ELEMENTS OF THE THEORY OF DYNAMIC DEVELOPED SUSPENSION MILITARY VEHICLE

The wheel drives of a military vehicle are intended for its movement to satisfy the performance of technological tasks in the zone close to combat, but this requirement is not fully satisfied. This is related to the performance of the above tasks in difficult conditions, in off-road conditions. In order to ensure the mandatory performance and reliability of technological movements in such conditions, construction specialists focused their actions on improving the running gear, especially the suspensions.

The article deals with the theoretical research of the design of the developed suspension of a military vehicle. The movement of the car is carried out with the help of wheeled motors, which partially satisfy the performance of technological tasks in the zone close to combat.

The main drawback is the fulfillment of the requirements for moving a military vehicle in off-road conditions, and in some cases, the impossibility of moving it. In order to increase the reliability of the technology of moving a car in off-road conditions, the development of world-class specialists is aimed at improving the design of its suspension, as well as the technology of moving it in off-road conditions of a military vehicle, the number of movements of the system, and the movement of the center of mass of this system.

The purpose of the study is to improve the technological scheme of loading the wheel drive when it moves the support, the transformation of the energy supplied to the wheel drive and the quantitative movements kinematically distributed in the wheel drive into the controlled relative to the wheel disc movement of the car with the addition of the traction force of the car with the portable forces of quantitative movement, 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 considered technology in which the law of change of mechanical energy is applied during the rotation of the wheel drive over an obstacle, i.e., the energy supplied to the wheel drive and the quantitative movements kinematically distributed in the wheel drive in the controlled motion of the car relative to the wheel disc with summing up the traction force of the car with the portable forces of the quantitative movement, and this allows us to approach the consideration of the implementation of the torque
on the wheel drive more expediently. The methodology of the study was to establish a mathematical relationship between the quantitative movements kinematically distributed in the wheel drive in the car movement controlled relative to the wheel disc and the parameter of quantitative movements, as well as with the dynamic mobility of the car itself. The result of the research is the development of the elements of the theory of quantitative movements kinematically distributed in the wheel drive. When revealing the concept of "dynamically developed suspension", equations were used that mathematically confirm the connection with the quantitative movements kinematically distributed in the wheel drive in the controlled movement of the car relative to the wheel disc, which allows overcoming obstacles on the way and supporting surface in certain conditions of vehicle operation. The value of the conducted research, the results of the conducted work will allow to make a contribution to the automotive industry. The proposed car model is suitable for use in order to increase the ability of vehicles to overcome obstacles.

Key words: physico-mathematical model, force, wheel, obstacle, car.
ному рушії в керованій відносно диска колеса рух автомобіля зі складанням тягового зусилля автомобіля з переносними силами кількісного руху, яка є допоміжним фактором до інноваційної технології його переміщення.

Науковий та практичний напрям роботи полягає в тому, що вперше розглянутий закон зміни механічної енергії, тобто, енергії підведеного до колісного рушії та кількісних рухів кінематично розсереджених в колісному рушії в керованій відносно диска колеса рух автомобіля зі складанням тягового зусилля автомобіля з переносними силами кількісного руху а це дозволяє більш дотично підійти до розгляду реалізації крутого моменту на колісному рушії. Методологією дослідження являлося встановити математичний зв’язок між кількісними рухами кінематично розсередженими в колісному рушії в керованій відносно диска колеса рух автомобіля та параметром кількісних рухів, а також з динамічною рухливістю безпосередньо автомобіля.

Результатом дослідження є розробка елементів теорії кількісних рухів кінематично розсереджених в колісному рушії. При розкритті поняття «динамічно розвинута підвіска» були використані рівняння, які математично підтверджують зв’язок з кількісними рухами кінематично розсередженими в колісному рушії в керованій відносно диска рух автомобіля, що дозволяє подолання швидкої та опорної поверхні в певних умовах експлуатації автомобіля. Цінність проведеного дослідження, результати проведеної роботи дозволять зробити висновок в галузь автомобільного будівництва. Запропонована модель автомобіля придатна для використання з метою підвищення можливостей подолання перешкод транспортними засобами.

Ключові слова: фізико-математична модель, сила, колесо, перешкода, автомобіль.

Formulation of the problem

A military vehicle carrying out tasks in unprepared road conditions receives the action of external forces as well as shocks from the side of the road, which contributes to the appearance of uncontrolled movements and oscillations along the longitudinal, transverse and vertical axes. To eliminate such shortcomings, a car suspension is designed, which directly perceives the action on the car P movement, Ga and Ra (Fig. 1).

![Fig. 1. Scheme of actions of force external loads on a military vehicle](image1)

Damping of such movements in the car between the running system and the supporting system is provided by a kinematic connection – elastic suspensions and shock absorbers. With a high-quality selection and execution of such a kinematic connection, it is possible to achieve consistency of the characteristics of the elastic elements of the suspension and shock absorbers, which weakens the negative forces and impulses on comfort, safety and high-quality performance of the task.

Car suspension is a device that ensures elastic coupling of car wheels with the supporting structure of the body. In addition, the suspension regulates the position of the vehicle body during movement and helps reduce the load on the wheels. In the modern automotive world, there is a large selection of different types of car suspensions, the most popular of which are spring, pneumatic, spring and lever.

Examples of testing a military vehicle in different road conditions are shown in (Fig. 2–4).

![Fig. 2. Movement of a military vehicle in mountainous terrain](image2)

When developing the suspension structure, we suggest considering elastic elements and a vibration damping system, which not only provide comfortable movement, but also as an auxiliary factor in realizing the traction capabilities of the
car. Thanks to this combination, the suspensions should not only resist external forces by limiting their transmission to the car body, but also contribute to increasing the traction capabilities of the car.

Fig. 3. Movement of a military vehicle when overcoming a stationary obstacle

Fig. 4. Movement of a military vehicle when diagonally hung

Highlighting previously unresolved parts of the overall problem

World-class automotive experts failed to come to the conclusion that the movement of the wheel drive car can be divided into two movements: the primary movement of the car wheel in the vertical plane and the secondary movement of the car wheel in the direction of the car’s movement (Fig. 5). Taking into account the explanation to (Fig. 5), we have given a model of the power load of a military vehicle (Fig. 6).

Fig. 5. Scheme of a new approach to determining the movement of an automobile wheel drive

Fig. 6. Power load of a military vehicle

\[ P_{\text{тр}} \] – traction force MEZ; \( P_r \) – tangential traction force of the MEZ; \( P_a \) – force of rolling resistance of the wheel drive MEZ; \( P_l \) – the lifting resistance force of the MEZ;

\( P_m \) – inertia force; \( P_{\text{пр}} \) – the driving force of the MEZ; \( G_{\text{тр}} \) – operating weight MEZ;

\( P_g \) – the force of the road’s reaction to the MEZ transmission

The movement of the car is carried out with the help of wheeled motors, which partially satisfy the performance of technological tasks in the zone close to combat. The main drawback is the fulfillment of the requirements for the suspension of a military vehicle used in off-road conditions, and in some cases the impossibility of moving it. To increase the reliability of the technology of moving a car in off-road conditions, the development of world-class specialists is aimed at improving the latest models of its suspension design with the improvement of the technology of moving it in off-road conditions [1, pp. 15–16, pp. 306–307].
Setting objectives

In order to increase the reliability of the movement of a domestically produced military vehicle, we proposed the design of a dynamically developed suspension of a military vehicle and the technology of its use for a vehicle with a modernized wheel drive, the movement of which is designed to overcome various obstacles and its movement is supported by inertial components that are formed during the movement of the vehicle.

Presentation of the main research material

According to the assigned task, we have developed a diagram of a model model of a car with a dynamically developed suspension (Fig. 7), which is additional to the main spring suspension.

Fig. 7. Military truck with dynamically developed suspension

1. The car frame is modernized with dynamic elastic elements;
2. Dynamic and dynamic elements are built into the frame of the car;
3. The vertical rack is hinged on the wheel axis;
4. Vertical elastic element;
5. Movable lever;
6. The wheel drive of the car.

(Fig. 8) shows an example of the implementation and installation of a dynamically developed suspension with a wheel drive in the frame of a military vehicle.

Fig. 8. Axenometric image of a dynamically developed suspension with a wheel drive

A physico-mathematical model (Fig. 9) was created to calculate the dynamically developed suspension.

Fig. 9. Physical model of the interaction of a car wheel with a dynamically developed suspension

The dynamically developed suspension system consists of three bodies: weight OO; moving wheel; rod AB.
The amount of movement of the system will be in vector form

\[ \mathbf{K} = \mathbf{K}_1 + \mathbf{K}_2 + \mathbf{K}_3 \]  

(1)

Where, \( \mathbf{K}_1 \) amount of lever movement;
\( \mathbf{K}_2 \) the number of wheel movements;
\( \mathbf{K}_3 \) the number of movements of the AB rod.

Each of the number of movements will have a mathematical form:

\[ \mathbf{K}_1 = \frac{P_1}{g} \mathbf{V}_c \]

(2)

\[ \mathbf{K}_2 = \frac{P_2}{g} \mathbf{V}_c' \]

(3)

\[ \mathbf{K}_3 = \frac{P_3}{g} \mathbf{V}_b \]

(4)

Where, \( P_1, P_2, P_3 \) – forces that are applied according to the lever \( \mathbf{O}_1 \) moving wheel 1, rod \( \mathbf{A} \mathbf{B} \).

Then the equation of the number of movements of the system takes the form:

\[ \mathbf{K} = \frac{P_1}{g} \mathbf{V}_c + \frac{P_2}{g} \mathbf{V}_c' + \frac{P_3}{g} \mathbf{V}_b \]

(5)

Where, \( \mathbf{V}_c, \mathbf{V}_c', \mathbf{V}_b \) speed points \( \mathbf{O}, \mathbf{C}_1 \) center of gravity of the lever \( \mathbf{O}_1 \mathbf{C}_1 \), \( \mathbf{C}_2 \) – center of gravity of the rod \( \mathbf{A} \mathbf{B} \). Points \( \mathbf{O}_1 \mathbf{C}_1 \) are on the lever \( \mathbf{O}_1 \mathbf{C}_1 \), which rotates about the axis \( \mathbf{O} \), therefore vectors \( \mathbf{V}_c, \mathbf{V}_b \) perpendicular to \( \mathbf{O}_1 \mathbf{C}_1 \), and correspond to:

\[ \mathbf{V}_{c_1} = \frac{r}{2} \mathbf{\omega} \mathbf{t} \mathbf{a} \mathbf{v}_{o_1} = r \mathbf{w}. \]

(6)

We assume that the rod \( \mathbf{A} \mathbf{B} \) moves gradually, then

\[ \mathbf{V}_{c_1} = \mathbf{V} \mathbf{A}. \]

(7)

Vector \( \mathbf{V} \mathbf{A} \) directed along the rod \( \mathbf{A} \mathbf{B} \). Instantaneous center of rotation of the wheel I is at a point \( \mathbf{C} \) wheel contact I and II so

\[ \mathbf{V}_{c_1} = \frac{r}{2} \mathbf{\omega} \mathbf{t} \mathbf{a} \mathbf{v}_{o_1} = 2 \mathbf{w} \sin (\mathbf{w} \mathbf{t}). \]

(8)

Where, \( \varphi = \mathbf{w} \mathbf{t} \) – angle of rotation of the lever \( \mathbf{O}_1 \mathbf{C}_1 \).

From the ratio (3) follows

\[ \mathbf{V}_{c_1} = 2 \mathbf{v}_{o_1} \sin \varphi = 2 \mathbf{w} \sin (\mathbf{w} \mathbf{t}). \]

(9)

Corresponding projections of the number of movements of this system

\[ K_x = -\frac{P_1}{g} \mathbf{V}_c \cos \varphi = -\frac{r \mathbf{w} \mathbf{t} \mathbf{a} \mathbf{v}_{o_1}}{2g} = -\frac{r \mathbf{w} \mathbf{t} \mathbf{a} \mathbf{v}_{o_1}}{2g} \]

(10)

\[ K_y = \frac{P_2}{g} \mathbf{V}_c \sin \varphi + \frac{P_2}{g} \mathbf{V}_b \sin \varphi = \frac{P_2}{g} \mathbf{v}_{o_1} \sin \varphi + \frac{P_2}{g} \mathbf{v}_{o_1} \sin \varphi + \frac{P_3}{g} \mathbf{v}_{o_1} \sin \varphi = \frac{r \mathbf{w} \mathbf{t} \mathbf{a} \mathbf{v}_{o_1}}{2g} (P_1 + 2P) \]

(11)

Research results

Research was conducted in the Excel environment. The results of calculations of the work process of a dynamically developed suspension are shown in (Fig. 10).

Fig. 10. Display of the operation of a dynamically developed suspension of a military vehicle
Conclusions

1. When considering the article elements of the theory of the dynamically developed suspension of a military vehicle, the equation of the projection of the number of movements of the dynamically developed suspension along the X and Y axes was obtained.

2. For the first time, the influence of the number of movements of a dynamically developed suspension on increasing the traction capabilities of a military truck was revealed.

3. The additional working area is shown on the graph (Fig. 10), and begins with 5кН до 12 кН.

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