DYNAMIC RESEARCH OF THE ROPE ELECTRIC DRIVES

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Formulation of the problem

Thus, the task of research is to compare means of computer simulation of the dynamics of an electric drive, taking into account and without considering the nonlinearities of the mechanical part, namely, the effect of the sagging of the rope.

Main material

The main factor to consider when creating a mathematical description of a sagging rope model is the factor of its variable elasticity, depending on the size of sagging. It should be noted that for the sagging rope, Hooke's law is not enforced. When deducing, the basic equations of statics for the system in balance are used:

the sum of the projections of all external forces on the coordinate axis is zero: $\Sigma X = 0$; $\Sigma Y = 0$;

the sum of the torques of all external forces or their projections for any point is zero: $\Sigma M = 0$.

Consider the part of the rope, cutting it at the lower point of *O* and at any point *D* with the coordinates (x; y). The cut off parts of the rope replaced by the corresponding forces according to the method: the force *H* acts at the lower point of the sagging curve, and at the point D – the force *Tx* (see Fig. 1).

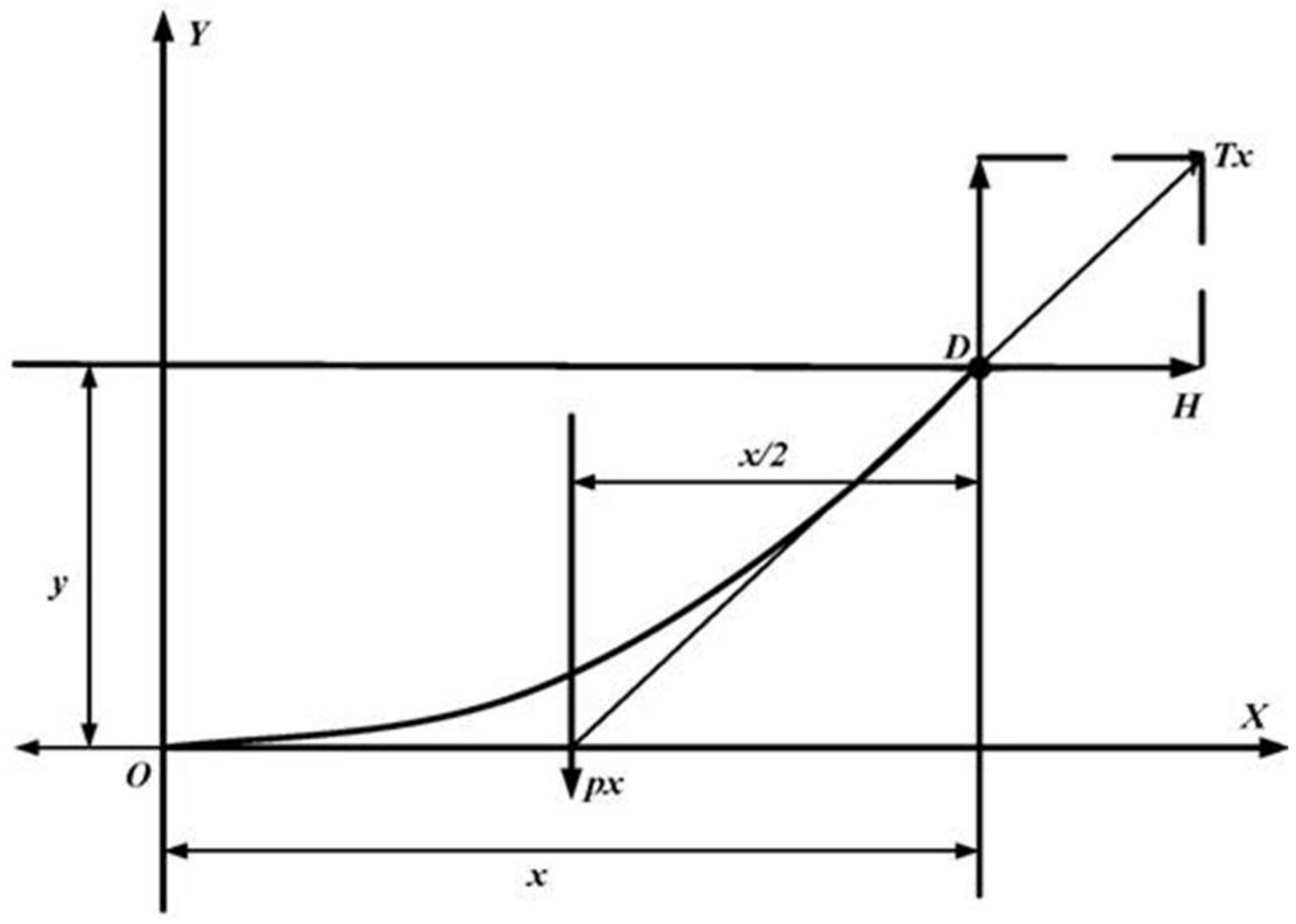

Fig. 1. External forces acting on the segment of the rope

For ropes, the tangent to the sagging curve at any point has a small angle with a horizontal straight line. This makes it possible to take the weight of this area evenly distributed horizontally and replace the concentrated force *px* acting in the middle of the considered section, that is, at a distance of *x*/2 from the points *O* and *D*. The force *Tx* is considered to be equal to the gravitational force at the lowest point *H* (Fig. 1) according to [12, 13]. This assumes that the rope is an ideal flexible thread.

The direction of the force action of *H* at point *D* is opposite to the direction of the same force at the lowest point of the curve of the sagging rope, because of the properties of an ideal flexible thread; it can only work on stretching only. In this case, the equation of the forces of forces relative to point D is written as follows:

$$\Sigma M_D = H \cdot y - p \cdot x \frac{x}{2} = H \cdot y - \frac{p \cdot x^2}{2} = 0$$

Having solved this equation with respect to the amount of sagging in, we obtain the basic equation of the curve of sagging of the rope:

$$y = \frac{p \cdot x^2}{2H}$$

where *p* – the unit load on the rope;
H – gravity at the lower point of the sagging curve;

$$y = \frac{p \cdot x^2}{2H} = \frac{\gamma \cdot F \cdot x^2}{2\sigma F} = \frac{\gamma \cdot x^2}{2\sigma} \qquad (1)$$

The sagging arrow f_k for the same height of the hanging points:

$$f_k = \frac{\gamma \cdot l^2}{8\sigma} = \frac{T}{q \cdot l} \qquad (2)$$

where *q* – weight of the rope;
T – force in the rope.

The rigidity of the "slack" from the sagging rope is determined by differentiation in length: $C_{nk} = d\tau/dl = 12qf_k^3$. The stiffness of the rope, respectively, is a combination of linear stiffness (in accordance with Hooke's law) and a nonlinear component of the rope sagging, and will be in accordance with:

$$C_k = C_l \frac{f_k^3 \dfrac{12q}{C_l}}{1 + f_k^3 \dfrac{12q}{C_l}} \qquad (3)$$

The description of the sagging ropes is a rather complicated mathematical problem, therefore, in the first stage of computer modeling, it will be logical to use a simplification. In connection with this, for the used in the article computer models of the mechanical part, the following assumptions adopted:

the rope is elastic and subject to Hooke's law;
the rope is the perfect thread;
the rope has the same suspension points.

In this case, the structural model of the rope stiffness variable due to its sagging based on formula (3) and will have the implementation shown in Fig. 3. The specific values of the model parameters correspond to the hoist drive of the Soviet excavator-dragline ЕШ-15/90 as example.

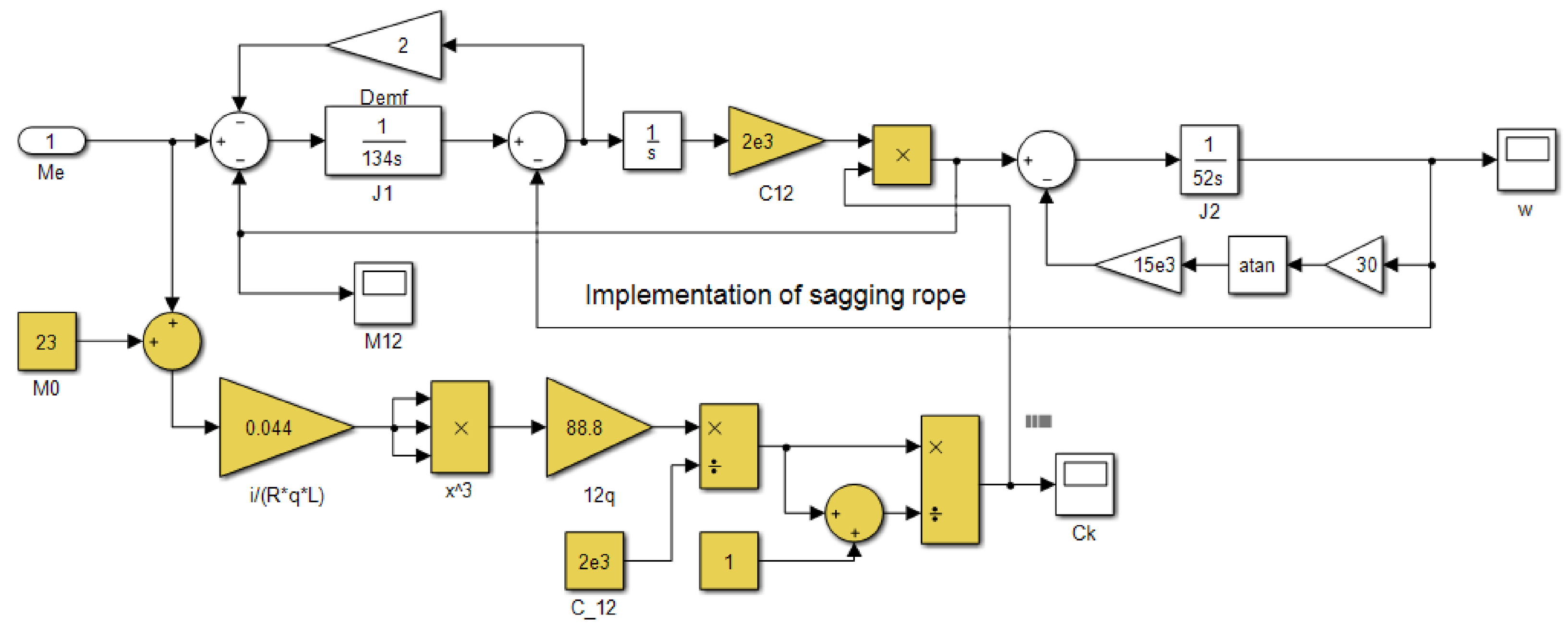

Fig. 3. Implementation of the computer model of the sagging rope by the formula (3)

The assumptions adopted for the model of the electric drive of the excavator-dragline ЕШ-15/90, which based on the Ward-Leonard system with magnetic amplifiers, are traditional. Such a simplification of the models of the drive elements explained by the purpose of research – the difference in the behavior of two types of models of the mechanical part of the dragline drive researched.

Using the developed computer model, the process of starting the lifting of the bucket of the excavator-dragline, including the moment of its separation from the ground, explored. The resulting transients plotted and one of them (relative stiffness of the rope) shown below in Fig. 4. There is that the effect of the rope sagging in this model is present only in the initial stage of the start, when the "weakness" of the rope was taken. Accordingly, further models of both systems behave in the same way.

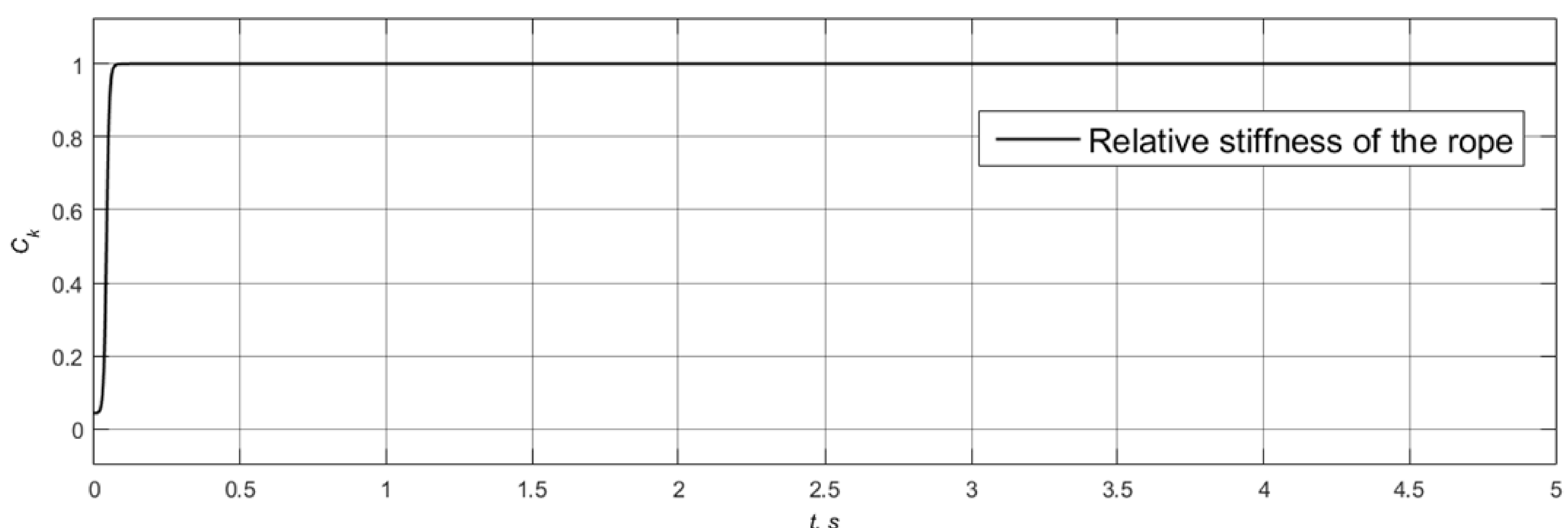

Fig. 4. A graph of the relative elasticity (stiffness) of the rope during the start

Conclusions

The application of the simplified model of the rope sagging by the method leads to an unjustified complication of the computer model without the expected effect of increasing accuracy. Thus, it is possible to consider the use of a linear model of the rope drives without justification of the sagging effect of the rope.