Influence of the rope sling system on dynamics of a carried load

Andrzej Urbaś, Krzysztof Augustynek and Jacek Stadnicki
*Department of Mechanical Engineering Fundamentals, University of Bielsko-Biala, Bielsko-Biala, Poland

Abstract. The dynamics analysis of the mobile crane carrying a load hung on different rope sling systems is presented in the paper. The considered mobile crane is modelled in the form of a tree structure of a main kinematic chain with auxiliary subchains. The carried load is modelled in two variants as a cylinder hung on one, three and four ropes sling system, and as a box is hung on one, two and four ropes sling system. Numerical results of the crane cycle input movement simulations for these models are compared with the simulation results of the model in which the load is modelled as a lumped mass hanged on a single rope.

Introduction

In most publications referring to dynamics of cranes, a load is treated as a lumped mass hung on a single rope. This simplification causes inaccuracy in determining the trajectory and energy of the load after finishing a cycle of crane input movement, which are important due to the precision of load positioning [1-4].

The model of the crane used in the dynamics analysis is presented in Fig. 1. The proposed model consists of: crane suspension subsystem b, supporting structure c_m (i.e. rotary column, two boom sections and telescopic boom section) and two load lifting subsystems $c_{a,\alpha}\big|_{\alpha\in\{1,2\}}$ (i.e. hydraulic cylinders). The carried load is modelled as cylinder l_c and box l_b, which can be hung on $r_\alpha\big|_{\alpha\in\{1,2,3,4\}}$ rope sling systems.

The crane input movement cycle is divided into five phases, i.e. load lowering ($\mathbf{f}^{(d_3)}$), crane rotation ($\mathbf{t}^{(d_1)}$), load telescoping ($\mathbf{f}^{(d_4)}$), load lifting ($\mathbf{f}^{(d_2)}$) and load swinging.

The dynamics equations are formulated using the joint coordinates, homogeneous transformation matrices and the Lagrange equations of the second order.

The proper simulations have been carried out and the results have been compared with the results obtained for lumped mass l_m on the graph of the kinetic energy integral mean value (Figs 2 and 3).

The contribution of this work is to point out that the application of a mathematical model of a crane with a load in the form of a lumped mass may not reflect the real dynamics of a crane.

It is worth adding that the value of the kinetic energy of the load after input movement cycle finishing is often assumed as a criterion in optimisation tasks.

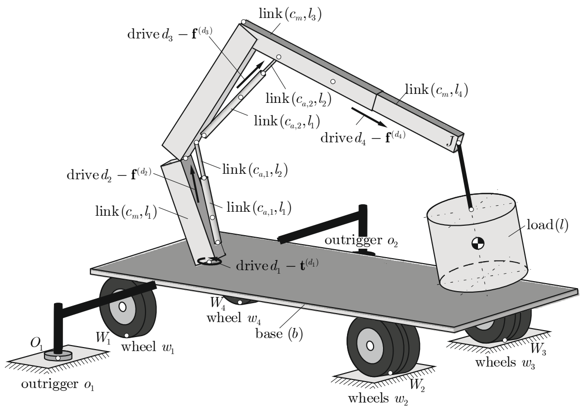

Figure 1: Model of the crane

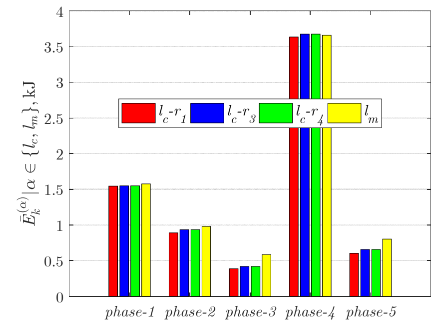

Figure 2: Kinetic energy integral mean value of the cylinder and the lumped mass in phases of input movement

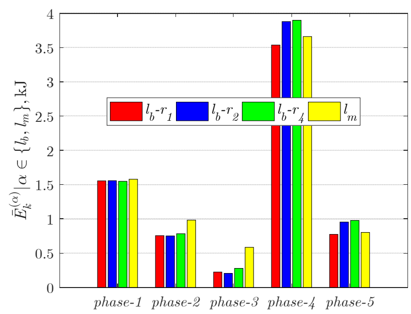

Figure 3: Kinetic energy integral mean value of the box and the lumped mass in phases of input movement

References

[1] Kacalak W., Budniak Z., Majewski M. (2018) Stability assessment as a criterion of stabilization of the movement trajectory of mobile crane working elements. *Int. J. Appl. Mech. Eng*. **23**:65-77.

[2] Cekus D., Kwiatoń P. (2021) Method of determining the effective surface area of a rigid body under wind disturbances. *Arch. Appl. Mech*. **91**:1-14.

[3] Gao T., Huang J., Singhose W. (2022) Eccentric-load dynamics and oscillation control of industrial cranes transporting heterogeneous loads. *Mech. Mach. Theory* **172**:104800.

[4] Urbaś A., Augustynek K., Stadnicki J. (2022) Kinetic Energy-Based Indicators to Compare Different Load Models of a Mobile Crane. *Materials* **15**:8156, https://doi.org/10.3390/ma15228156.