MATHEMATICAL MODEL OF AN ELASTOMERIC DRAFT GEAR

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ABSTRACT

When transporting hazardous liquid cargo by rail a need arises not only for immediate protection of people and infrastructure, but also for preventive measures relating to structural, technical features of tank wagons. At the same time improving reliability and safety of vehicles, according to the author, can be realized by the calculated model for damping devices and, in particular, elastomeric coupler draft gear. The objective of the author is to present a mathematical model of an elastomeric draft gear. To do this, the author uses simulation method, analysis, mathematical methods.

An issue of traffic safety of tanks is considered. A mathematical model is developed, describing operation of elastomeric draft gear. This model is a dependence of device reaction and deformation rate, taking into account initial straining of a device and properties of working medium. Mathematical model allows for simulation of elastomeric draft gear operation at any options of shunting collision and transient modes of train motion.

Keywords: railway, traffic safety, tank, liquid cargo, energy absorbing device of a car, elastomeric draft gear, mathematical model.

Background. *Significant volumes of rail transportation of oil, oil products, liquefied gases, acids, alkalis and similar products, define higher requirements for the design of rolling stock, transporting liquid cargo. These goods are transported in tanks, and are classified as hazardous. Tanks must meet conditions for ensuring safety (including environmental) for operation on the rail network. Serious consequences of emergencies force designers to pay special attention to the behavior of cars in emergency situations, to develop different ways of protection. The creation of new, more advanced designs of tank wagons, having a high load capacity and reliability with a minimum consumption of materials, is also justified by international standards.*

Objective. *The objective of the author is to present a mathematical model of an elastomeric draft gear.*

Methods. *The author uses simulation method, analysis, mathematical methods.*

Results.

Motivation of protective equipment

Load of car's elements to a large extent depends on frequency and level of longitudinal forces acting on them. In the current operation conditions their value is determined by characteristics of center-coupler draft gears, and values occur at shunting collisions and transient conditions of the train motion mode. In all cases, the relationship is visible between the level of longitudinal forces and trouble-free operation of coupling, traction clamp, and other design elements of cars.

Unlike other types of wagons loading of structural elements of tank cars under operational impacts depends largely on the behavior of liquid cargo, having a free surface. One of unavoidable factors is operating tank ullage due to specific properties of goods and technical requirements of their transportation. This leads to movement of the liquid medium and appearance of additional loads on tank shell, its mounting components, and other structures of supporting elements. In addition, fluctuations in the liquid cargo in tanks located in the train, influence the formation of dynamic forces in intercar joints during movement.

In the complex of measures designed to counteract these phenomena, an important place is occupied by improvement of damping devices of cars, including center-coupler draft gears.

Parameters and calculations

Serial spring-friction draft gears do not fully satisfy the conditions of operation. Their disadvantages are instability of power characteristics, probability of jamming, wear of friction assembly, low power consumption in a state of delivery and after running at rated power of operation.

Therefore, one of the main directions of engineering search to reduce longitudinal loading of the rolling stock is improving the energy absorbing device of coupler equipment. Per totality of economic and technical indicators the most promising in terms of reliability and safety can be considered a draft gear design with the use of volume-compressible high viscosity polymer as a working medium. Accordingly, at its creation or operation it is necessary to have a reference design model that would help orient protective functions of devices used in tank-wagons.

Mathematical model of an elastomeric draft gear should reflect the following features:

– *The presence of the initial tightening;*

– *Elastic properties of the working medium, independent of strain rate;*

– *The presence of dry friction;*

– *The presence of viscous friction in the flow of the working medium, the amount of effort in which depends on the strain rate.*

Let's construct a mathematical model that describes the operation of the draft gear. It is designed to take into account inter alia the dependence of the device reaction from possible deformation and its speed:

$$R_d = R_0 + cx_d \pm F_{fr} \pm \beta V_d^2, \qquad (1)$$

where R_d is effort in an automatic coupler, acting on the body of the device;

R_0 is value of force of the initial tightening;

C is stiffness of the working medium during compression;

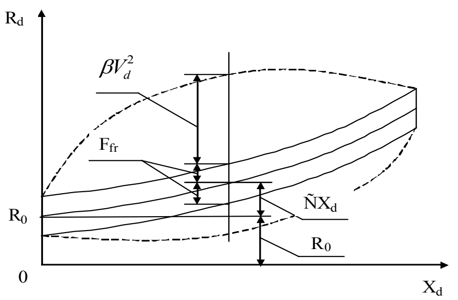
X_d is deformation value of the device;

F_{fr} is dry friction force;

β is viscous friction coefficient;

V_d is deformation rate of the device.

Each of the terms in equation (1) approximates one of the properties of the working medium behavior, that affect the elastomeric draft gear. Signs of dissipative forces depend on the direction and speed of deformation: if Vd> 0 (compression mode of the device), friction forces are positive; if Vd <0 (return mode), friction forces are negative.



Pic. 1. Components of the power characteristics of the elastomeric draft gear.

It should be noted that coefficients C, β, F_{fr} in formula (1) are generally variables. This is due, on the one hand, to the fact that when the device operates, volume of chambers changes and passage section of holes through which the elastomer flows in, and the other hand- to the fact that the properties of an elastomer modify during its deformation.

Pic. 1 shows examples of static (solid line) and dynamic (dashed line) characteristics of the elastomeric device. They demonstrate the geometric meaning of device reaction components – terms of the expression (1).

Parameters of the mathematical model can be defined in two ways: firstly, from the properties of the elastomer, secondly, formally, based on the experimental power characteristics of the device.

The link of the mathematical model with properties of the elastomer and geometric characteristics of the device is set by following equations.

The rigidity of the device is expressed through the elasticity modulus of the working medium:

$$C = \frac{S_a}{l_a} E, \qquad (2)$$

where S_a is reduced area of the working chamber with the elastomer;

l_a is initial length of the working chamber;

E is elasticity modulus of the elastomer.

Viscous friction coefficient is expressed in terms of the coefficient of hydraulic resistance during the flow of the elastomer through holes:

$$\beta = \frac{S_a^3}{S_1} \zeta, \qquad (3)$$

where S_1 is reduced area of holes through which the elastomer flows in from the working chamber at compression of the device;

ζ is hydraulic resistance coefficient.

Dry friction force, as shown by real power characteristics of elastomeric devices varies slightly during deformation of the device.

Equations (2) and (3) allow to perform inverse transformation, i. e. based on generalized mathematical model parameters, established experimentally, to determine properties of the elastomer.

Conclusions. *Dependences of stiffness, dry friction coefficient friction and viscous friction coefficient from device deformation allow simulate operation of elastomeric draft gear at all options of shunting collision.*

Furthermore, on their basis properties of the working medium (elastomer) can be determined and thereby devices of other models can be simulated using the same brand of elastomer.

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