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ADVANTAGES OF HIGH-TERRAIN VEHICLE WITH ARTICULATED FRAME

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Abstract: The machine with hinged frame is widely used in the construction of automobile roads, mining and agriculture, as well as other earthworks and underground railways.The article presents the results of a theoretical analysis of the kinematics of rotation of a four-axle articulated vehicle, taking into account its design features.

Keywords:articulated vehicle, turning kinematics, layout, maneuverability, cross-country ability, productivity.

As you know, an articulated construction machine, designed for construction, loading, cleaning and other work, is a multifunctional universal equipment designed to work in confined spaces. For example, many of the functions of an articulated skid steer are determined primarily by the size of the attachment used.

The first such forklifts were developed by the American company Clark Equipment Co. in 1917 at the foundry. They were designed to transport sand as well as workpieces and were called Trutractor, which was a three-wheeled cart with a platform and a gasoline engine [1].

The Trutractor had no gearbox, no brakes, no hydraulic system, and the steering was primitive. To slow down this car, special barriers were installed on its path. Despite this, Trutractor coped with its task, which stimulated further improvements.

At the beginning of the 20th century, Ed Wagner & Sons Concrete Contractors of Portland, Oregon, in need of mechanization of concrete transportation, developed a unique autonomous concrete mixer truck called the Mixermobile.

In 1936, the Wagner family founded the Mixermobile Manufacturers company to produce these mixermobiles. In an attempt to make bucket loading more efficient, Mixermobile developed one of the world's first wheel loaders, called the Scoopmobile. The Scoopmobile featured an unusual three-wheel design (two wheels in the front and one in the back) and was steered by a rotary handle like a boat [2].

However, the Wagners' biggest contribution to the wheel loader industry came in 1953 when they introduced the Scoopmobile models LD5 and LD10. These were the world's first articulated loaders. [3].

Of course, over several decades, the design of an articulated loader has undergone significant changes, only the articulated layout has remained unchanged [4].

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The design of an articulated loader is characterized by the presence of two semi-frames, front and rear, connected to each other by a hinge. The rotation is carried out during the movement and control of the mini-loader, when one of the semi-frames, using a hydraulic cylinder, changes the angle of position relative to the other in the horizontal plane.

Thus, the rotation of the mini-loader is carried out not by the angle of the wheels, as happens with conventional wheeled mini-loaders, but by bending (fracture) in two. This allows the mini-loader to turn literally “on its heels”; thanks to the bend in the frame, small turning radii are achieved, which is especially important for equipment designed to work in cramped conditions.

As a rule, such machines have a hydrostatic transmission, and the most modern articulated mini-loaders do not even have axles as such - the flow of working fluid is transmitted directly through a hydraulic pump to four wheel motors [5].

At present, the development of road and construction engineering is associated with an increase in the production of machines with increased unit capacity for construction, serial production of machines based on powerful industrial tractors and wheeled tractors. Such machines serve to increase unit capacity, reliability and durability, improve the quality of machines in general and increase productivity.

As is known, articulated vehicles are widely used mainly in specialized work in difficult conditions: mining and underground work, road construction, agricultural work, earthworks, etc.

In addition, three-axle articulated dump trucks are used to transport light soils that do not require an armored body and reinforced suspension, as in quarry short-base dump trucks. Articulated agricultural machines were created when the requirements for the productivity of tillage operations increased significantly. So much so that even machines with improved traditional layouts became too clumsy. Due to the breakable frame, machines with articulated frames gained an advantage in maneuverability, despite their greater massiveness [6].

In addition, machines with articulated frames "bend" in the vertical plane, which ensures constant adhesion of the propellers to the ground.

This makes it possible to increase stability, controllability, cross-country ability and traction quality of machines on uneven terrain. Agricultural tractors with an articulated frame are designed specifically for use in complex earthworks.

The layout of the machines allows for a virtually ideal weight distribution along the axles and the installation of equal-sized wheels on wheeled machines, which increases the contact patch of the propellers with the ground and provides uniform pressure, improving cross-country ability and traction performance. Also, articulated vehicles are capable of converting almost all of the engine power into the traction force of the propellers [7].

If articulated wheeled vehicles are equipped with twin wheels, their already high efficiency increases even more. In practice, working with twin wheels has shown many advantages:

- reduction of ground pressure up to two times;

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- reduction of inefficient slippage;
- increase of traction force on the hook;
- higher productivity;
- lower fuel consumption.

Also, the productivity of construction and road machinery with a predominantly transport mode of operation is largely determined by their off-road capability and weak soils.

One of the ways to increase the cross-country ability of basic energy-intensive machines is to install large-sized low-pressure tires, pneumatic tires and arched tires.

However, large-size low-pressure tires, pneumatic tires and arched tires are not aggregated with standard controlled drive axles of serially produced machines. Installation of pneumatic tires leads to an increase in the distance between the axis of the kingpin and the longitudinal plane of the wheel, limits the angles of rotation around the kingpins, and also complicates the movement of machines due to an increase in the overall dimensions in width.

Therefore, the choice of the optimal design scheme of the chassis, ensuring maximum unification of the developed machines on tires of this type, is of great practical interest.

The desire to use large-diameter wheels on a vehicle (without changing the width of the frame), reduce its own weight, improve maneuverability and cross-country ability led to the creation of vehicles with an articulated breakaway frame.

The articulated chassis design allows for the installation of non-steering drive axles, large-size low-pressure tires on a standard suspension. In this case, the machine turns by relative rotation of the front and rear sections of the frame in the horizontal plane [8].

Since the articulated vehicle consists of two breakable half-frames, for the kinematic analysis each section is considered as two separate rigid bodies, and for each of these bodies a separate kinematic equation is derived. When deriving the kinematic equation of an articulated vehicle, the elasticity of pneumatic tires is taken into account only by the rolling radii of the wheels and the slip angles. All kinematic parameters, including the slip angle value, are expressed through independent coordinates and geometric dimensions [9].

Let us consider the kinematics of rotation of a four-axle articulated vehicle relative to a frame of reference associated with a flat road. In this case, we find the projections of the velocities of the coordinates of the wheel centers of the front $A_1 \ldots A_4$ and rear $B_1 \ldots B_4$ sections; the center of mass of the rear section and the articulated joint 0, on the coordinate axes

As is known, the projection of the velocity on the axis is equal to the time derivative of the corresponding coordinate.

Taking into account the dependence of the folding angles of the front φ_A and rear section φ_B on time relative to the road coordinates, we obtain:

For articulated joint:

$$\dot{x}_0 = \dot{x}_{C_A} + a_2 \dot{\varphi}_A \cos \varphi_A + a_1 \dot{\varphi}_A \sin \varphi_A ;$$

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$$\dot{y}_0 = \dot{y}_{C_A} + a_2\dot{\varphi}_A \sin\varphi_A - a_1\dot{\varphi}_A \cos\varphi_A . \qquad (1)$$

For the center of mass of the rear section:

$$\dot{x}_{C_в} = \dot{x}_{C_A} + \varphi_A\,(a_1 \sin\varphi_A + a_2 \cos\varphi_A\,) + \dot{\varphi}_B(B_1 \sin\varphi_B - B_2 \cos\varphi_B)\,;$$

$$\dot{y}_{C_в} = \dot{y}_{C_A} - \varphi_A\,(a_1 \cos\varphi_A + a_2 \sin\varphi_A\,) + \dot{\varphi}_B(B_1 \cos\varphi_B + B_2 \sin\varphi_B). \qquad (2)$$

Based on the projection of the velocities of the wheel coordinate centers of the front and rear sections, expressions for the tangents of the wheel slip angles can be obtained. These angles can be obtained as the difference between the wheel center velocities $\dot{x}_{A_1}...\dot{x}_{A_4}$ with the x-axis and the angles φ_A, φ_B formed by the geometric axes of the sections x_{C_A}, y_{C_A} , $x_{C_в}$ and $y_{C_в}$ with the same x axis from the following relationships:

for each wheel of the front section

$$\operatorname{tg}\alpha_1 = \frac{\dot{y}_{A_1}}{\dot{x}_{A_1}};\,.\;.\;.\;.\;.\;.\;.\;.\;\operatorname{tg}\alpha_4 = \frac{\dot{y}_{A_4}}{\dot{x}_{A_4}}, \qquad (3)$$

for each rear section wheel

$$\operatorname{tg}\beta_1 = \frac{\dot{y}_{B_1}}{\dot{x}_{B_1}};\,.\;.\;.\;.\;.\;.\;.\;.\;\operatorname{tg}\beta_4 = \frac{\dot{y}_{B_4}}{\dot{x}_{B_4}}. \qquad (4)$$

Thus, as a result of the theoretical analysis of the kinematics of the articulated machine, a system of equations was obtained that describes the kinematics of the main points of the machine depending on the design parameters for all cases (straight and turning) of movement and the nature (plane-parallel, flat and inclined) of the support surface.

The implementation of the obtained system of kinematic equations in combination with the equations of the dynamics of an articulated machine, using a computer system, would allow the designer-researcher to select the most effective machine configuration, taking into account its operational properties, even at the pre-design stage.

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