge Crane and Crane Runway

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Abstract. Horizontal forces between the crane and the crane runway girder occur during a motion of an overhead travelling crane on the crane runway. There are several methods for calculation of these forces. The most significant load caused by motion of crane is the skewing and the acceleration of the crane and of the crab. This paper deals with the acceleration of the crane and with the skewing of the crane. In present the skewing of crane is defined as the motion of the overhead bridge crane with the constant velocity but with the angle relative to the crane runway. The transverse forces caused by acceleration of the crane are calculated separately. But the skewing of the crane can occur also during the accelerating of the crane. Present standards don't take this situation into account. A dynamical model presented in this paper describes motion of the overhead double bridge crane during its acceleration. The basic assumption of this model is that there the contact between the rim of the firs crane wheel and the rail of the crane runway.

1. Introduction

The transverse horizontal forces between the overhead bridge crane and the rail of crane runway girder occur during a motion of the crane. These forces are caused by various causes. They can be caused by accelerating or decelerating of crane, acceleration or deceleration of crab and the by the skewing of the crane which results into significant transverse forces between the crane wheel and the rail of the crane runway. There are some procedures and computational models which enable to calculate these horizontal transverse forces. Some of them were presented and compared in [1]. The comparison of different models shows the big differences between models and results. These big differences are caused by different interpretations of what is skewing of crane. N. A. Lobov [2-4] created dynamical model describing motion of the overhead bridge crane. This model enables to determinate the horizontal transverse forces. The model considers the crane as the rigid body with the load of crab rigidly connected to the crane. It means the swinging of the load on the crab rope was neglected.

The dynamical model created and presented in [5] considers some factors that Lobov's model did not consider. This includes the deformation of crane bridges (so-called S-deformation), the swinging of the crab load in the direction of the crane and the inclusion of crane drive control. Model is designed for a double bridge crane. The model is made up of rigid bodies that are connected to each other by equivalent springs, which represent the system's deformations. The motion equations of the model are assembled using Lagrange equations II. kinds. The basic assumption of this model is that there is no contact between the rim of the crane wheel and the rail of the crane runway.

2. Dynamical Model of the overhead double bridge crane

The dynamical model presented in this paper is based on the model presented in [5]. The dynamical model in this paper assumes the contact between the rim of the crane wheel and the rail of the crane runway. The factors like deformation of crane bridges (so-called S-deformation), the swinging of the crab load in the direction of the crane and the inclusion of crane drive control are still taken into account.

Figure 1shows the created dynamical model which takes the contact between the rim of the crane wheel and the rail of the crane runway.

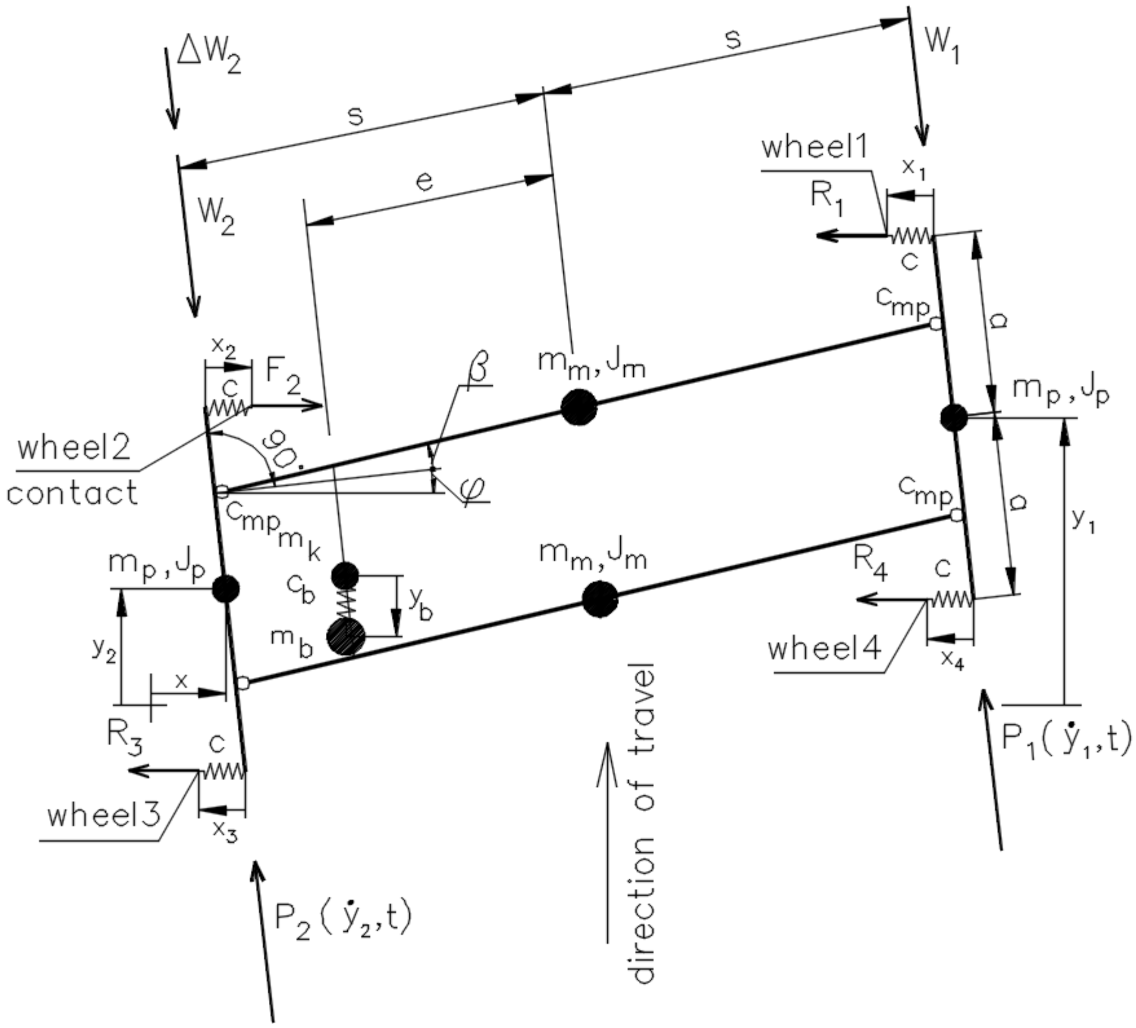

Figure 1. Dynamical model of the overhead bridge crane with contact of the wheel rim.

The symbols used in Figure 1 are explained in [5]. But compared to the model without the contact of the wheel rim and with the contact presented on Figure 1in this paper, some new symbols appeared and some symbols are different.

The situation for wheel 2 has changed, where force F_2 acts instead of force R_2. In this case, the force F_2 is the force that loads the crane runway girder and the crane structure. The situation of the forces acting on the wheel at location 2 is illustrated on the Figure 2.

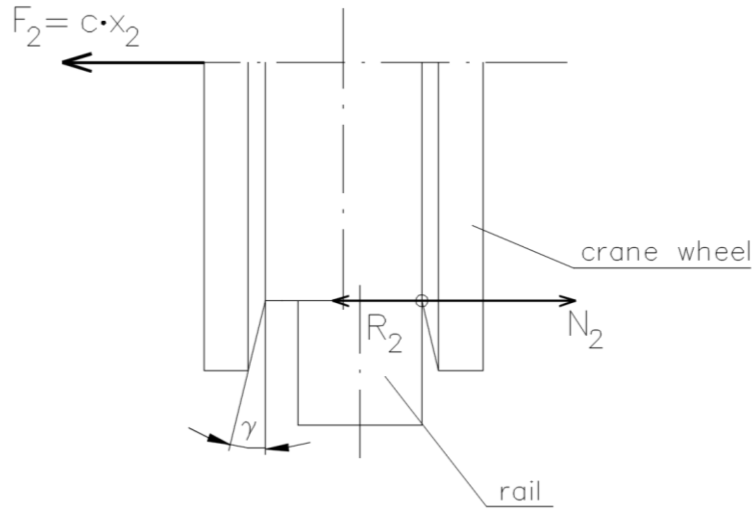

Figure 2. Forces acting on the crane wheel 2.

Legend to Figure 2:

- N_2	the contact force between the guide means (the rims or the guide rollers) and the rail side. This contact force is important in terms of wear of the rims of the wheels or of dimensioning of the guide rollers
- R_2	slip force between wheel and rail
- F_2	the force acting by the crane on the wheel

It's a fact, that:

$$N_2 = R_2 + F_2 \tag{1}$$

As a result, the loading of the guide means is higher than the loading of the crane rail and the crane structure when the crane is inclined on the crane runway.

The force ΔW_2 occurs in this computational model compared to the model without the contact of the rim. This force is caused by the friction of the guide means along the side of the track. In the case where the guiding means are realized like rims, the force ΔW_2 shall be determined from the following formula which is given in [2]:

$$\Delta W_2 = N_2 \cdot \frac{f \cdot |\varphi + \beta_2|}{tg\gamma} \tag{2}$$

where:

- N_2	the contact force between the wheel rim and the rail side
- R_2	coefficient of friction between the wheel rim and the rail side
- φ	crane rotation according to calculation model

- β_2 — the angle between the wheel in the end carriage measured between the end carriage and the crane wheel
- γ — angle of deflection of the trims from the rail side

In [6] there is presented another formula that can be used to calculate the friction force ΔW_2 in case the guiding elements are the rims:

$$\Delta W_2 = N_2 \cdot f \cdot \frac{\frac{z^2}{R_k^{\,2}} + (\varphi + \beta_2)^2 \cdot (\tan(\frac{\pi}{2} - \gamma))^2}{\sqrt{\frac{z^2}{R_k^{\,2}} \cdot (\sin(\frac{\pi}{2} - \gamma))^2 + (\varphi + \beta_2)^2 \cdot (\tan(\frac{\pi}{2} - \gamma))^2}} \qquad (3)$$

The meaning of the symbols in formula (3) is the same like in formula (2). But in formula (3) two more symbols occurred:

- R_k — radius of crane wheel
- z — depth of contact of the rim on the side of the rail – see Figure 3

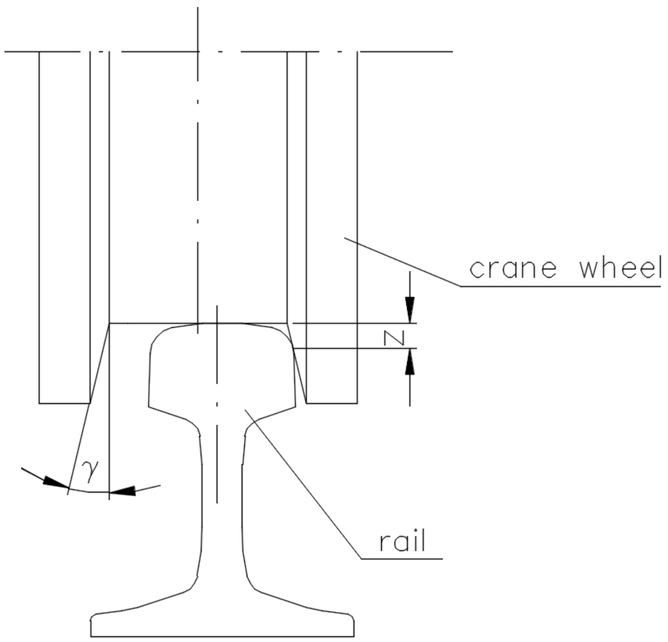

Figure 3. Depth of contact of the rim on the side of the rail.

Comparison of formulas (2) and (3) was made. The result is shown in the graph in Figure 4 (input values: $f = 0.3$, $\gamma = 0.175\ rad$, $R_k = 0.185\ m$, $N_2 = 1\ N$, the value $(\varphi + \beta 2)$ is like whole variable). If $z = 0$ is entered in formula (3) (which would be true, for example, for a rail made of a square cross section without chamfering), relation (3) coincides with relation (2). The relationship (3) is used in the model.

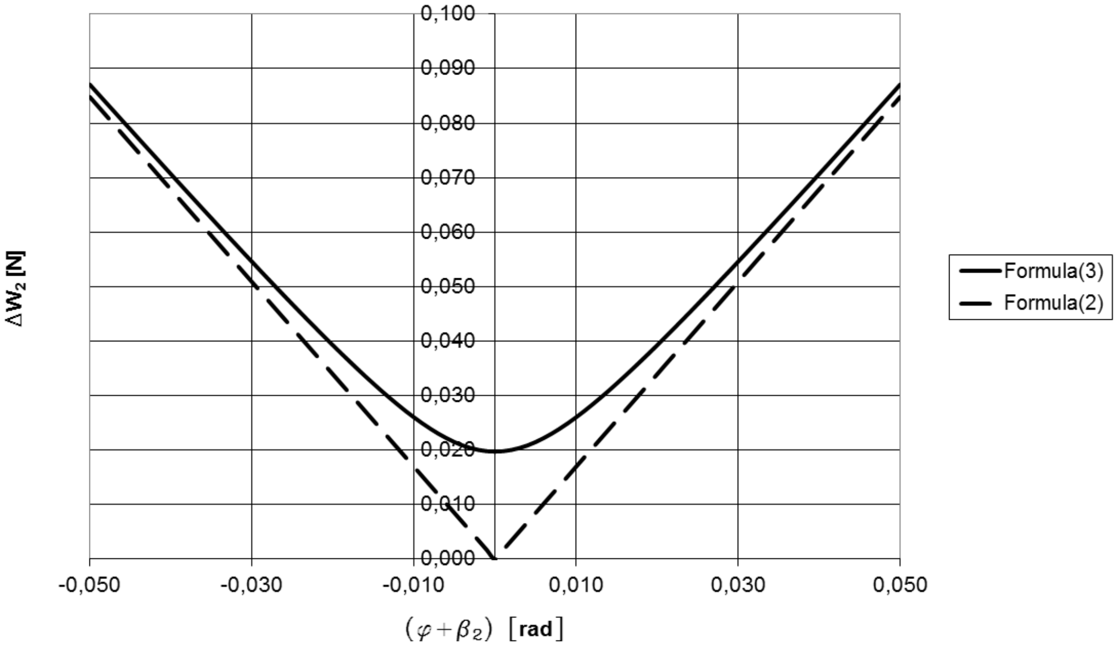

Figure 4. Comparison of formulas (2) and (3).

3. Motion equations of the dynamical model

The creation of motion equations is explained in [5]. The motion equations form model presented in this paper are the same like for the model presented in [5] but due to the contact of the rim at the wheel 2, the model lost one degree of freedom. The model now has 8 degrees of freedom. The variable *x2* is no longer unknown and can be expressed using the following condition:

$$x_2 = a \cdot \varphi - x - \delta \tag{4}$$

Where:

- δ is the half clearance between the rim and rails
- a, φ, x variables according to Figure 1

The formulas (3) and (4) complete the system of motions equations for dynamical model with the contact between the rim of the crane wheel and the rail of the crane runway.

4. Results and discussions

The dynamical model presented here is the extension of the dynamical model created by the author in [5]. The model presented in this paper assumed the contact between the rim of the crane wheel and the rail of the crane runway. The combination of these two models with the contact of the rim and without the contact of the rim enables to simulate the behavior of the crane moving on the crane runway. These two models enable to investigate not only the movement of the crane in general, but also the magnitude of the transverse forces acting between the wheels and the rail of the crane runway.

5. Conclusions

The extension of dynamical model created by author describing the motion of the overhead bridge crane on the crane runway was created. The construction of the extended model was explained and the extension of motion equations was shown. The main meaning of model extension is in considering contact between the the rim of the crane wheel and the rail of the crane runway.

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