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Development and research of a new type of vibration reduction system for wheel bucket loaders

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Abstract: While driving, various industrial off-road vehicles with booms experience intense vibrations. These vibrations significantly reduce the comfort of their operation and efficiency. Due to the specificity of the operation of these machines, it is usually impossible to apply the vibration reduction measures developed for other types of vehicles. In turn, the developed and implemented vibration reduction methods for these particular machines are insufficient. The article analyses the possibility of using a new type of vibration reduction system in the mentioned machines. The proposed system is an active system, while other systems used so far in practice are passive systems. The very idea of using active vibration reduction systems has already been considered in the technical literature, but to this day it has not been unequivocally assessed. Depending on the control algorithms used, the researchers obtained significantly different final results. The paper describes the results of a synthesis of the control system made by the author based on the analytical model of a wheel bucket loader. The author's analytical model of the loader used in the calculations takes into account three degrees of freedom of the real machine. The effectiveness of the developed vibration reduction system was verified using a more complex simulation model built in MSC Adams. The performance of the developed vibration reduction system was compared with that of a typical passive vibration reduction system.

Keywords: active vibration reduction system, bucket loader, industrial off-road vehicle

1. Introduction

A large part of industrial vehicles with a boom with a working tool, e.g., in the form of a bucket, cannot be equipped with the traditional suspension of road wheels. Such suspension would unacceptably reduce, inter alia, the tipping stability of this type of mobile machinery. As a result, excitations from the road are able to stimulate the vehicle with vibrations of low frequency and high amplitude. Due to the fact that the energy stored in the form of vibrations is not dissipated, the vibrations can persist for a relatively long time. This results in a reduction of the operator's work comfort and efficiency. To minimize this effect while driving, the lower chambers of the boom's hydraulic cylinders are connected to the hydraulic accumulators. As a result, a flexible support of the boom is obtained and an increase in the intensity of damping of the excited vibrations of the vehicle. Unfortunately, the reduction of vibrations obtained this way is insufficient. That is why new and better solutions are sought. One of the ideas currently being researched is to force micromovements with the boom actuators while driving. Several solutions of this type have been submitted for patent protection. However, the results of research conducted by independent research units so far give contradictory results as to the effectiveness of such an approach. Therefore, the author decided to develop a control algorithm and test the vibration reduction system based on it.

2. Results and Discussion

To synthesize the controller for the active vibration reduction system, a mathematical model of a vehicle with a boom was built. The model was based on an actual bucket loader. The physical model of the vehicle, which is the basis for the construction of the mathematical model, is presented in Figure 1. In deriving the equations of motion, the formalism of the 2nd type Lagrange equations was used.

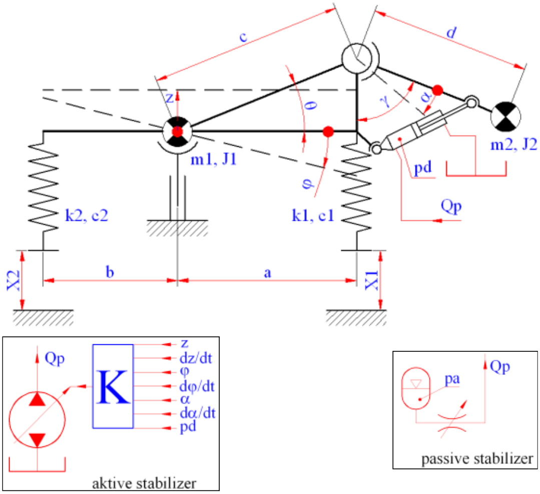

Fig. 1. Physical model of a bucket loader with a passive and active vibration reduction system (vibration stabilizer)

For the synthesis of the controller, the mathematical model was linearized. The linearized form of the model was written in the form of state equations. The model in this form was used to synthesize the LQR (Linear-quadratic regulator) regulator. While determining the parameters of the LQR controller, various parameters of the weight matrices in the cost equation were experimented with. To verify the effectiveness of the developed vibration reduction system with the LQR controller, a simulation model was built in the MSC Adams system (see Figure 2). Then the virtual bucket loader was driven over a road with stochastic unevenness with a passive and the other time with an active vibration reduction system. The test runs made it possible to compare both solutions.

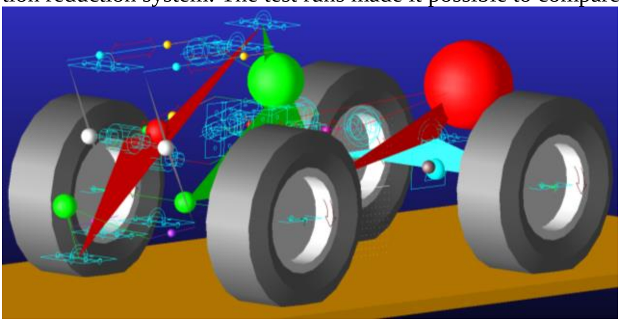

Fig. 2. A simulation model of a bucket loader built in the MSC Adams system to test the performance of the developed vibration reduction system

3. Concluding Remarks

The article proposes a synthesis method for the LQR controller for an active vibration reduction system of a bucket loader. The performance of the proposed vibration reduction system was compared with that of the passive system commonly used in modern bucket loaders.