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## MATHEMATICAL MODEL OF DYNAMICS OF CHANGE IN DEPARTURE OF MANIPULATOR WHEN COMBINING THE MOVEMENTS OF JIB ELEMENTS

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In the enterprise of the national economy, cargo cranes-manipulators on vehicles, which increase productivity in carrying out load-lifting and transport operations, and also facilitate working conditions of workers, are widely used. The use of crane-manipulator makes it possible to accelerate the carriage of goods.

In the process of performing loading and unloading operations in the jib system of the crane-manipulator there are dynamic forces due to the uneven rotation of the jib system of the crane-manipulator with a hydraulic drive with hydraulic-cylinder rod.

These forces affect the load perceived by the jib system, and the elements of the crane-manipulator drive during its operation. Dynamic forces depend on the kinematic parameters of the crane-manipulator and on the speed of movement of the hydraulic-cylinder rod.

To reduce the dynamic loads and, accordingly, increase the reliability of metal structures and hydraulic equipment, it is rational to use the combination of the following operations:

- lifting (lowering) the jib and turning the crane-manipulator;
- lifting (lowering) of the arm and turning of the crane-manipulator;
- lifting (lowering) the jib and lifting (lowering) of the arm.

In addition, combining operations provides an opportunity to increase the productivity of the crane-manipulator.

To study the dynamic loads when combined movements of the links of the jib system crane-manipulator, is developed mathematical model in the process of flight change. To construct a mathematical model, a dynamical model of a crane-manipulator with a hydraulic drive was constructed. When constructing a dynamic model assumptions were made:

- we assume that all links of the jib system are absolutely solid, except for the cargo that fluctuates on the hinged suspension in the plane of change of radius;
- friction in moving elements and viscous friction of fluid in pipelines are not taken into account;
- the compressibility of the working fluid in the elements is neglected.

Based on the assumption, the crane-manipulator is represented as a holonomic mechanical system with four degrees of freedom. For generalized coordinates, the angular coordinates of the rotation of the jib, the arm and the deviation of the grab with the cargo from the vertical are taken, as well as the linear coordinate of the telescopic section of the arm. In this model, the driving forces in power cylinders are determined from the mechanical characteristics, which are represented in the form of quadratic

relationships between the force and speed of the displacements of the power hydraulic cylinders.

On the basis of the dynamic model, a mathematical model is compiled, in the form of a system of four nonlinear differential equations of the second order.

As a result of the numerical solution of these equations for a particular manipulator in the process of changing the radius of cargo with the combination of movements, determined kinematic characteristics of the links of the jib system, the existing forces and power in the drive hydraulic cylinders, as well as fluctuations of the device with the load, which made it possible to identify the structural and dynamic disadvantages of the hydraulic control system of the crane-manipulator.