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Stability analysis of mobile crane during load sway induced by wind

DAWID CEKUS[1], PAWEŁ KWIATOŃ[2*]

1. Department of Mechanics and Machine Design Fundamentals, Czestochowa University of Technology, 42-201 Czestochowa, Poland, cekus@imipkm.pcz.pl [0000-0002-5551-1153]
2. Department of Mechanics and Machine Design Fundamentals, Czestochowa University of Technology, 42-201 Czestochowa, Poland, kwiaton@imipkm.pcz.pl [0000-0002-0067-0384]

* Presenting Author

Abstract: The paper presents an analysis of the stability of a mobile crane during the process of transporting a load affected by wind force. The load was treated as a rigid body suspended on a deformable rope. The obtained results of numerical simulations were compared with the case where the load is modelled as a material point and the case where the rope system was rigid. The surface area of a rigid body loaded by the wind was assumed to be variable. The analysis was carried out for several cases differing in the operation time of the control functions, as well as a wind direction and its speed. The initial problem of motion was calculated using the Runge-Kutta fourth-order method.

Keywords: crane stability, dynamics, load sway

1. Introduction

The process of load transporting using mobile cranes should take place with appropriate safety conditions for people and other devices. Due to the high centre of mass, small spacing of support system, or the effect of wind pressure, mobile cranes are exposed to the risk of stability loss [1]. The stability parameter is closely related to the definitions such as overturning contour (or edge), stabilizing torque (M_u) and overturning torque (M_w) [2]. The crane remains in permanent equilibrium (is stable), when at each stage of the duty cycle, the value of stabilizing torque is greater than the value of the overturning torque [1]:

$$M_U > M_W \,. \tag{1}$$

In this work, the stability analysis of the Liebherr LTM 1030-2.1 mobile crane was carried out, taking into account the wind pressure and deformability of the rope system. The proposed model allows to determine the influence of external forces on the crane's stability. In order to determine the stability of the crane during its working cycle, it was necessary to determine the centre of mass of the entire system and the overturning contour of the machine.

The position of the centre of mass of the system in the global coordinate system can be written in the form:

$$\mathbf{s_C} = \frac{1}{M}\sum_{i=1}^{n} m_i \mathbf{s_i} \,, \tag{2}$$

where: the total mass of the system M is a sum of individual masses m_i of the crane's components and $\mathbf{s_i}$ is their centre of mass.

The motion of the load modelled as a rigid body can be presented as a combination of the translational motion of the load mass centre and a spherical motion around its centre of mass [3]. Taking into consideration the deformability of the rope system, the spherical motion of the load and the interaction of external forces in the model, a system of seven second-order differential equations can be obtained, which is presented in the form [4,5]:

$$\mathbf{\Lambda}\ddot{\mathbf{\Omega}} = \mathbf{E}\,, \tag{3}$$

where coefficients of matrix $\mathbf{\Lambda}$ and vector $\mathbf{E}$ depend only on generalized coordinates and derivatives of a vector of unknowns accelerations $\ddot{\mathbf{\Omega}}$.

Possess information about the position of the mass centre of load and all crane components, it is possible to determine the stability of the mobile crane.

2. Results and Discussion

During the simulation test, it was assumed that the crane's outrigger system is fully unfolded. In this case, the overturning contour is 6.305 x 6.000 meters. Various cases of numerical calculations were analysed differing in control functions time or wind velocity. The exemplary results of the numerical simulations as the trajectory of the centre of mass and the marked stages of loss of crane stability are shown in Figure 1.

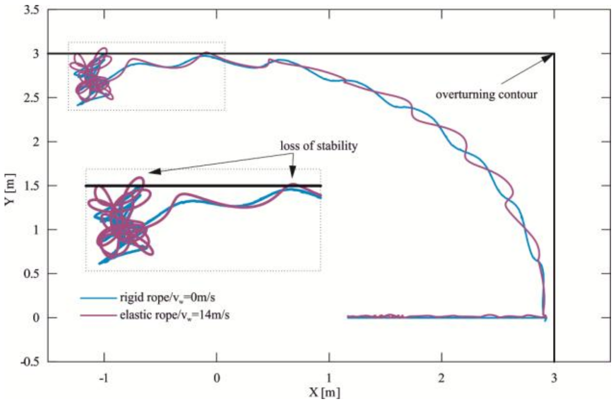

Fig. 1. Centre of the mass trajectory of the analysed system

The presented results showed the need to take into account in the theoretical model all the important parameters (interaction of external forces, spherical motion of the body) for the analysed system of crane operation.

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