MATHEMATICAL MODELING OF THE DYNAMICS OF A FOUR-POINT PLATFORM OF A HEAVY-DUTY VEHICLE

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I. INTRODUCTION

The suspension is designed to reduce the intensity of vibration and dynamic loads acting on a person, the cargo being transported and the structural elements of the car when it is moving on an uneven road [1].

The purpose of this work is to develop and study a model of a four-point suspension of a vehicle using the example of a heavy-duty vehicle (HDV). The choice of such an object of research is due to the fact that such vehicles \ platforms can be specialized for solving a variety of tasks with different requirements for speed and stability of movement, smoothness, permissible longitudinal transverse \ vertical overloads, etc.

II. FORMATTING MATHEMATICAL MODEL OF THE PLATFORM WITH A FOUR-POINT SUSPENSION

When constructing the mathematical model, the following assumptions were made [2]:

1. Transport platform is a solid body with a longitudinal plane of symmetry, ie. frame deformations are not taken into account;
2. The contact of wheels / tires with the road is constant and point;
3. Vibrations of the platform and wheels are small;
4. The movement of the vehicle is straight and uniform;
5. Forces of rolling resistance and air resistance not taken into account;
6. The masses of the front wheels are equal $m_1 = m_2 = m_f$, the masses of the rear wheels are equal $m_3 = m_4 = m_r$;
7. Tire damping is not taken into account, since tire damping is insignificant in comparison with suspension damping;
8. The suspensions of the right and left wheels are mirrored, matching in stiffness and damping.

The general vibration model of a vehicle is called a complete car model. Such a model, shown in Figure 1, includes vertical movement of the body x, body roll ϕ, body pitch θ, wheel deflections x_1, x_2, x_3, x_4 and independent road excitations y_1, y_2, y_3, y_4.

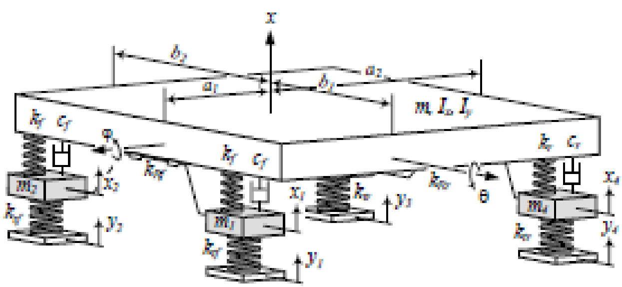

Figure 1. Four-point model of the platform

The equations of moments of inertia have the form

$$I_x = m b_1 b_2, \qquad I_y = m a_1 a_2$$

I_x – longitudinal moment of inertia of the mass, I_y – transverse moment of inertia of the mass, m – body weight, a_1 – distance from the center of gravity of the car to the front axle, a_2 – distance from the center of gravity of the car to the rear axle, b_1 – the distance from the center of gravity of the car to the left side, b_2 – the distance from the center of gravity of the car to the starboard side.

The stiffness of the front and rear tires is indicated by k_{tf} and k_{tr} respectively. The suspension of the car has rigidity k_f and damping c_f in the front and rigidity k_r and damping c_r in the back [3].

The complete vibration model of the sprung part of the platform with a four-point suspension has seven degrees of freedom and can be described by the following equations obtained on the basis of Newton's laws:

$$\ddot{m} \text{[illegible]} + c_r(\text{[illegible]}) \text{[illegible]} k_f(x - x_1 + b_1\varphi - a_1\theta) + k_f(x - x_2 - b_2\varphi - a_1\theta) + k_r(x - x_3 - b_1\varphi + a_2\theta) + k_r(x - x_4 + b_2\varphi + a_2\theta) = 0 \quad (1)$$

$$I_x \text{[illegible]} \; b_2 c_r(\text{[illegible]}) \text{[illegible]} b_1 k_f(x - x_1 + b_1\varphi - a_1\theta) - b_2 k_f(x - x_2 - b_2\varphi - a_1\theta) - b_1 k_r(x - x_3 - b_1\varphi + a_2\theta) + b_2 k_r(x - x_4 + b_2\varphi + a_2\theta) = 0 \quad (2)$$

$$I_y \ddot{\theta} - a_1 c_f(\text{[illegible]}) + a_2 c_r(\text{[illegible]}) \text{[illegible]} a_1 k_f(x - x_1 + b_1\varphi - a_1\theta) - a_1 k_f(x - x_2 - b_2\varphi - a_1\theta) + a_2 k_r(x - x_3 - b_1\varphi + a_2\theta) + a_2 k_r(x - x_4 + b_2\varphi + a_2\theta) = 0 \quad (3)$$

$$m_f \text{[illegible]} k_f(x - x_1 + b_1\varphi - a_1\theta) + k_{tf}(x_1 - y_1) = 0 \quad (4)$$

$$m_f \text{[illegible]} k_f(x - x_2 - b_2\varphi - a_1\theta) + k_{tf}(x_2 - y_2) = 0 \quad (5)$$

$$m_r \text{[illegible]} k_r(x - x_3 - b_1\varphi + a_2\theta) + k_{tr}(x_3 - y_3) = 0 \quad (6)$$

$$m_r \text{[illegible]} k_r(x - x_4 + b_2\varphi + a_2\theta) + k_{tr}(x_4 - y_4) = 0 \quad (7)$$

III. CONCLUSIONS

A mathematical vibration model of a vehicle platform with a four-point passive suspension is constructed. A computer numerical model of the vehicle platform with a four-point passive suspension is constructed. The conducted computer simulation using real numerical parameters of a specific vehicle - the KAMAZ-5490 heavy-duty vehicle showed the full operability and adequacy of the developed models.

REFERENCES

[1] Wong J.Y. Theory of ground vehicles. Third Edition. Ottawa: John Wiley & Sons, Inc, 2001.

[2] Rajesh Rajamani Vehicle Dynamics and Control. State Minnesota: Springer, 2006.

[3] Asanov A.Z. Introduction to mathematical modeling of control systems: Textbook / A.Z. Asanov. - M.: MIREA-Russian Technological University, 2019. -198 p.