ОЗБРОЄННЯ ТА ВІЙСЬКОВА ТЕХНІКА

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Petrov L. M., Candidate of Technical Sciences,
Associate Professor, Teacher
Odesa Military Academy
ORCID: 0000-0001-5709-9986

Kishianus I. V., Senior Lecturer
Odesa Military Academy
ORCID: 0000-0001-7838-5607

Petryk Yu. M., Senior Lecturer
Odesa Military Academy
ORCID: 0000-0003-4589-4282

Nikishyn V. A., Teacher
Odesa Military Academy
ORCID: 0000-0003-2737-403X

Sheluhin S. V., Candidate of Technical Sciences,
Senior Research Fellow, Associate Professor
Odesa Military Academy
ORCID: 0000-0003-4417-4283

STRUCTURAL IMPROVEMENT OF THE WHEEL DRIVE OF A MILITARY VEHICLE

The movement of the car is carried out due to the loading of the wheel driver by forces: gravitational force and tangential force of traction, which sometimes leads to a delay in the movement of the rotation of the tire during its deformation, as well as to the incomplete realization of the power created by the engine and which is transmitted to the wheel driver. The article examines the questions and presents elements of the theory of a military vehicle with a structural improvement of the wheel drive of a military vehicle, as well as theorems on the change in kinetic energy of such a wheel drive.

The technological diagram of the developed and improved design of the wheel drive allows the process of transferring the motion of the car to be carried out at the expense of the kinematically connected with it movable additional wheel, the transformation of the energy supplied to the wheel drive into the controlled relative to the center of its hub and with the addition of the traction force of the car with the transfer 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 is considered in which the law of change of mechanical energy is applied during the rotation of the wheel drive on the road by using the wheel drive with an additional wheel kinematically connected to it.

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 study is the development of elements of the theory of a military vehicle with a new design of a wheel drive with an additional wheel kinematically connected to it, which allows 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 new design of a wheel drive with an additional wheel kinematically associated with it 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, wheel drive with an additional wheel kinematically associated with it, wheel, gravitational and tangential force, moment of inertia, kinetic energy.*

Петров Л. М., Кішянус І. В., Петрик Ю. М., Нікішин В. А., Шелухін С. В. Конструкційне удосконалення колісного рушія військового автомобіля

Рух автомобіля здійснюється завдяки навантаженню колісного рушія силами: гравітаційною силою та дотичною силою тяги, що іноді приводить до затримки руху обертання шини при її деформації, а також не повною реалізації *потужності, яку створює двигун і яка передається на колісний рушій. В статті розглянуті питання та приведенні елементи теорії військового автомобіля з конструкційним удосконаленням колісного рушія військового автомобіля, а також теореми про зміну кінетичної енергії такого колісного рушія.*

Технологічна схема розробленої удосконаленої конструкції колісного рушія дозволяє процес передачі руху автомобілю здійснювати за рахунок кінематично-пов'язаного з ним рухливого додаткового 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 колісного рушія з кінематично-пов'язаним з ним додатковим колесом.

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 новою конструкцією колісного рушія з кінематично-пов'язаним з ним додатковим колесом що дозволяє підвищити динамічну рухливість безпосередньо автомобіля.

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

Запропонована модель автомобіля з новою конструкцією колісного рушія з кінематично-пов'язаним з ним додатковим колесом придатна для використання з метою ефективної реалізації потужності двигуна з перетворенням її в тягове зусилля на колесі.

Ключові слова: *фізико-математична модель, сила, колісний рушій з кінематично-пов'язаним з ним додатковим колесом, колесо, гравітаційна та дотична сила, момент інерції, кінетична енергія.*

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 the design of a wheel drive with an additional wheel kinematically connected to it, as a system with two degrees of freedom, (fig. 1).

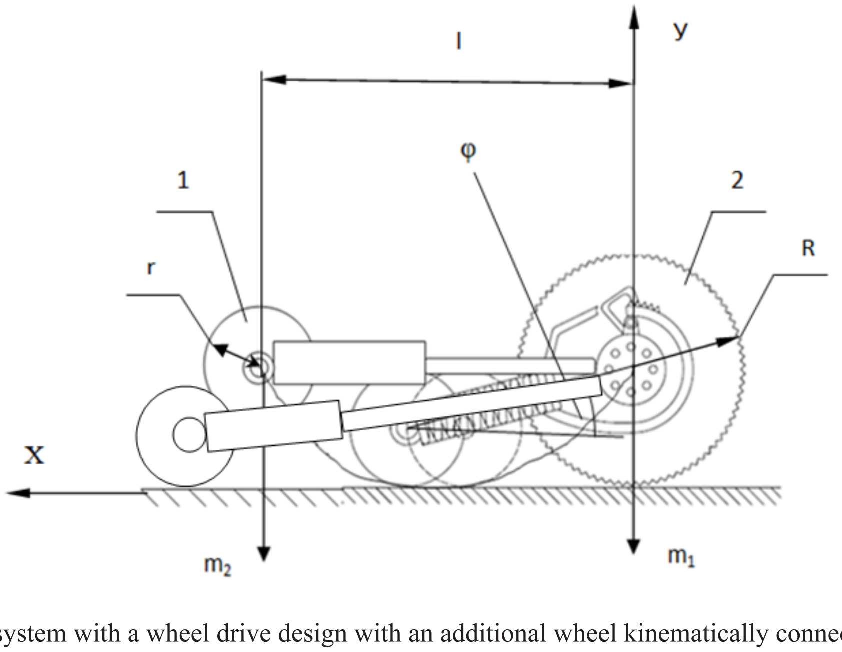

Fig. 1. A system with a wheel drive design with an additional wheel kinematically connected to it:
1 – an additional wheel, 2 – a wheel drive

Coordinate axes are tied directly to the wheel drive with an additional wheel kinematically connected to it. We choose the abscissa as the generalized coordinates

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 of a wheel drive with an additional wheel kinematically connected to it [3, p. 99–103].

Bridge beam attachment of a wheel drive with a kinematically associated additional wheel to a military vehicle is shown in (fig. 2). [2, p. 25].

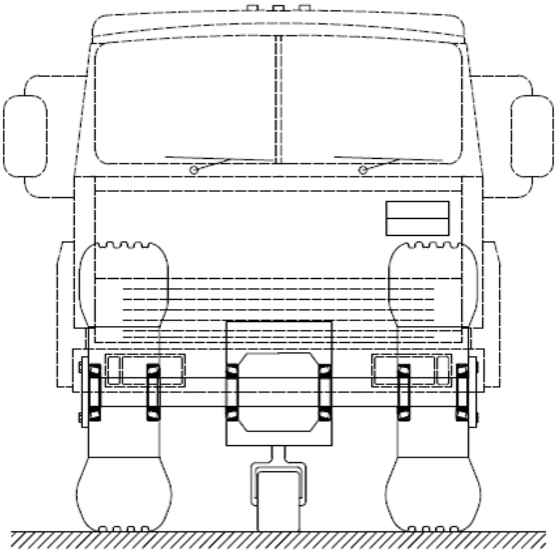

Fig. 2. General view of a military vehicle with an additional wheel kinematically associated with it

The attachment to the wheel hub by the kinematically-related additional wheel wheel to the military vehicle is shown in (fig. 3).

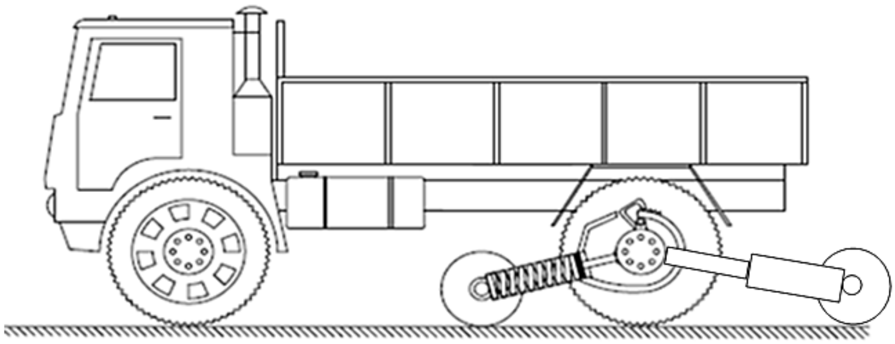

Fig. 3. A military vehicle with an additional wheel kinematically associated with it

In figure 4 shown separately by a kinematically-related additional wheel drive, which has a mechanical connection with the beam of the driving bridge.

To solve the problem of the movement of a military vehicle with an additional wheel kinematically associated with it, consider the physical and mathematical model of this vehicle in (Fig. 5), which is closely related to the system with an additional wheel kinematically associated with it, (Fig. 1).

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.

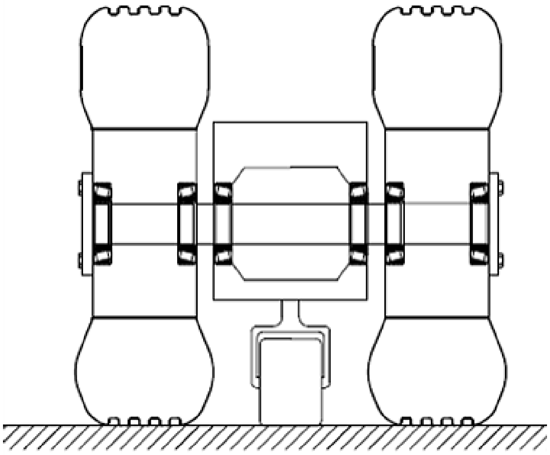

Fig. 4. A separately by a kinematically-related additional wheel wheel drive, which has a mechanical connection with the beam of the driving bridge

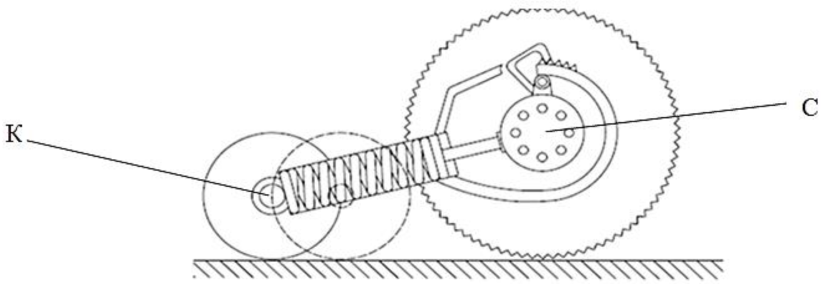

Fig. 5. A physical model of a kinematically linked wheel drive.

For the selected system, we will add two Lagrange equations:

$$\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{x}}\right).\frac{\partial T}{\partial x}=\boldsymbol{Q}_X \tag{1}$$

$$\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{\varphi}}\right)-\frac{\partial T}{\partial \varphi}=\boldsymbol{Q}_\varphi \tag{2}$$

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;

$$\boldsymbol{T}_1=\frac{\boldsymbol{m}_1 V_C^2}{2}+\boldsymbol{I}_C\,\frac{\omega_1^2}{2} \tag{3}$$

$$\boldsymbol{T}_2=\frac{\boldsymbol{m}_2 V_K^2}{2}+\boldsymbol{I}_K\,\frac{\omega_2^2}{2} \tag{4}$$

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,

$$T = T_1 + T_2 = \frac{m_1 \nu_k^2}{2} + \frac{y_c \omega_1^2}{2} + \frac{m_2 \nu_k^2}{2} + \frac{y_k \omega_2^2}{2} \quad (5)$$

We mean

$$\nu_c = \dot{x}; \;\; \nu_k = \dot{x}; \;\; Y_c = \frac{m_1 R_2}{2}; \;\; Y_k = \frac{m_2 r^2}{2}; \quad (6)$$

$$\omega_1 = \frac{\nu_C}{R} = \frac{\dot{x}}{R}; \quad \omega_2 = \frac{\nu_K}{r} = \frac{\dot{x}}{r}; \quad (7)$$

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 X_K and $У_K$ through the selected generalized coordinates:

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

$$Y_K = L \cdot L\cos\varphi \quad (9)$$

The derivative of these formulas

$$\dot{X}_K = \dot{x} + l\cos\varphi\dot{\varphi}; \;\; \dot{Y}_K = -l\sin\varphi\dot{\varphi}. \quad (10)$$

So,

$$V_K^2 = X_K^2 + Y_K^2 = \left(\dot{x} + l\cos\varphi \cdot \dot{\varphi}\right)^2 + l^2 \sin\varphi \cdot \varphi^2 = x^2 + 2\dot{x} \cdot l\cos\dot{\varphi} + l^2 \cdot \cos^2\varphi \cdot \dot{\varphi}^2 + l^2 \sin^2\varphi \cdot \dot{\varphi}^2 =$$
$$= x^2 + 2x \cdot l\cos\varphi \cdot \dot{\varphi} + l^2 \cdot \varphi^2\left(\cos^2\varphi + \sin^2\varphi\right) = \dot{x}^2 + l^2 \cdot \dot{\varphi}^2 + 2\dot{x} \cdot l \cdot \cos\varphi \cdot \dot{\varphi} \quad (11)$$

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

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

Let's calculate the generalized force, the time derivative of the kinetic energy:
For the generalized coordinate *x*:

$$x_0 = 0; \quad \dot{x}_0 = 0;$$
$$\varphi_0 = 0; \quad \dot{\varphi}_0 = 0. \quad (13)$$

For the generalized coordinate φ:

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

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

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

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

– forces P_1X and P_2X are perpendicular to all, and therefore $P_1X = P_2X = 0$.

– forces P_1 and P_2 are parallel to the y axis, and therefore P_1y and P_1; P_2y and P_2.

Coordinates $Y_C = 0$, since the force P_1 is applied at point C.

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

Then the generalized forces Q_x and Q_φ will be tied to the formulas:

$$Q_x = P_1 \frac{\partial Y_c}{\partial x} + P_2 \frac{\partial Y_k}{\partial x} = 0. \tag{17}$$

$$Q_\varphi = P_1 \frac{\partial Y_c}{\partial \varphi} + P_2 \frac{\partial Y_k}{\partial \varphi} = -P_2^l \sin\varphi = -m_2 gl \sin\varphi \tag{18}$$

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 P_1 and P_2, which exist as a force function for the car, then the force function for these forces will be written in the form:

$$L = P_1 Y_c + P_2 Y_k = P_2 L \cos\varphi \tag{19}$$

so,

$$Q_x = \frac{\partial L}{\partial x}; \quad Q_\varphi = \frac{\partial L}{\partial \varphi} = -P_2^l \sin\varphi = -m_2 gl \sin\varphi. \tag{20}$$

Lagrange’s equations take the form:

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

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

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:

$$\left(\frac{3}{2}m_1 + \frac{3}{2}m_2\right)x + m_2^l\varphi = 0, \tag{23}$$

$$x + l\varphi + g\varphi = 0. \tag{24}$$

From the first equation, we select the generalized coordinate:

$$X = -\frac{m_2^l}{\frac{3}{2}m_1 + \frac{3}{2}m_2} \cdot \varphi \tag{25}$$

Having integrated this equation, we get

$$X = -\frac{m_2^l}{\frac{3}{2}m_1 + \frac{3}{2}m_2}\varphi + C_1 \tag{26}$$

The second integration makes this equation look like this;

$$X = -\frac{m_2^l}{\frac{3}{2}m_1 + \frac{3}{2}m_2} + C_1 t + C_2 \tag{27}$$

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):

$$\frac{m_2 l}{\frac{3}{2}m_1 + \frac{3}{2}m_2}\varphi + \text{lg} + g\varphi = 0. \tag{28}$$

or

$$\frac{3}{2}m_1 l\varphi + \left(\frac{3}{2}m_1 + \frac{3}{2}m_1\right)g\varphi = 0 \tag{29}$$

finally:

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

let's enter the notation:

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

Then the equation into formula (30) takes the form

$$\ddot{\varphi} + n^2\varphi = 0. \tag{32}$$

The general solution of this equation will have the form:

$$\varphi = C_3 \cos nt + C_4 \sin nt \tag{33}$$

Derivative 3 of this equation has the form:

$$X = C_1^t + C_2 - \frac{m_2^l}{\frac{3}{2}m_1 + \frac{3}{2}m_2}\left(C_3 \cos nt + C_4 \sin nt\right) \tag{34}$$

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:

$$X_0 = -\frac{m_2^l}{\frac{3}{2}m_1 + \frac{3}{2}m_2}\varphi_0 + C_1; \tag{35}$$

$$\dot{X}_0 = \frac{m_2^l}{\frac{3}{2}m_1 + \frac{3}{2}m_2}\dot{\varphi}_0 + C_1; \tag{36}$$

let:

$$x_0 = 0; \quad \dot{x}_0 = 0\text{, but } \varphi = 0; \quad \dot{\varphi}_0 = 0. \tag{37}$$

then

$$C_1\text{=0; } n = \sqrt{\left(1 + \frac{m_2}{m_1}\right)\frac{g}{l}} = \sqrt{\left(1 + \frac{P_2}{P_1}\right)\frac{g}{l}}\text{; } C_3 = \varphi_0\text{; } C_4 = 0 \tag{38}$$

Therefore, the final equation takes the form:

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

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

where

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

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 scheme of the kinematically connected wheel drive is 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 of the kinematically connected wheel drive is developed wheel drive can be normalized when diagnosing a car based on energy indicators.

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