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RESISTANCE FORCES AFFECTING AUTOMOBILE MOVEMENT ON THE ROAD

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Abstract. This article analyzes the key factors ensuring the safe and efficient movement of vehicles on modern highways. Automobile movement is a complex mechanical process influenced by road conditions, the technical characteristics of the vehicle, and the driver's factor. The study highlights the influence of rolling resistance, air resistance, lifting resistance, and inertia forces on motion. The results are important for road design and traffic optimization, contributing to increased safety and efficiency.

Keywords: car, motion, rolling, resistance, aerodynamic, speed, inertia force, coefficient.

INTRODUCTION

All elements of modern highways must ensure the safe operation of vehicles at design speeds. The higher the traffic intensity on the road, the greater the mutual interference of the cars and the lower their speeds [1]. Therefore, requirements for individual elements of the route are established based on the conditions for the movement of a single vehicle on the road. A moving car moves along a road in a complex system: it moves forward along a straight line, rotates around its vertical axis when moving along curves, oscillates in longitudinal and transverse directions when wheels pass over surface irregularities, and so on. All these features cannot yet be fully taken into account when designing roads [2,3]. Therefore, when justifying requirements for road elements in plan and profile, it is assumed that the vehicle moves without oscillations on a flat, solid surface.

LITERATURE REVIEW

The patterns of vehicle movement on modern highways have been studied by many domestic and foreign scientists. In particular, Uzbek scientists A. Kadyrov, B. Khudoyberdiev, and Sh. Ergashev's works extensively cover the geometric elements of highways and their impact on the safety of traffic flow. In these studies, the quality of the road surface and the parameters of the longitudinal and transverse profile are considered factors directly influencing transport speed.

Also, in domestic research, issues of rolling resistance and energy losses depending on the type of road surface occupy an important place. In this regard, the technical condition of the road and the operational characteristics of vehicles are analyzed as an interconnected system [4, 5, 6].

Among foreign scientists, L. D. Landau and E. M. Lifshitz developed the foundations of mechanics and motion theory, which serve as an important theoretical basis for explaining the dynamics of vehicles [7]. Issues of vehicle motion and aerodynamic resistance were studied in detail in the research of Hucho W. H. He substantiated the dependence of aerodynamic resistance on speed and its impact on transport efficiency [8].

Furthermore, the scientific works written by Gillespie T. D. are dedicated to a comprehensive analysis of vehicle dynamics, rolling resistance, and inertia forces. These studies are of great importance in determining what forces affect vehicles under real driving conditions [9].

METHODOLOGY

In our study, theoretical and analytical methods were used to identify and evaluate the forces acting on the vehicle's movement. First of all, the ideal conditions for driving on a road with a flat and hard surface were considered. Based on this, rolling resistance, aerodynamic resistance, lifting resistance, and inertia forces were expressed using mathematical formulas.

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RESULT AND DISCUSSION

The tractive force generated by the engine on the vehicle's driving wheels is used to overcome forces that impede movement. In general, the following resistance forces act on a vehicle moving with acceleration on an ascent: the wheel resistance (rolling friction) force R_j, the ascent resistance force R_j, the air resistance R_j, and the inertia forces of the rotating masses of the vehicle and its mechanisms arising when the speed of movement changes. Depending on the longitudinal profile of the road and the vehicle's driving mode, ascent resistance and inertia forces can be either completely absent or even have a negative sign, facilitating movement (when descending or braking at the foot of a mountain).

Rolling resistance occurs due to the expenditure of energy on the deformation of tires and the road. The main factor determining rolling resistance in flat cement concrete and asphalt concrete pavements is tire compression. On uneven surfaces (crushed stone, gravel, or paved roads), this is supplemented by wheel travel over surface irregularities. On soft-surface soil roads, resistance is caused by the forces exerted on the deformation of tires and soil during wheel tracks. When driving on hard surfaces, rolling resistance is directly proportional to the pressure exerted on the road:

$P_f=\Sigma G_i f_i$

where G_i is the load on the road from individual wheels, and

N, f_i is the rolling resistance coefficient.

There is a more complex relationship between the rolling resistance coefficient and the load on the wheel during wheel tracking on deformable soil surfaces:

$Pf = \xi\ Gi\sqrt{H/D}$

where ξ is a coefficient varying from 0.75 to I depending on the soil condition; H is the depth of the track formed after the wheel has passed; D is the diameter of the wheel.

Usually, the rolling resistance coefficient is reduced to the total weight of the vehicle, i.e., it is assumed that:

$fur=\Sigma P_f/G_{avt}$

where ΣP_f is the total rolling resistance of all wheels in the vehicle; G_{avt} is the weight of the vehicle.

Rolling resistance depends on the flatness of the coating, the speed, and the elasticity of the tires. However, when moving at speeds below 50 km/h, rolling resistance increases so slowly that the rolling resistance coefficient can be considered practically constant and has the following values:

Table 1

Coating	value of f
Cement concrete and asphalt concrete	0.01-0.02
A flat surface made of crushed stone or gravel treated with organic binders	0.02-0.025
There are small indentations made of crushed stone or gravel not treated with binders.	0.03-0.04
Paved road	0.04-0.05
Smooth, dry, and paved dirt road	0.03-0.06
Plowed land, very moist marshy soil, loose sand	0.05-0.03 and more

At speeds close to the calculated ones, the rolling resistance coefficient on smooth, hard-surface roads at a speed of υ (60< υ < 150 km/h) can be expressed as follows:

$f_\upsilon = f_0\ (1 + 4\ .\ 5*1\ 0^{-5}\upsilon^2)$

where f_0 is the rolling resistance coefficient at speeds up to 60 km/h.

CONCLUSION

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In our study, the process of vehicle movement on modern highways and the main factors influencing it were comprehensively analyzed. According to the research results, it was determined that the efficiency and safety of vehicle movement are directly dependent on road conditions, the technical condition of the vehicle, and the driver's factor. Additionally, rolling resistance, aerodynamic resistance, ascent resistance, and inertia forces were evaluated as the primary limiting factors of vehicle movement. It was noted that the sharp increase in air resistance with increasing speed significantly affects the energy consumption of vehicles.

The results obtained are of great scientific and practical importance for selecting optimal geometric parameters in road design, improving road surface quality, and effectively managing traffic flows. At the same time, it is advisable to expand this study in the future, taking into account more complex real-world traffic conditions.

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