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ELEMENTS OF THE THEORY OF A MILITARY VEHICLE WITH A PERMANENTLY DEVELOPED WHEEL DRIVE

The working process of the car is accompanied by the load of the wheel drive by the gravitational force, which leads to a delay in the movement of the rotation of the tire during its deformation, as well as a decrease in the power transmitted to the power to the wheel drive. The article deals with the research of the elements of the theory of a military vehicle with a permanently developed wheel drive using the Lagrange equation, as well as the theorem on the change in kinetic energy of such a wheel drive. The purpose of the study is to improve the technological scheme of loading the wheel drive (permanently developed wheel drive) with the developed transfer of energy to the wheel drive due to the kinematically connected moving wheel, the transformation of the energy supplied to the wheel drive into the controlled relative to the center of its hub and with assembly traction force of the car with the carrying force, which is an auxiliary factor to the innovative technology of its movement.

The scientific and practical direction of the work consists in the fact that for the first time the technology was considered, in which the law of change of mechanical energy is applied during the rotation of the wheel drive on the road by applying a permanently developed wheel drive, and this allows a more expedient approach to the consideration of the implementation of the torque on the wheel drive.

The research methodology was to establish a mathematical relationship between the speed of the cyclic movement of the additional wheel, which is associated with the center of the car wheel hub, and this allows to increase the dynamic mobility of the car directly.

The result of the research is the development of the elements of the theory of a military vehicle with a permanently developed wheel drive, which allows to develop a design of a permanently developed wheel drive and to increase the dynamic mobility of the vehicle directly.

The value of the conducted research, the results of the conducted work will allow to make a contribution to the automotive industry.

The proposed model of a car with a permanently developed wheel drive is suitable for use in order to effectively implement engine power and convert it into traction force on the wheel.

Key words: *physical-mathematical model, force, permanently developed wheel drive, wheel, moment of inertia, kinetic energy.*

Formulation of the problem. The kinetic energy of the car's gradual movement can be an indicator of its energy level. When the technical condition of the car deteriorates, greater (than for a technically sound condition) engine energy consumption is required to maintain the given level of kinetic energy of the gradual movement of the car. At a fixed speed, the car's speed fluctuates relative to its average value. Fluctuations and levels of kinetic energy resulting in additional engine energy consumption.

Highlighting previously unresolved parts of the overall problem

The level of kinetic energy of the car's gradual movement can be an indicator of the car's energy load. Previously conducted studies between kinetic energy and additional energy consumption during car movement show the existence of a relationship between them.

Setting objectives. It is necessary to solve the problem of choosing and substantiating indicators that affect the implementation of energy indicators of the technical capabilities of the car.

Presentation of the main research material

We consider a system with a permanently developed wheel drive as a system with two degrees of freedom, (fig. 1).

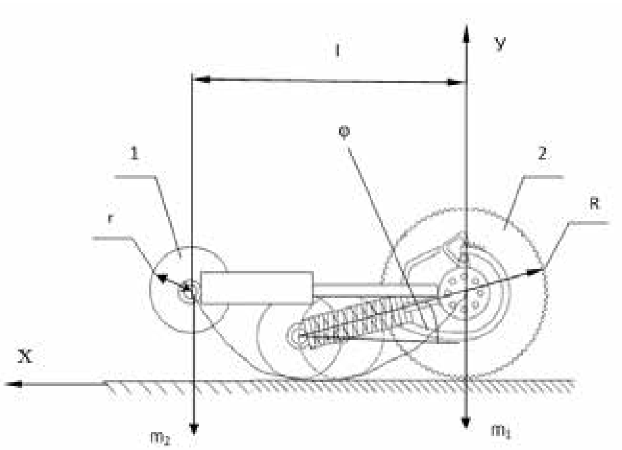

Fig. 1. A system with a permanently developed wheel drive

We tie the coordinate axes directly to the permanently developed wheel drive. As generalized coordinates, we choose the abscissa X of point C and the angle φ of deviation of point K, which is located on the flexible element, from its initial state. In accordance with this, two Lagrange equations are formed for a system with a permanently developed wheel drive. [3, p. 19]

The attachment to the beam of the bridge of the permanently developed wheel drive to the military vehicle is shown in (fig. 2).

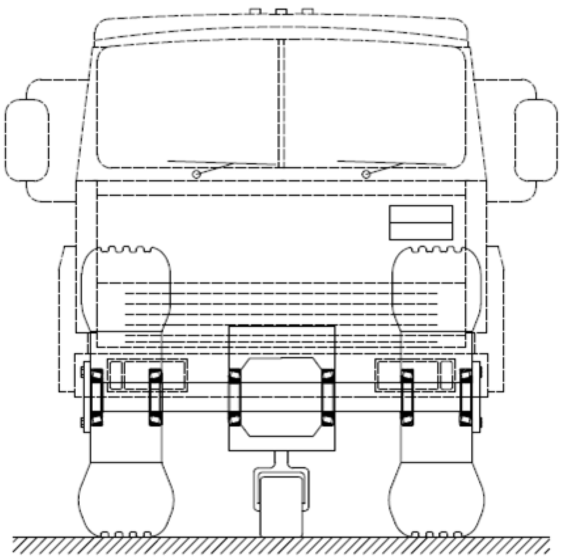

Fig. 2. General appearance of a military vehicle with permanently developed wheel drive

The attachment to the hub of the wheel of a permanently developed wheel drive to a military vehicle is shown in (fig. 3).

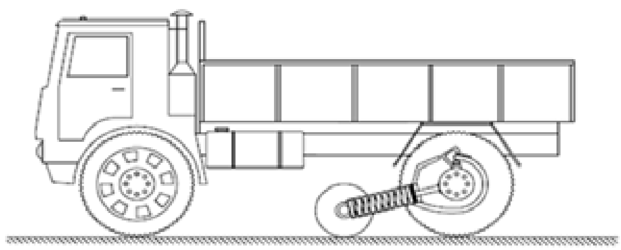

Fig. 3. A military vehicle with permanently developed wheel drive

In figure 4. shows a separate permanent-developed wheel drive, which has a mechanical connection with the beam of the driving bridge.

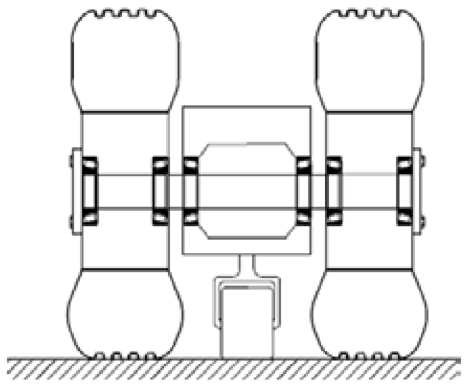

Fig. 4. A permanently developed wheel drive is separately allocated, which has a mechanical connection with the beam of the driving bridge.

To solve the problem of the movement of a military vehicle with a permanently developed wheel drive, consider the physical and mathematical model of this vehicle, (fig. 5), which is closely related to the system with a permanently developed wheel drive, (fig. 1). [4, p. 22-29]

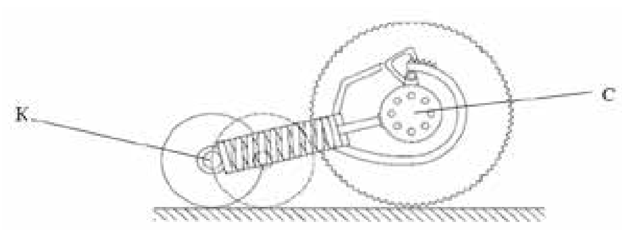

Fig. 5. Physical model of a permanently developed wheel drive

A system with two degrees of freedom is considered. As generalized coordinates, we will choose the abscissa x of the point C of the wheel drive and the angle φ of the deviation of the SC rod from the vertical position.

For the selected system, we will add two Lagrange equations [1, p. 480]:

$$\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{x}}\right) \cdot \frac{\partial T}{\partial x} = Q_X \qquad (1)$$

$$\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{\varphi}}\right) - \frac{\partial T}{\partial \varphi} = Q_\varphi \qquad (2)$$

We denote the total mass of the wheels of wheeled vehicle 1 by m[1], and the mass of wheel 2 with a center at point K by m[2],

Let's find the kinetic energy T of the formed system:

– kinetic energy T_1 of the wheels of the wheel drive 1;

– kinetic energy T_2 of wheel 2;

$$T_1 = \frac{m_1 V_c^2}{2} + I_C \frac{\omega_1^2}{2} \qquad (3)$$

$$T_2 = \frac{m_2 V_K^2}{2} + I_K \frac{\omega_2^2}{2} \qquad (4)$$

where

V_C and V_K speeds of points C and K;

ω_1 – angular speed of the wheels of the wheel drive 1;

ω_2 – angular speed of wheel 2;

I_C is the moment of inertia of the wheels of wheel drive 1 relative to the axis of rotation that passes through point C;

I_K is the moment of inertia of wheel 2 relative to the axis of rotation that passes through point K.

So,

$$T = T_1 + T_2 = \frac{m_1 V_C^2}{2} + \frac{y_C \omega_1^2}{2} + \frac{m_2 V_K^2}{2} + \frac{y_K \omega_2^2}{2} \qquad (5)$$

We mean

$$V_C = \dot{X};\ V_K = \dot{X};\ y_C = \frac{m_1 R^2}{2};\ y_K = \frac{m_2 r^2}{2}; \qquad (6)$$

$$\omega_1 = \frac{V_C}{R} = \frac{\dot{X}}{R};\ \omega_2 = \frac{V_K}{r} = \frac{\dot{X}}{r} \qquad (7)$$

R is the radius of the wheels of wheeled vehicle 1; r is the radius of wheel 2.

Let's represent the speed of point K through generalized coordinates

To determine the speed of movement of point K, we determine its Cartesian coordinates Xk and Уk through the selected generalized coordinates:

$$X_K = X + L\sin\varphi \qquad (8)$$

$$y_K = L \cdot L\cos\varphi \qquad (9)$$

The derivative of these formulas

$$\dot{X}_K = \dot{x} + l\cos\varphi\dot{\varphi};\ \dot{y}_K = -l\sin\varphi\dot{\varphi} \qquad (10)$$

So,

$$\begin{aligned} V_K^2 &= X_K^2 + Y_K^2 = (\dot{x} + l\cos\varphi\cdot\dot{\varphi})^2 + l^2\sin^2\varphi\dot{\varphi}^2 = \\ &x^2 + 2\dot{x}\cdot l\cos\varphi\dot{\varphi} + l^2\cdot\cos^2\varphi\dot{\varphi}^2 + l^2\sin^2\varphi\cdot\dot{\varphi}^2 \\ &= x^2 + 2\dot{x}\cdot l\cos\varphi\cdot\dot{\varphi} + l^2\cdot\dot{\varphi}^2(\cos^2\varphi + \sin^2\varphi) \\ &= \dot{x}^2 + l^2\cdot\dot{\varphi}^2 + 2\dot{x}\cdot l\cdot\cos\varphi\cdot\dot{\varphi} \end{aligned} \qquad (11)$$

Let's substitute the expressions of the components included in the equation for kinetic energy [2, p. 196].

$$T = \frac{m_1 x^2}{2} + \frac{1}{2}m_1 R^2 \frac{\dot{x}^2}{2R^2} + \frac{m_2}{2}\left(\dot{x}^2 + l^2\dot{\varphi}^2 + 2\dot{x}\cdot l\cos\varphi\dot{\varphi}\right) + \frac{1}{2}m_2 r^2\frac{x^2}{2r^2} = \frac{1}{2}\left[\left(\frac{3}{2}m_1 + \frac{3}{2}m_2\right)\dot{x}^2 + m_2 l\left(l\dot{\varphi}^2 + 2\dot{x}\dot{\varphi}\cos\varphi\right)\right] \qquad (12)$$

Let's calculate the generalized force, the time derivative of the kinetic energy:

For the generalized coordinate x:

$$\begin{aligned} &x_0 = 0; \\ &\dot{x}_0 = 0; \\ &\varphi_0 = 0; \dot{\varphi}_0 = 0 \end{aligned} \qquad (13)$$

For the generalized coordinate φ:

$$\frac{\partial T}{\partial \dot{\varphi}} = m_2 l\left(l\dot{\varphi} + \dot{x}\cos\varphi\right); \qquad (14)$$

$$\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{\varphi}}\right) = m_2 l\left(l\dot{\varphi} + \ddot{x}\cos\varphi - \dot{x}\dot{\varphi}\sin\varphi\right); \qquad (15)$$

$$\frac{\partial T}{\partial \varphi} = -m_2 l\dot{x}\dot{\varphi}\cdot\sin\varphi \qquad (16)$$

The generalized forces Qx and Qφ, with respect to the generalized coordinates, are found using the following formulas:

– forces P1X and P2X are perpendicular to all, and therefore P1X = P2X=0.

– forces P1 and P2 are parallel to the y axis, and therefore P1y and P1; P2y and P2.

Coordinates $y_c = 0$, since the force P1 is applied at point C.

Coordinates : $y_k = 1\cdot\cos\varphi$.

Then the generalized forces Qx and Qφ will be tied to the formulas:

$$Q_X = P_1\frac{\partial y_c}{\partial x} + P_2\frac{\partial y_k}{\partial x} = 0. \qquad (17)$$

$$Q_\varphi = P_1\frac{\partial y_c}{\partial \varphi} + P_2\frac{\partial y_k}{\partial \varphi} = -P_2 l\sin\varphi = -m_2 gl\sin\varphi \qquad (18)$$

At the same time, taking into account that the wheel drive of a car with a movable wheel relative to the cell K is under the influence of weight forces P1 and P2, which exist as a force function for the car, then the force function for these forces will be written in the form:

$$L = P_1 y_c + P_2 y_k = P_2 l\cos\varphi \qquad (19)$$

so,

$$Q_x = \frac{\partial L}{\partial x}; Q_\varphi = \frac{\partial L}{\partial \varphi} = -P_2 l\sin\varphi = -m_2 gl\sin\varphi. \qquad (20)$$

Lagrange's equations take the form:

$$\left(\frac{3}{2}m_1 + \frac{3}{2}m_2\right)\ddot{x} + m_2 l\left(\varphi\cos\varphi - \dot{\varphi}^2\sin\varphi\right) = 0 \qquad (21)$$

$$l\varphi + \dot{x}\cos\varphi\cdot g\sin\varphi = 0. \qquad (22)$$

We will take into account that the cell K of the moving wheel deviates from the cell t. C of the wheel drive of the car, and therefore Lagrange's equations take the form:

$$\left(\frac{3}{2}m_1+\frac{3}{2}m_2\right)x+m_2l\varphi=0 \qquad (23)$$

$$x+l\varphi+g\varphi=0. \qquad (24)$$

From the first equation, we select the generalized coordinate:

$$X=-\frac{m_2 l}{\frac{3}{2}m_1+\frac{3}{2}m_2}\varphi \qquad (25)$$

Having integrated this equation, we get

$$X=-\frac{m_2 l}{\frac{3}{2}m_1+\frac{3}{2}m_2}\varphi+C_1 \qquad (26)$$

The second integration makes this equation look like this;

$$X=-\frac{m_2 l}{\frac{3}{2}m_1+\frac{3}{2}m_2}+C_1t+C_2 \qquad (27)$$

The function of the generalized coordinate φ is the most decisive in creating (giving) dynamism and power to the wheel drive. To determine this function from Eqs into formula (24) and formula (25):

$$\frac{m_2 l}{\frac{3}{2}m_1+\frac{3}{2}m_2}\varphi+\lg+g\varphi=0. \qquad (28)$$

or

$$\frac{3}{2}m_1l\varphi+\left(\frac{3}{2}m_1+\frac{3}{2}m_2\right)g\varphi=0 \qquad (29)$$

finally:

$$\varphi+\left(1+\frac{m_2}{m_1}\right)\frac{g}{l}\varphi=0. \qquad (30)$$

let's enter the notation:

$$\left(1+\frac{m_2}{m_1}\right)\frac{g}{l}=n^2 \qquad (31)$$

Then the equation into formula (30) takes the form

$$\ddot{\varphi}+n^2\varphi=0. \qquad (32)$$

The general solution of this equation will have the form:

$$\varphi=C_3\cos nt+C_4\sin nt \qquad (33)$$

Derivative 3 of this equation has the form:

$$X=C_1t+C_2-\frac{m_2 l}{\frac{3}{2}m_1+\frac{3}{2}m_2}(C_3\cos nt+C_4\sin nt) \qquad (34)$$

The obtained equations, which are tied to the generalized coordinates x and φ from time t, determine the dynamics of the car wheel and the force on the wheel drive of the car.

Let's define the free constants: C_1, C_2, C_3, C_4 at t=0, we have:

$$X_0=-\frac{m_2 l}{\frac{3}{2}m_1+\frac{3}{2}m_2}\varphi_0+C_1; \qquad (35)$$

$$\dot{X}_0=\frac{m_2 l}{\frac{3}{2}m_1+\frac{3}{2}m_2}\dot{\varphi}_0+C_1; \qquad (36)$$

let:

$$x_0=0;\ \dot{x}_0=0;\ \text{but}\ \varphi_0=0;\ \dot{\varphi}_0=0. \qquad (37)$$

then

C1=0; $n=\sqrt{\left(1+\frac{m_2}{m_1}\right)\frac{g}{l}}=\sqrt{\left(1+\frac{P_2}{P_1}\right)\frac{g}{l}}$; C3=φ0; C4=0 (38)

Therefore, the final equation takes the form:

$$\varphi=\varphi_0\cos nt$$

$$X=\frac{m_2 l\varphi_0}{\frac{3}{2}m_1+\frac{3}{2}m_2}(1-\cos nt) \qquad (39)$$

where

$$n=\sqrt{\left(1+\frac{m_2}{m_1}\right)\frac{g}{l}}=\sqrt{\left(1+\frac{P_2}{P_1}\right)\frac{g}{l}} \qquad (40)$$

Conclusions

1. The proposed scientific and methodological approach allows to increase the level of technical use of the energy indicators of the wheel drive of the car.

2. The proposed permanently developed wheel drive allows to increase the efficiency of using the power of the car engine to overcome the forces of external resistance to its movement, and thus, with the help of the generated kinetic energy of gradual movement, it is possible to determine the rational speed of the car, at which the task of the work process is more efficiently performed.

3. The maximum value of the efficiency of using a permanently developed wheel drive can be normalized when diagnosing a car based on energy indicators.

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Петров Л.М., Кішянус І.В., Петрик Ю.М., Нікішин В.А. ЕЛЕМЕНТИ ТЕОРІЇ ВІЙСЬКОВОГО АВТОМОБІЛЯ З ПЕРМАНЕНТНО-РОЗВИНУТИМ КОЛІСНИМ РУШІЄМ

Робочий процес автомобіля супроводжується навантаженням колісного рушія гравітаційною силою, що приводить до затримки руху обертання шини при її деформації, а також зменшення потужності, яка передається потужності на колісний рушій. В статті розглянуті питання дослідження елементів теорії військового автомобіля з перманентно-розвинутим колісним рушієм з застосуванням рівняння Лагранжа, а також теореми про зміну кінетичної енергії такого колісного рушія. Метою дослідження є удосконалення технологічної схеми навантаження колісного рушія (перманентно-розвинутим колісним рушієм) при розвинутої передачі енергії на колісний рушій за рахунок кінематично-пов'язаного з ним рухливого колеса, перетворення енергії підведеної до колісного рушія в керований відносно осередком його маточини та зі складанням тягового зусилля автомобіля з переносною силою, яка є допоміжним фактором до інноваційної технології його переміщення.

Науковий та практичний напрям роботи полягає в тому, що вперше розглянута технологія в якій при обертанні колісного рушія по дорозі застосовано закон зміни механічної енергії шляхом застосування перманентно-розвинутим колісним рушієм, а це дозволяє більш доцільно підійти до розгляду реалізації крутного моменту на колісному рушії.

Методологією дослідження являлося встановити математичний зв'язок між швидкістю циклічного переміщення додаткового колеса, яку пов'язано з осередком маточини автомобільного колеса, а це дозволяє підвищити динамічну рухливість безпосередньо автомобіля.

Результатом дослідження є розробка елементів теорії військового автомобіля з перманентно-розвинутим колісним рушієм що дозволяє розробити конструкцію перманентно-розвинутого колісного рушія і підвищити динамічну рухливість безпосередньо автомобіля.

Цінність проведеного дослідження, результати проведеної роботи дозволять зробити внесок в галузь автомобільного виробництва.

Запропонована модель автомобіля з перманентно-розвинутим колісним рушієм придатна для використання з метою ефективної реалізації потужності двигуна з перетворенням її в тягове зусилля на колесі.

Ключові слова: *фізико-математична модель, сила, перманентно-розвинутим колісним рушієм, колесо, момент інерції, кінетична енергія.*