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INVESTIGATION OF THE DYNAMICS OF THE TRANSMISSION OF A MOBILE CAR WITH AN 8X8 WHEEL FORMULA

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Tests are an integral part of the design, manufacturing process and operation of wheeled vehicles. A feature of bench tests of automotive equipment on "running drums" is a wide ability to control combinations of traction loads, speed modes, external influence conditions, and the steady state mode can be implemented for a long time, which allows you to perform all the necessary measurements, including those related to video and photo registration of the experiment [2]. It is noted that the advantages of type testing on stands with running drums include a wide range of possible research modes that do not depend on weather and climatic conditions, as well as the possibility of automating programs during experiments.

At the same time, it is known that the main disadvantage of bench tests of full-size cars is the discrepancy between the rolling conditions of car tires on a drum and real road surfaces, which are difficult to simulate on the surface of the drums. The solution to this problem can make testing of wheeled vehicles on the "Running Drums" stands the most preferable research method in terms of efficiency. Thus, the task of simulating road conditions at the stand is relevant. At MSTU im. N.E. Bauman developed the following approach to its solution (Figure 1a).

When running tests of a wheeled vehicle, indicators are recorded that determine the movement in given operating conditions. These parameters are input to the drive control system of the stand with running drums. The control of the drive motors of the stand is organized so that the values of the power and kinematic parameters of the vehicle dynamics, recorded during road tests, are exactly repeated in the studies on the stand. Figure 1b shows an algorithm for solving this problem using simulation mathematical modeling of the dynamics of a wheeled vehicle on a computer, i.e. the movement of real objects on the road and on the stand is replaced by the corresponding mathematical models.

The general model also includes a mathematical description of the driver's actions, which must be synchronized for the car on the road and the car on the bench, as well as a mathematical model of the bench control system, including a computing module for generating a control action on the bench drive, depending on the ratio of input parameters. a) b) The principle of control of the drive of the stand "Running drums" The problem of imitation mathematical modeling was solved for a car with an 8 × 8 wheel formula and an individual drive of propulsors. The calculation scheme of the car dynamics on the "Running Drums" stand is shown in Figure 2. Even wheel numbers correspond to the right side of the car, odd - to the left (not shown in Figure 2). As assumptions, let us imagine a holding device that prevents the car from leaving the surface of the drum, in the form of an elastic-damping connection.

Calculation scheme of the car dynamics on the stand "Running drums" In modern design of the stands, as a rule, the running drum is connected to an electric drive (Figure 3), due to which both braking torque and torque can be applied. Car on the "Running Drums" stand We will assume that the moment on the drum created by the driving electric motor of the stand can take both negative values (braking torque) and positive values (torque). Consider the definition of the quantities included in the system of equations (1).

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The longitudinal reaction of the wheel when interacting with the surface of the drum depends on the magnitude of the normal reaction and the interaction coefficient: , The surface of the drum is practically not deformable, in this regard, as the initial data for modeling, we take the same value of all given in the technical characteristics of the stand. The value should be understood as the rolling radius of the i-th wheel without slipping on the i-th drum. For a wheel-drum pair, we take S_0 = 0.04 and S_1 = 0.15. The conditions for the interaction of all wheels with the corresponding drum are the same. The moment of rolling resistance of the i-th wheel , acting in the plane of its rotation, is determined primarily by internal losses and can be approximately estimated by the dependence [5]: , (5) where: is the coefficient of resistance to rotation of the wheel on the drum. We will assume that the moment of resistance transmitted to the drum from the wheel .

(6) Normal reactions are determined from the solution of the system of equations (7): (7) where: - the sum of torques relative to the projection of the center of mass of the car on the reference plane; - height of the center of gravity of the vehicle; - the height of the application of force on the hook, - the distance from the center of mass of the car to the i-th wheel along the x axis. Additional equations for solving system (7) are based on the assumption that the ends of the normal reaction vectors lie in the same plane. To control the transmission of a wheeled vehicle with an individual drive of propellers, the law of redistribution of moments was adopted in proportion to the relative normal loads on each wheel [6].

The torque (drive) moment on the i-th wheel is determined based on the fact that the device that supplies the moment to the wheel is a traction electric motor (TEM) with a hyperbolic dependence of the torque on the output shaft on the rotational speed with restrictions on their maximum values;

the control parameter is the degree of use of the total power of all TEDs, taking into account the coefficient that determines the redistribution of normal reactions over the wheels. The value of the moment is determined by the formula: (8) where: - the maximum power of the i-th TEM; - the level of use of the total power of all the powers of the TED [0 - 1] (analogue of the "gas" pedal); n - the number of wheels of the car, - the angular velocity of the output shaft of the i-th TEM; - correction factor.

The correction factor is determined by the following formula: . (9) The following input data were adopted for TEM modeling: 1) maximum power of each TEM = 60 kW; 2) the output torque is limited to the maximum value = 39 kN·m; 3) the maximum angular speed of rotation of the wheel is = 31 rad / s (restriction on the maximum possible speed of the car). The force on the hook , which prevents the car from moving off the drum surface, can be determined taking into account the elastic-damping characteristics of the holding device: (10) where: is the coordinate of the longitudinal movement of the center of mass of the car; c is the rigidity of the holding device in the longitudinal direction; - damping coefficient of the holding device in the longitudinal direction.

We will assume that the moment on the i-th drum depends on the design parameters and control parameters and can be determined from the dependence: (11) where: - the maximum moment realized on the drum (determined by the design capabilities); - level of maximum torque on the i-th drum [-1 - 1]. Calculation scheme of vehicle movement When describing the mathematical model of the movement of an 8 × 8 vehicle with a gross weight of 60 tons, the following assumptions were made. The movement of a car as a rigid body is considered in a horizontal plane on a flat, non-deformable support surface, taking into account the angle of elevation in the direction of movement, and consists of the translational movement of the center of mass and rotational movement around the center of mass (Figure 6). The system of equations (12), which describes this movement, makes it possible to calculate the current accelerations from the values of forces and moments acting on the car.

To describe this case of vehicle movement, the following coordinate systems are introduced: fixed ; mobile associated with the body of the car; coordinate system associated with the i-th wheel (Figure 6).

(12) where: m is the mass of the vehicle; Jz is the moment of inertia of the car about the z axis; - velocity vector of the center of mass of the car; - acceleration vector of the center of mass of the car; - the vector of the angular velocity of the car; θ - the angle of rotation of the vehicle relative to the fixed coordinate system; , - coordinates of the center of mass of the car in a fixed coordinate system; - vector of the force of interaction with the ground acting on the i-th wheel; - air resistance force vector; Mpki - the moment of resistance to the rotation of the i-th wheel; - the angle of the climb (descent) to be overcome in the direction of movement. Systems of equations (1) and (12) are solved independently of each other. The coefficient of slippage for the pair "wheel - support base" when rolling in the leading mode is determined by the dependence:

Normal reactions when a car moves along the road are determined from the solution of the system of equations (14): (14) where: - the sum of torques relative to the projection of the center of mass of the car on the support base in the longitudinal plane; - the sum of torques relative to the projection of the center of mass of the car on the support base in the transverse plane; - distance from the center of mass of the car to the i-th wheel along the x axis; - distance from the center of mass of the car to the i-th wheel along the y axis; - the height of the point of application of air resistance forces. rolling conditions on the stand do not match the road conditions. In the process of simulating the movement of a car on the road, the of torques on the wheels are continuously (or with some frequency) monitored, which are determined in the same way as in the dynamics on the stand, i.e. according to formula (8).

Thus, on the stand it is possible to realize full synchronization of the drive torques that are realized when driving on the road, with the same level of power use of all TEDs, it is possible to achieve complete coincidence of the angular speeds of rotation of the i-th wheels on the stand and on the road. The coincidence in terms of drive torques and angular speeds of rotation means that the load mode that occurs when driving on the road is fully reproduced in the conditions of the stand. In the process of modeling, from the subsystems "Dynamics of the car on the road" and "Dynamics of the car on the bench", the moments and are fed into the subsystem "Model of the control system of the bench" (Figure 5). On the right side of the third equation of system (1) there are moments on the drums for each drive motor, by controlling which it is possible to achieve the coincidence of the drive moments on the wheels when rolling on the road surface and on the running drums.

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