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ELEMENTS OF THE DRAUGHT VEHICLE KINEMATICAL MODEL THEORY

Leonid Petrov*, Anatoliy Yakovenko*,
Olena Chumak**, Wojciech Tanaś***

* Odessa State Agriculture University
Kanatna Str. 99, 65039 Odessa, Ukraine, e-mail: yakovenkoan@ukr.net
** Odessa State Freeze Academy
***The Agricultural University of Lublin
Głęboka Str. 28, 20-612 Lublin, Poland, wojciech.tanas@ar.lublin.pl

Summary. The paper presents the theory of comparative mobility of energetic vehicle, which allows to improve the calculation methods of energetic vehicle mobility parameters that have influence on its energy balance in a moving process.

Key words: energetic vehicle, kinematics, mobility, tractive force

INTRODUCTION

The search for hidden ways of moving energetic vehicle mobility improvement is needed at present [Gierniet 1965, Butyenin 1971]. An improvement of energetic vehicle mobility evaluation theory allows to display its hidden possibilities [Vodyanik 1994], which is confirmed by results of scientific researches in the field.

The evaluation of energetic vehicle mobility is characterized by resisting force. An energetic vehicle is fixed to caterpillar chain, and that is why evaluation of its mobility is conducted by resisting force within fixed moving, which consists of frictional force inside the supporting bearings during their swing on caterpillar rinks [Antonom 1949, Krasowski E. (red.) 2005].

For general evaluation of energetic vehicle mobility to resisting force, the friction force is given, that appears in caterpillar links elements from the previous tension, and forces that act normally on the road surface deformation of the ground [Butyenin 1971, Vodyanik 1994].

It is also possibe to include the never-before solved problem – excessive mobility of energetic vehicle, which appears within interaction of moments from forces of friction in longitudinal direction [Dobronravov and Nikitin 1954, Loycyanskiy and Lurye 1954, Targ 1963, Yablonskiy 1971, Palko 1977, Stradjinskiy 1980].

THE METHODS OF RESEARCH

The creation of moving energetic vehicle kinematical model was the aim of our research, and energetic vehicle moving process – was the object of testing.

The evaluation of the process of energetic vehicle moving efficiency was the subject of investigation.

The scientific purpose of research was an establishment of energetic interaction regularity between friction force in longitudinal and back directions and influence of such interaction to energetic vehicle mobility, and reception of general evaluation of energetic vehicle mobility was the aim of research.

For the achievement of the mentioned aim in research were decided to separate the tasks:

– a kinematical model for accomplished process of energetic vehicle moving was worked out,

– a method of energetic vehicle moving evaluation was worked out.

The scientific task was solved with the help of theoretical mechanics equations.

THE RESULTS OF RESEARCH

The most important scientific result, that was received within research is energetic vehicle moving kinematical model improvement by way of additional liberty stage introduction for energetic vehicle. The distinctive feature of this model from the known one is that it counts energetic component of interaction between forcers in longitudinal and back directions. Such kinematical model adequately describes energetic vehicle moving. This allows for a difference from existing mathematical models, obtaining the dependence between energetic parameter of draught vehicle moving. A part of such parameters were received first, but the part is the development of the already known model – energetic vehicle moving with the help of engine.

The criteria, which is the method of energetic vehicle model's general parameters evaluation is the component of force balance, which is applied by energetic vehicle in the process of moving.

The difference of our criteria from the known is that it allows to define the additional liberty stage energy of the energetic vehicle.

The only limit concerning application of the criteria is energetic part of friction forces interaction in longitude and back directions.

The researches [Antonom 1949, Vodyanik 1994, Krasowski E. (red.) 2005] looked into the moving of energetic vehicles and their separate chains without counting the factors that cause their moving, which are components of forces, their parity in time and space. However, the moving of energetic vehicle was considered only from geometrical side, with counting only the time factors. But any moving of energetic vehicle is characterized by its moving in space, speed and acceleration of points moving. If you do not take into account such characteristics of moving, you can lose the control while driving an energetic vehicle, and also underestimate its possibilities as to energy saving.

We made an attempt to find out possible consecutive situations of energy vehicle movers, within this to solve the problem concerning possible points trajectories (of mechanisms) of an energetic vehicle, which are not given by vehicle's scheme.

The draught vehicle (Fig. 1) is placed to horizontal plane 2. The *Q* force, normal to plane, acts on it, which causes reaction *N* from the side of plane. This reaction is equal to its size and directed opposite *Q* force.

Let us admit, that under the action of touch force $P\partial$ *a* draught vehicle (DV) will move in regular intervals. Such conditions of DV respond to terms of its balance situation, i.e. equal work of all the forces applied to DV must be equal to zero.

As DV touches the basic surface, which is not perfectly smooth, the reactions which appear in points of touch have some deviations from the normal.

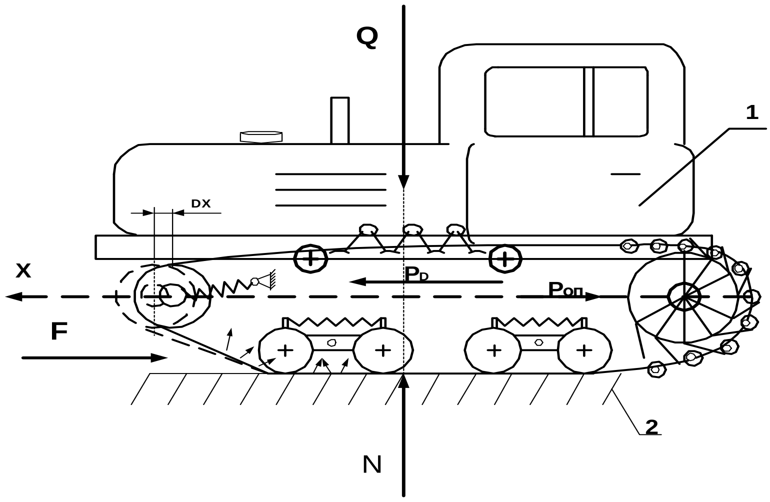

Fig. 1. Kinematical model of a draught vehicle (1) at basic surface (2)

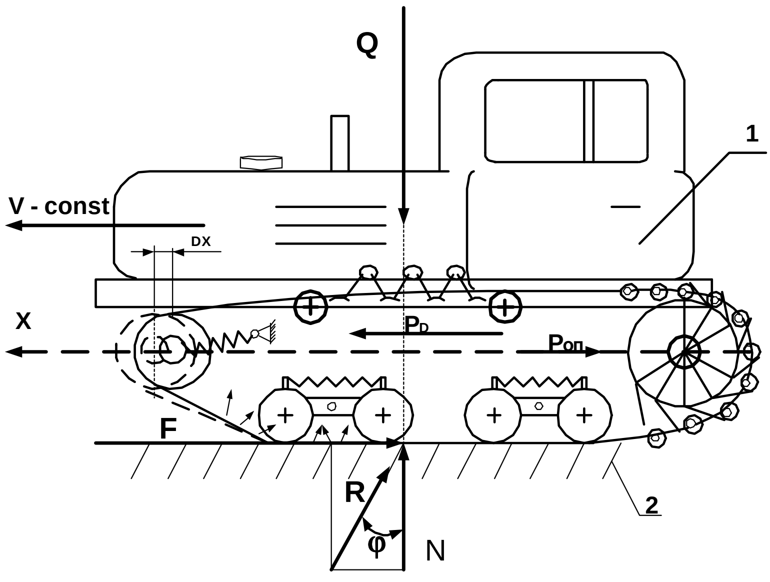

Fig. 2. Kinematical model of a draught vehicle moving with regular intervals

When these reactions are projected to direction of force *Q* action and then P composes appropriate projections, we will get *N* and *F* forces, which are the result of basic surface action to DV (Fig. 2).

The *N* force will be a normal reaction and it is directed perpendicularly to basic surface, and *F* = *Pon* force is directed parallel to basic surface and opposite to $P\partial$, so for moving with regular interval case DV (Fig. 2) rather to basic surface:

$$N = Q \qquad (1)$$
$$F = P\partial$$

The *N* and *F* forces are parts of DV basic surface full reaction. Let us combine these two forces and we will get full reaction *R*, which is directed under some corner φ to normal reaction *N* (Fig. 2).

In theoretical mechanics with a sufficient for technical calculations grade of accuracy taken into account, that quantity of *F* force is connected by linear dependence with *N* force [Dobronravov and Nikitin 1954, Loycyanskiy and Lurye 1954, Gierniet 1965, Butyenin 1971].

In accordance to (1) and Figure 2 we will get the following coefficient of resistance:

$$f = F/N = \text{tg } \varphi \qquad (2)$$

Let us call corner φ – sliding.

From the mentioned formula (2) it follows, that DV could carry out work (move) under the attitude to basic surface in conditions, in which the force applied to it is sufficient for overcoming resistance force Pon. But as investigations showed, for doing work you should apply more force. That is why a connection between such force $P\partial$ and force *N* will be made by equations.

$$P\partial = f\,N \qquad (3)$$

Formula (3) defines the force, which makes a draught vehicle to move.

The connection between draft force of touch can be shown by the following diagram (Fig. 3).

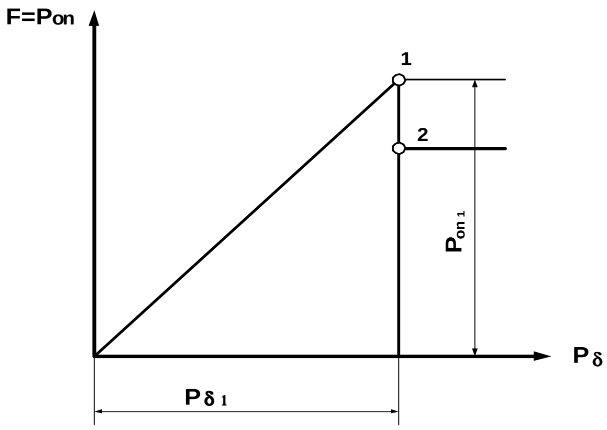

Fig. 3. The diagram of connection $P\delta$ and *Pon* (1 – $P\partial$ = *Pon* , 2 – $P\partial$ > *Pon*)

With an increase of $P\partial$ force form zero resistance, *Pon* force will grow up till a certain value and DV will move in accordance to the equation:

$$Pon = P\partial \tag{4}$$

At some moment of time, the force of draft touch will achieve a value, which responds to the term of coupling with basic surface. When at this time the moving force drops till value $P\partial = Pon$, then a draught vehicle will move with regular interval. In the case when the force of resistance drops to value *Pon*

$$P\partial > Pon \tag{5}$$

DV will move with acceleration, so

$$P\partial - Pon = ma, \tag{6}$$

where:

m – mass of DV,
a – acceleration of DV.

As we can see from Figure 2, the sum reaction

$$R = \overline{N} + \overline{F} \tag{7}$$

directed under the corner φ to N reaction line.

So, for calculation of total resistance force, reaction R is directed under the corner φ to action line N.

Let us move to looking up the resistance force accounting for conduct star (Fig. 4).

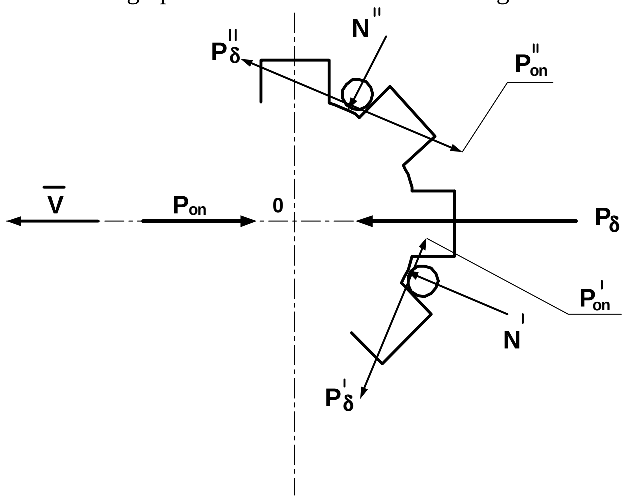

Fig. 4. Scheme of forces at conduct star for figurative moving of a draught vehicle

For accounting resistance forces let us accept law of pressure allocation by contact surfaces of conduct star. For reduction of calculations let us accept this law as linear.

Resultant forces of normal caterpillar pressures to teeth of conduct star are the following:

$$N = \overline{N}' + \overline{N}'' \tag{8}$$

but moving force of resistance DV:

$$P'on = N' \cdot f$$
$$P'' = N'' \cdot f \tag{9}$$

Full resistance force will be the following:

$$Pon = P'on + P''on = f\,(N' + N'') \tag{10}$$

where:

coefficient *F* is total coefficient of DV moving resistance.

Total coefficient of moving resistance depends on size of normal pressures *N'* and *N''*, which are defined by normal force *Q* measure, the place of its put and geometrical sizes of caterpillar parts (Fig. 5).

Let us give additional moving to a draught vehicle, or rather its caterpillar part, though DV moving will consist of two: figurative together with caterpillar chain and figurative to caterpillar chain (Figs 6, 7).

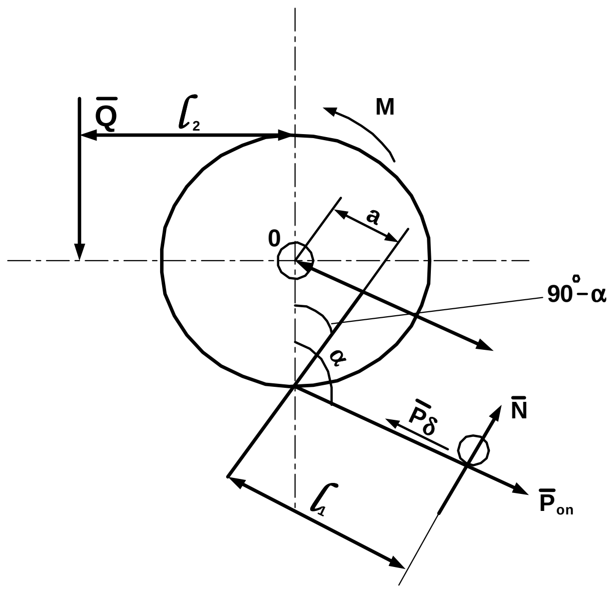

Fig. 5. Kinematical model of caterpillar chain with two steps of liberty

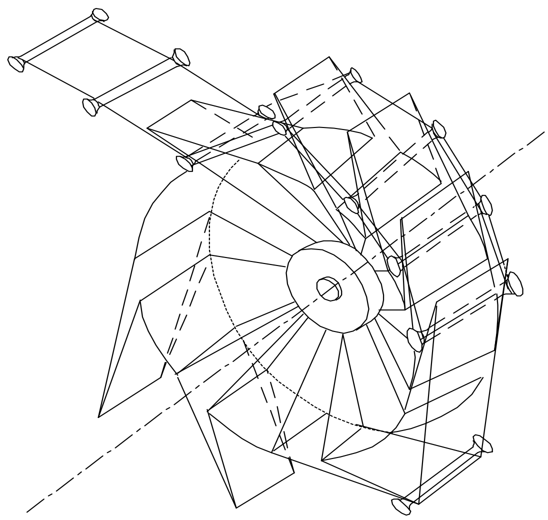

Fig. 6. General view of caterpillar chain with two steps of liberty

If we go from value of moment from *Pon* force and compose equation of moment sum concerning centre 0 of conduct star, then we will get the equation.

$$N\,(l_1 + r\cos\alpha) = Q\,l_2 \tag{11}$$

$$Pon/f\,(l_1 + r\cos\alpha) = Q\,l_2 \tag{12}$$

$$f = Q\,l_2/Pon(l_1 + r\cos\alpha) \tag{13}$$

From (10)–(13) it follows that for avoiding big losses of energy in moving DV it is necessary to give its caterpillar chain additional stage of liberty.

In Figure 7 the scheme of caterpillar mover is shown, which allows DV to take part in two processes of moving: figural and relative.

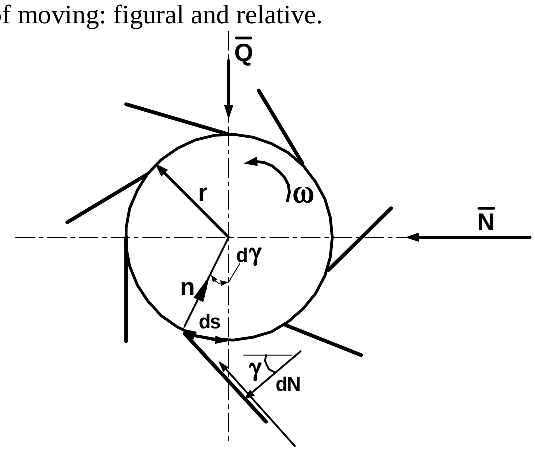

Fig. 7. Scheme for calculation of conduct star

For future conclusions let us agree, that touch between teeth and pool is carried out in the lower part, in point. The loading of all the conduct star's teeth will be conducted at all coupling surface with caterpillar chain.

Under the action of loading *Q* (Fig.7) appears pressure *n*, which acts from the side of caterpillar chain to conduct star.

These pressures are allocated by a certain law, which in the first approach will be considered as symmetric relatively to horizontal axis. The effort *dN*, which acts to one tooth with platform of lonely length *dS*, will be determined from the formula:

$$dN = ndS = n\, r\, d\gamma \tag{14}$$

Elementary force of resistance will be equal to:

$$dPon = f\, d\, N = f\, n\, d\, \gamma \tag{15}$$

Full pressure force, which acts from the side of caterpillar chain to teeth, will be equal to geometrical sum of a normal elementary force *dN*, but line of its action comes through the center of conduct star in a consequence of symmetric allocation of pressures.

Projection of normal elementary pressure force to line of resultant pressure action is equal to

$$dN \cos \alpha = n\, r \cos\gamma\, d\gamma \tag{16}$$

Let us integrate equation (16) by length of caterpillar chain contact and we will get:

$$N = r \cdot \int_{\frac{\pi}{2}}^{\pi/2} n \cdot \cos\gamma \cdot d\gamma \tag{17}$$

Resultants of resistance force are equal to algebraic sum of elementary resistance forces:

$$F = f \cdot r \cdot \int_{\frac{\pi}{2}}^{\pi/2} n \cdot d\gamma \tag{18}$$

Then total coefficient of the moving resistance will have the following look:

$$f_c = f\, \frac{\int_{\frac{\pi}{2}}^{\pi/2} n \cdot d\gamma}{\int_{\frac{\pi}{2}}^{\pi/2} n \cdot \cos\alpha \cdot d\gamma} \tag{19}$$

So, for evaluation of the total moving resistance coefficient of DV with caterpillar mover and two steps of liberty it is necessary to know the law of allocation of pressure:

$$N = f(\gamma) \tag{20}$$

For practical calculations let us accept, that the pressure on the teeth is allocated by the order:

$$N = \text{const}$$

$$N = n \cos \gamma \tag{21}$$

Let us put these values $N\gamma$(20) and we will get:

$$f_c = 1,27\, f \tag{22}$$

Within displacement of pool to teeth of conduct star full part of touch draft power deviated from the line, which was passed through the center of the star to corner ρ (Fig. 8)

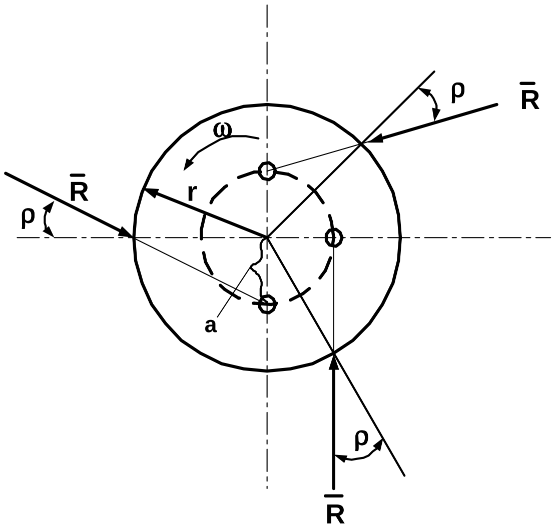

Fig. 8. The scheme of touch draft power full part deviation *R* = *Pon*.

Let us continue the line of reaction activity *R* and omit to this line perpendicular from center of conduct star 0.

The size of this perpendicular equals:

$$a = r \sin \rho \tag{23}$$

The size *a*, which was proposed to call pale of tangent draught force *P∂*.

With the aim of approbation of the received mathematical dependences (20) and (23) was created a draught vehicle on the base of tractor MT3–142 and transport module; the reliability of theoretical conclusions was shown by test.

CONCLUSIONS

1. Tangent draught force of draught vehicle is proportional to normal reaction of basic surface.
2. General resistance force accounted by total reaction, which is directed under the corner of sliding to normal reaction of basic surface.
3. Total coefficient of moving resistance depends on the size of normal reaction, place of its application and geometrical dimensions of caterpillar chain parts.
4. In order to escape big losses of energy to moving of draught vehicle it is necessary to give to it an additional step of liberty relatively to caterpillar chain

5. At the conduct star exists a theoretical circle of tangent draught force.

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