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ELEMENTS OF THE THEORY OF CRAWLER TRACTOR MOVEMENT

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The article gives the analysis of track mover moving with advanced energy saving design for lower overall energy consumption and high efficiency of running systems of *energy resources, according to the theory proposed* by *Associate Professor Petrov L.M* .

Introduction

Review of the literature on the subject of research [1] showed that the resistance to traction energy facility movement is characterized by means of power Pk. In the work [2] for track energy facility the resistance force to rolling during a movement consists of frictional forces in the bearings of road wheels and at rolling of road wheels on a treads of track chain.

In the work [3] the resistance forces to rolling are added to frictional forces that occur in the track link elements from its previous tension and the force that is spent at the normal to the road surface deformation of the soil.

As we can see from the literature review, part of the unsolved problem, can be identifined: unrecorded moments of frictional forces that arise at sliding of track chains on the driving wheel.

Theoretical principles

The aim of the study is to develop a mathematical model of the drive sprocket of the track mover with energy savings, which involves removing sliding moments of friction that occur when the track chains move on the draving wheel and obtain an overall assessment of the improved movement of track mover tractor.

The object of the research is the drive sprocket of energy facility with track mover. The subject of the study is improved kinematics motion of track chain on the drive sprocket tooth.

Scientific research task is to establish relationships between coordinates of linear motion of tractor on tracks and the angle of rotation of drive sprocket.

To achieve this goal some problems were solved in the work:

- Tooth slope of driving sprocket was changed;
- Development of mathematical model of track pin efficient movement on the tooth.

Research results

The scientific problem is solved with the basic concepts of theoretical mechanics.

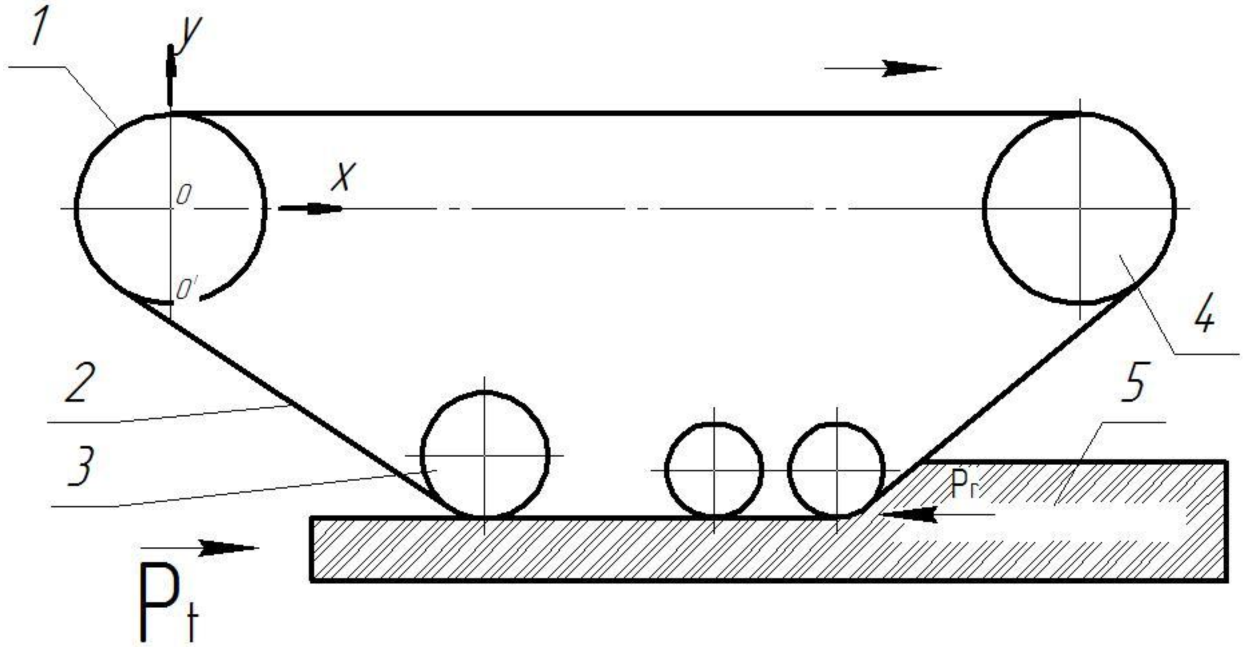

Figure – 1. Scheme of track energy facility movement: 1- drive sprocket; 2-track chain; 3-road wheel; 4- directing wheel; 5- reference background

The resistance force at the established movement consists of the frictional forces that occur in the bearings of road wheels, when rolling on treads of track links, track friction elements because of pre-loading and power that is consumed in the normal to the surface of road deformation of soil. In uneven movement of facility the point of tangential forces of inertia (Pt) and the horizontal component of the resultant reaction of soil on the frontal area of track in their motion on the deformed road surface - drag Pr should be considered.

The criteria for basic parameters of track mover assessing is the torque on the drive wheel. To simplify the calculations we do not take into account the friction force.

Restrictions on the use of the criteria is the number of shift platforms.

Figure 2 shows the scheme of track chain tension on the drive wheel and track when using conventional track mover, and Figure 3 (a, b) is a scheme of the proposed track mover, made by energy saving technology.

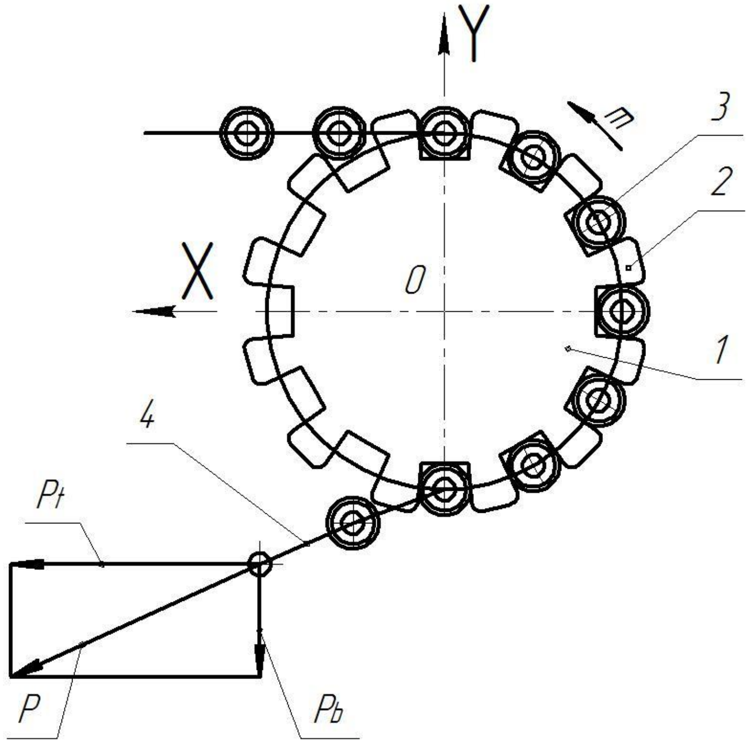

Figure – 2. Scheme of track chain tension by analog method: 1- drive wheel; 2 - trickle; 3 - pin; 4 - track chain.

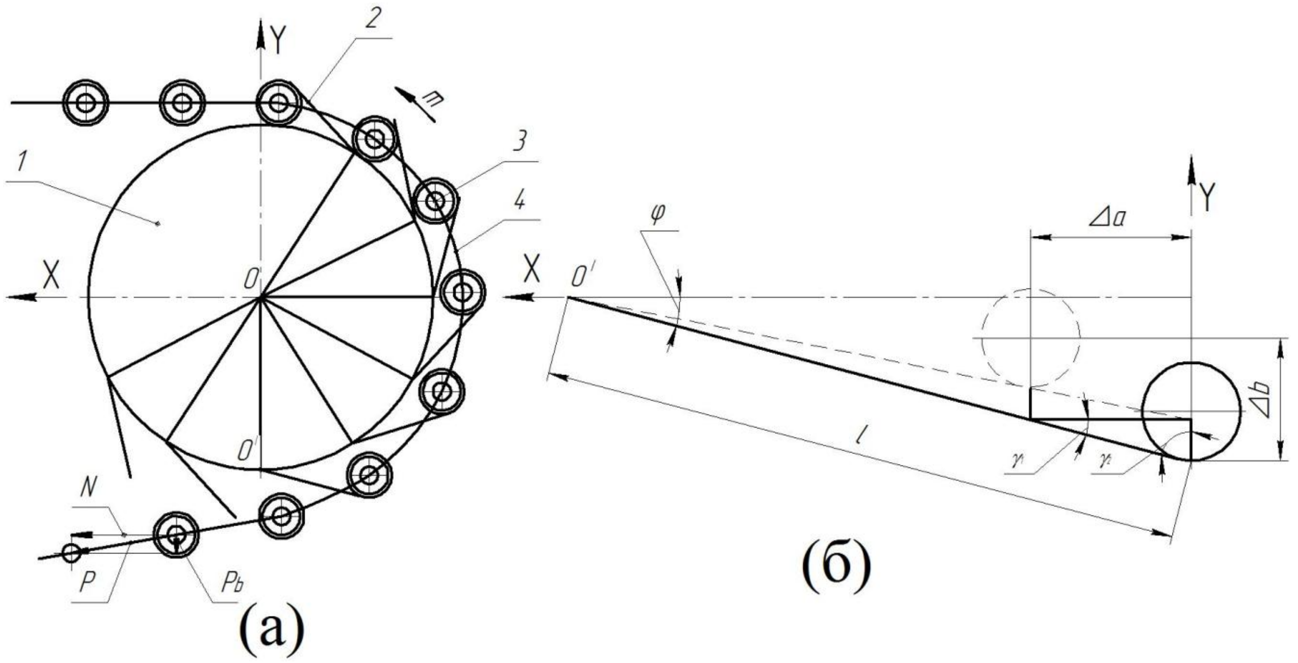

Figure - 3 Scheme of track mover tension with energy savings technology by proposed method (a) and modeling of drive sprocket pin inclination (b): 1- drive wheel; 2 – shift platform, 3-pin; 4 - track chain

Let’s consider changing of the x and y coordinates when moving tractor on tracks:

$$\begin{cases} \dfrac{x}{l} = \sin\varphi \\ \dfrac{y}{l} = \cos\varphi \end{cases} \qquad (1)$$

where φ - angle of tooth profile;

l - the tooth length, m

Both sides of the equation (1) we reduce to the square and make:

$$\left(\frac{x}{l}\right)^2 + \left(\frac{y}{l}\right)^2 = \sin^2\varphi + \cos^2\varphi = 1 \qquad (2)$$

$$\frac{x^2 + y^2}{l^2} = 1 \rightarrow \ln\left(x^2 + y^2\right) - \ln l^2 = 0 \qquad (3)$$

Let's make logarithm of expression (3), we obtain the equation:

$$x^2 + y^2 = e^{\ln l^2} \qquad (4)$$

Let's consider a segment of track, which is located on the sprocket and limited by central angle dφ

This segment of tracks is influenced by such forces: dN - normal reaction of a pin; F – the meaning of efforts on pin at the moment, which position is determined by the angle φ ; F + dF - efforts on the pin in the position defined by coordinate φ+ d φ ; fdN – pin friction on teeth; f - coefficient of friction between the driving sprocket tooth and track pin.

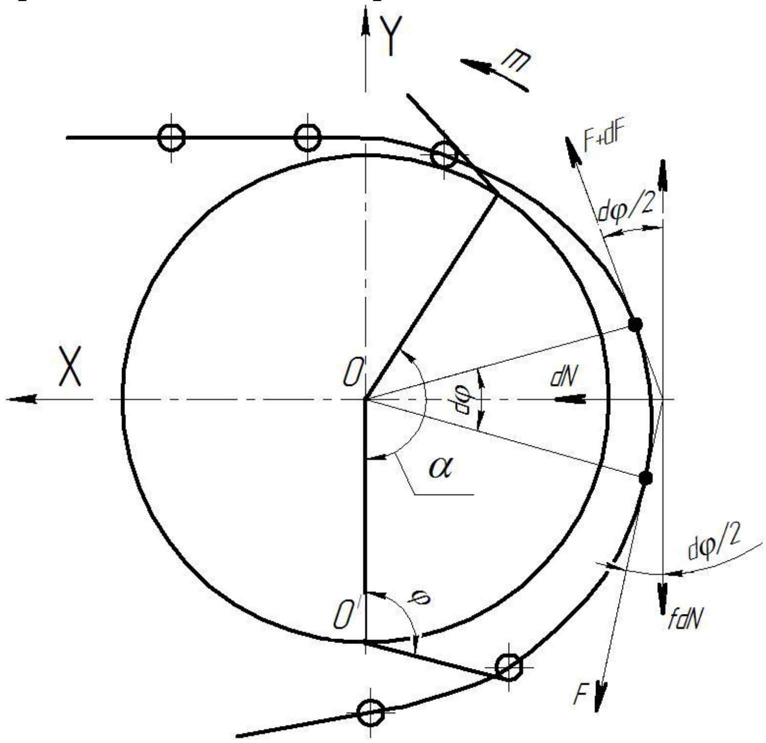

Figure - 4 Scheme to methods for determining the load forces of modernized track mover sprocket

$$[F + fdN - (F + dF)] \cdot dx = 0 \qquad (5)$$

$$dN - F\sin\left(\frac{d\varphi}{2}\right) - (F + dF)\sin\left(\frac{d\varphi}{2}\right) = 0 \qquad (6)$$

Reject in (6) equilibrium conditions the members of the second order of smallness

$\left(dF \cdot \sin\left(\frac{d\varphi}{2}\right)\right) \approx 0$ and taking into account $\sin\left(\frac{d\varphi}{2}\right) \approx \frac{d\varphi}{2}$ get

$$dN = Fd\varphi$$

$\frac{dF}{F} = f$ because $dN = \frac{dF}{f}$

$$dN = \frac{dF}{f} = Fd\varphi \Rightarrow \frac{dF}{F} = fd\varphi$$

Integrating the left side of the equality from F2 to F1, and right from 0 to α, we get

$\int_{F_2}^{F_1} \frac{dF}{F} = \int_0^{\alpha} fd\varphi,$ obtain $\ln\left(\frac{F_1}{F_2}\right) = f\alpha$

$$\frac{F_1}{F_2} = e^{f\alpha} \qquad (7)$$

Thus the ratio between efforts in drive of the driving sprocket considering the friction force between the pin and bent tooth is:

$$F_1 = F_2 e^{f\alpha} \qquad (8)$$

where e – is the base of natural logarithm; α - angle of coverage of the drive sprocket working area with track chain; F - resultant resistance force, N; F1 - starting resultant resistance force on bented tooth, H; F2 - final resultant resistance force on bent tooth at working angle α, N; f - coefficient of metal friction (track pin on the driving sprocket tooth)

In order to set pattern of the influence of pin moving across the inclined tooth on the balance of load power of pin input and output while pin moving on the tooth in horizontal and vertical directions, we will make the equation of points equilibrium:

$$\sum M = 0 \Rightarrow Fr - (F - dF) \cdot (r + dr) = 0 \qquad (9)$$

where r – arc curvature, which is formed by moving the pin of driving sprocket $r = e^{\ln l^2}$

Neglecting second order values from (8) we get:

$$rdF = Fdr \qquad (10)$$

Dividing the variables and integrating the obtained formulas

$$\int_{F_2}^{F_1} \frac{dF}{F} = \int_{l}^{r} \frac{dr}{r} \qquad (11)$$

Finally we get

$$\frac{F_1}{F_2} = e^{\frac{l}{r}} \qquad (12)$$

In equations (8) and (12) let's fill literal content by scalar values and display the results in Fig. 7.

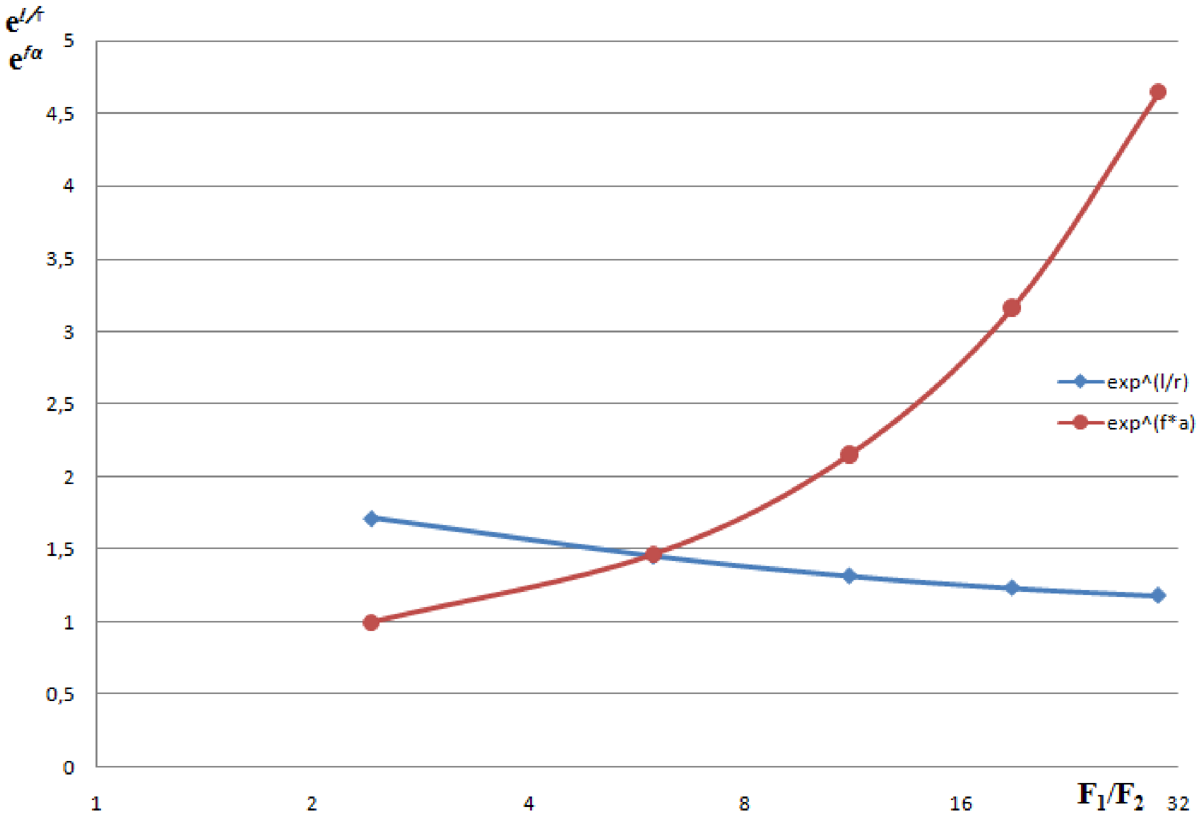

Figure- 5. Dependency graph of of geometrical parameters impact of modernized drive sprocket on the balance of input and output load force of drive sprocket

The working point of the tooth, which corresponds to the horizontal pin displacement when chain is in active part of sprocket, forms the instant process of providing relative motion of the tractor on track chain, let's call it special.

Let’s refer to equation (1), and substitude the variables x and y by the final values on the pin movement contact point with the drive sprocket tooth while this pin is on this tooth:

$$\begin{cases} \dfrac{\Delta a}{\Delta b} = tg\gamma_1 \\ \dfrac{\Delta b}{\Delta a} = tg\gamma_2 \end{cases} \qquad (13)$$

where –

Δa- horizontal movement of track chain pin on working part of tooth;

Δb - Longitudinal movement of track chain pin on working part of tooth;

γ_1 - rotation angle, which corresponds to a horizontal movement;

γ_2 - rotation angle, which corresponds to the vertical movement.

Conclusions

1. Modeling the process of pin entry and exit on the modernized sprocket tooth we have found that the ratio of force on the pin tooth and going down from the tooth of this pin is changing at an exponent, the power of which is the product of the friction coefficient and angle of coverage of the drive sprocket working area.

2. Modeling moments of changes on the pin of modernized sprocket with the change of location coordinates of the pin on tooth, the dependence has been established, which is proportional to the exponent, which power is the ratio of the tooth length to the curvature of the arc of rotation and sprocket displacement.

3. The exponential dependence of the coverage angle and tooth lengthfrom the ratio of the input and output force of the pin is defined by the curves which intersection forms special point.

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