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Vehicle Test Methods

Bahromjon Bakhtiyorovich Turgunbaev [1]

[1] MIA Malaka a teacher of the Institute of Higher Education

Abstract:

The safety of vehicles includes a complex of design and operational features that reduce the probability of accidents and the severity of consequences, as well as their harmful effects on the environment. Vehicles active, passive, post-accident and environmentalist k differ in security.

Keywords: operational properties, power and torque, laboratory tests, road tests, load-speed properties, center load, lobe area, dynamic corridor, braking system, torque inertia.

The safety of vehicles includes a complex of design and operational features that reduce the probability of accidents and the severity of consequences, as well as their harmful effects on the environment. Vehicles active, passive, post-accident and environmentalist k differ in security.

Normative documents and laws on ensuring the safety of various systems of vehicles are developed mainly by all car-producing countries. In 1958, a number of countries signed the "Agreement for Official Approval of Uniform Conditions and Mutual Recognition of Motor Parts, Equipment and Articles of Transport Vehicles" within the framework of the Committee on Inland Transport, the European Economic Commission, and the United Nations Organization for Inland Transport. According to this document, the participating states are obliged to:

development and adoption of recommendations on uniform requirements for vehicles and their separate parts, as well as indicators of testing methods;

conducting tests and verifying that the indicators of the obtained results correspond to the regulatory requirements of the developed methods.

placing an officially approved mark based on the test results of the vehicle;

internationally approved mark issued by the country that conducted the test is recognized in the territory of all agreed participating states.

Forces acting on the vehicle

In order for a vehicle to move, it must overcome the resistance forces acting on it. To do this, it is necessary to bring a traction force greater than the resistance forces to the leading wheels. Together with the traction force on the leading wheels. it is required that the force of tire contact with the ground cover does not exceed. That is , the traction force must be greater than the resistance force and less than or equal to the traction force (when the resistance forces are equal, the balance of forces occurs, the car moves at a constant maximum speed, and when the traction force is equal, the leading wheels are on the verge of slipping).

$R\ q\ _R \leq_t \leq P_i$

where, R_q is the resistance force acting on the car,

R_t is the traction force on the leading wheels,

P_i - adhesion force between the tire and the ground surface.

The forces and moments acting on the vehicle are presented in Figure 1.

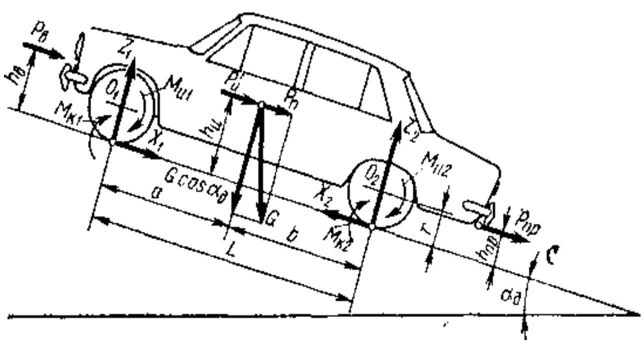

Figure 1. Forces and moments acting on the vehicle

The forces of resistance to movement: the force of resistance to rolling (rotation) of the wheels - R_f , the force of air resistance - R_w , the force of resistance in climbing - R_i , the force of inertia - Rg.

The power produced by the car's engine is used to overcome the resistance forces. The torque generated in the engine is transmitted to the driving wheels through the transmission. The wheels turn and generate a rotational force that acts on the road surface. The reaction force of the road causes the vehicle to move. All the forces acting on the car can be expressed as:

$R_t = R_f + R_w + R_i + Rg.$ (1)

where, R_t is the traction force,

R_f is the force of resistance to rolling,

R_i is the resistance of height,

R_w - air resistance,

Rg. - inertia force.

This expression is known as the gravity balance formula or force balance equation and determines how the gravitational force is distributed.

The force of resistance to rolling of the wheel is generated as a result of the impact of the tire with the road surface and is determined by the following expression:

$R_f = Ga * f * SOS\alpha$ (2)

where, R_f is the rolling resistance force,

Ha is the weight of the car,

f - coefficient of resistance to rolling of the wheel,

α - longitudinal slope of the road, grad.

The wheel rolling resistance coefficient f takes into account all the factors affecting the resistance force of the road and is equal to the following values:

asphalt in good condition - 0.015-0.018

asphalt in satisfactory condition - 0.018-0.020

gravel road - 0.020 – 0.025

paved road - 0.023–0.030

dirt road - 0.025 - 0.030

dry, sandy road - 0.100 – 0.300

ice (ice) - 0.018-0.020

The force of resistance to climb to a height (steep height). Roadways consist of horizontal, slope and elevation. The slope of the road is its angle α or is characterized by i .

$$i = \frac{H}{B} = tg\alpha \quad (3)$$

where, H is the height of the slope, m

V - the length of the slope, m

At small slopes $i = tg\ \alpha = sin\alpha$ can be considered equal.

The force of gravity of a car moving on a slope is Ga has two components: Ga *sin parallel to the slope* α and Ga cos perpendicular to the slope α we divide into forces, in this

Ri = Ga $sin\alpha$ (4)

Wheel resistance force R_f

$R_f = Ga\, f \cos\ \alpha$ (5)

Road resistance force R_y :

$R_y = Ri + R_f$ or $R_y = Ga\ sin\alpha + Ga\, f \cos\ \alpha$

This force is reversed when the vehicle moves up a slope . Slopes in the cross-sectional profile of highways can change continuously. The resistance to climbing also changes.

Air resistance. During the movement of the car, it is affected by the force of air resistance. This force is defined by the following expression:

$R_{w =} K\ FV_a{}^2$ (6)

where, K is the coefficient of air resistance,

F - the front transverse surface of the car,

And $_a$ - the speed of the car.

Inertia force. The car is affected by inertial forces during movement. The change in the speed of the car creates the inertial force. The inertial force depends on the mass and acceleration of the vehicle. The inertial force is defined by the following expression:

$$Rg = \frac{Ga}{g} j \quad (7)$$

where Ga is the weight of the car,

g - acceleration of free fall,

j - acceleration of the car.

The contact force of the wheel tire with the road surface.

As a result of the contact of the road surface with the leading wheel for the movement of the car, the contact force R_{sts} appears.

Coupling force depends on the vehicle's weight Ga, tire and road φ conditions :

$R_{sts} = Ga\ \varphi$ (8)

where, R_{sts} is the coupling strength,

Ha - the weight of the car,

φ - coupling coefficient.

The method of determining the traction-speed characteristic of the vehicle

The description of traction under laboratory conditions can be obtained on a test stand, Fig. 2.

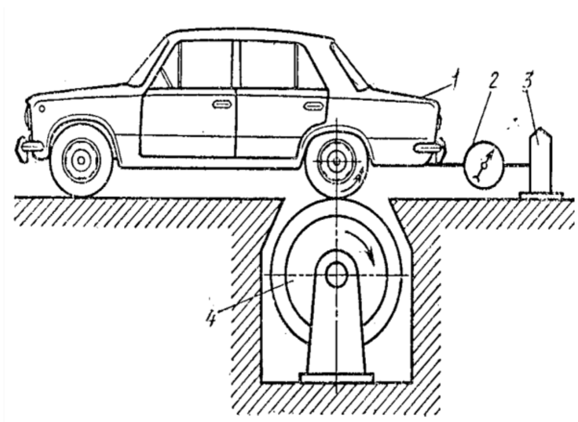

Figure 2 . Vehicle Towing Description Stand:

1 – car; 2 – dynamometer; 3 – column; 4 – rotating drum.

For testing, the leading wheels of the car are installed on the rotating drum 4, and the dynamometer 2 is fastened to the car 1 and the column 3 through a cable, Fig. 2.

When the crankshaft of the engine rotates at the maximum angular speed, a hydraulic or electric brake is used to create such a resistance on the rotating drums that the angular speeds of the rotating drums remain constant.

the angular speed ω_{k} of the leading wheels with the help of a tachometer and measuring the radius of the wheel, it is determined how fast the car can move:

$$V = \omega_{k} r, \quad (9)$$

The angular speed of the driving wheels ω_k and the angular speed of the crankshaft ω_e are related by the following equation:

$$\omega_e = \omega_k i_{tr}, (10)$$

i_{tr} is the transmission number of the transmission.

Therefore:

$$V = \omega_e r / i_{tr}, (11)$$

If the loss of energy in the rotation of the leading wheels on the rotating drums is not taken into account, since the value of the traction force is equal to the dynamometer reading, the R_t value of the traction force can be determined from the dynamometer reading.

If there are no test (experimental) values, the value of the traction force on the wheels is determined by calculating R_t, using the speed description of the engine.

the torque of the engine M_e is transmitted to the leading wheels through transmission units, its value changes proportionally to the number of transmission units. Torque M_t applied to the leading wheels when the car is moving in a plane :

$M_t = M_e i_{tr} - M_{tr}$, (12)

M_{tr} - resistance moment of the transmission

or, $M_t = M_e i_{tr} \bar{e}_{tr}$, (13)

η_{tr} – transmission F.I.K.

Traction force: $R_t = M_t / r = M_e i_{tr} \bar{e}_{tr} / r$. (14)

The method of determining the center of gravity of the vehicle

The center of gravity (h) of the vehicle, its position in the range of the base length L_a and above the support surface (point O), the distribution of the weights falling on the front axle G_1 and rear axle G_2 can be determined by weighing, Fig. 3a.

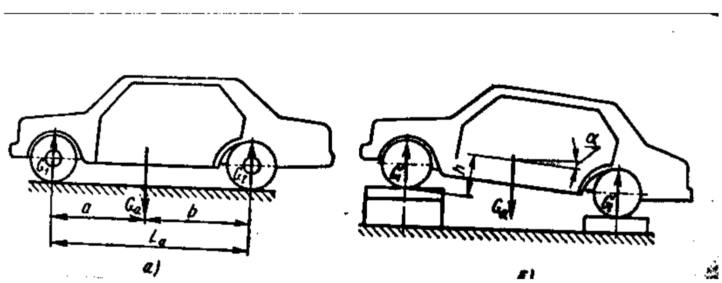

Figure 3. The scheme of determining the coordinates of the center of gravity of the car: a – in the horizontal position; b – in a vertical position.

The distance (a) from the center of the front axle to the center of gravity (O): $a = (G_2 / G_a) L_a$, (15)

Distance (b) from the center of the rear axle to the center of gravity (O):

$b = (G_1 / G_a) L_a$, (16 **)**

The method of determining the height (h) distance of the center of gravity (O), Fig. 3b.

$h = ((G_2{}^1 / G_a) L_a - a)\, ctg\, \alpha$, (17)

where, $G_1 + G_2 = G_a$.

The angle of deviation of the body in the transverse plane $\alpha \leq 6...8^{0}$

The method of determining the front transverse surface of the car

To determine the front transverse surface of the car, a scale sketch projection of the car is drawn on the vertical screen, and the surface is measured using a planimeter (surface measuring device), Fig. 4.

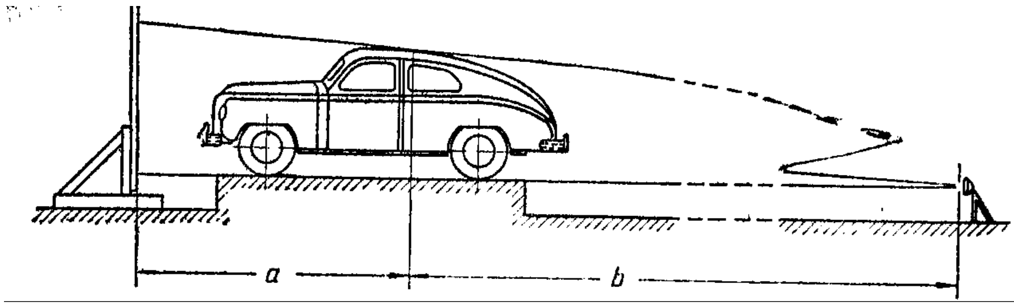

Figure 4. The method of determining the front transverse surface of the car by projecting it on the screen

The projection of the car on the screen is drawn and measured. Since the measured surface is greater than the actual surface of the car, the actual surface is calculated using the following formula:

$G' = G'^{1} (b / a + b)^{2}$, (18)

where, b is the distance between the light source and the car gauge;

a is the distance from this point to the screen;

G' is the front transverse surface of the car;

G'^{1} is the surface of the projection of the car.

In order for the measurement accuracy to be high, the light source should be installed at a distance of 50...60 m from the car.

Determining the dynamic corridor of the car

Due to the larger dynamic gauge width of automobile trains compared to individual cars, when making a right turn at intersections, they cannot occupy the farthest right lane of the carriageway, Fig. 5.

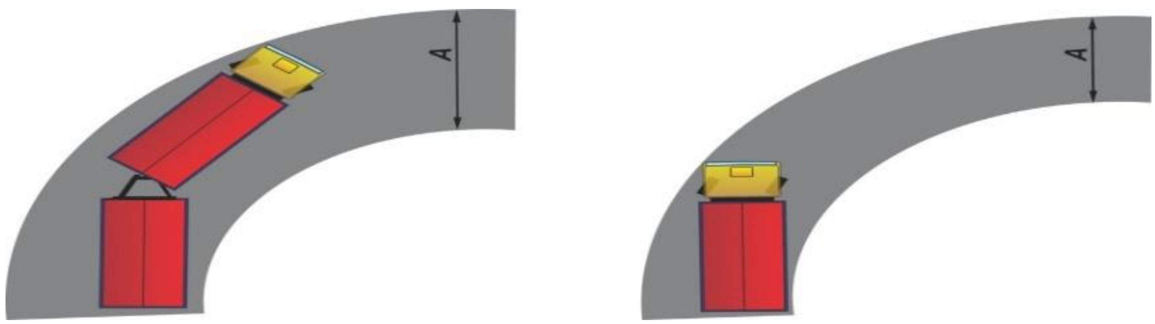

Figure 5. Dynamic gauge width: a) for a train, b) for a single car, a - dynamic gauge width

The width of the car's dynamic corridor depends on its overall dimensions and speed. In the calculations, the width of the dynamic corridor of vehicles is taken in the following recommended values: passenger cars 2.8 - 3.1m; medium weight trucks, buses 3.5 - 4.3 m; large-size trucks, largecapacity buses and auto-trains 3.7 - 4.5 m. The smallest value of the corridor width is at a speed of up to 11 m/s, the largest value is at a speed of up to 30 m/s.

The width of dynamic corridors when turning a car can be determined by the following formulas:

for a single vehicle:

$$V_k = R_n - R_v = R_n - \sqrt{R_H^2 - (L')^2 + B_a}, \quad (19)$$

where , R_n and R_v – respectively, in the turn of the car outside and

internal gauge radii;

$L' = L + C$ – from the rear axle to the edge of the front part of the car

the distance **(** L is the base of the car,

S is the distance from the front axle to the edge of the front part of the car (front "sves").

for the bus:

$$V_k \approx \sqrt{(R_a + \frac{B_a}{2})^2 + (L - C)^2} + \frac{B_a}{2} + C_k - R_0, \quad (20)$$

here, R_0 - the center of the rear axle is moving

radius of curvature of the circular trajectory;

V_a, L and S – respectively, the gauge width of the tire,

base and front "sves" ;

S_k – the back of the trailer in relation to the drawbridge

bridge shift.

When the front wheels of the car are turned to the maximum angle, the width of the dynamic corridor changes by about 1.5 times, and by about 2 times in the case of auto trains and city buses.

Testing the car's braking system

the narrow moz system is carried out in the "0", " I ", " II " modes. In cars with a pressure limiter or an anti-lock braking system (ABS) in the braking system, braking tests are additionally conducted when turning and changing lanes. The working brake system is tested in all modes, and the backup brake system is tested only in the "0" mode.

Type "0". in the mode, the brake system in the cold state is tested. The car is accelerated to such a speed that it should be greater than the initial braking speed by 3-5 km/h.

Before braking, the temperature of the braking mechanisms should not increase by 100 °C. The driver disconnects the engine from the transmission and quickly depresses the brake lever when the initial speed is reached (Effectiveness of the working brake system Cabinet of Ministers Decision No. 191 of July 4, 2012 specified in the general technical regulation on "Safety of vehicle construction under conditions of use" approved by Braking is performed until it comes to a complete stop.

Type "I" testing is carried out in the following two stages: preliminary and main. At the initial stage, brake mechanisms are heated, for example, up to 250-270 °C in passenger cars, 140-150 °C in medium-weight trucks, 170-200 °C in heavy-duty trucks. This stage is performed on a 7% slope and a distance of 1.7 km, while maintaining a constant speed of 40 km/h.

The main test stage of type "I" shall be carried out within 45 seconds after the initial control braking and the test of type "0".

In the "II" test mode, long-term braking on a slope is performed and the loss of braking torque is evaluated. The initial stage is 6 km long on a 6% slope and long-term braking at a speed of 30±5 km/h.

Additional tests are performed on vehicles with a pressure limiter or (BQT) in the braking system, with different adhesion coefficients of the left and right tires, braking in lane change mode when turning. When turning, the determination of the braking road section in the lane change mode is presented in Fig. 6.

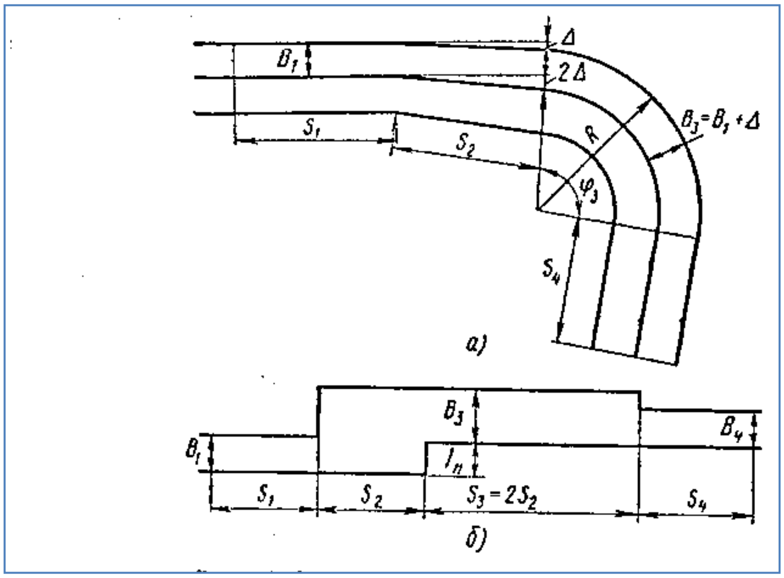

Figure 6 . Designation of road section for braking test

a – turning; b – when replacing a piece (perestavka)

The car travels the distance S $_1$ in a straight line, the width of the passage S $_2$, changing from V $_1$ to the width V $_{1}$ +Δ at the curved angle φ $_3$, and exits to the final straight road section S $_4$.

Braking when changing lanes is performed in four stages. The first stage is a control test, in the second stage - the direction of movement is changed, in the third stage - the car is directed to a new lane, in the fourth stage - straight line movement is controlled.

The method of determining the moment of inertia of the car

To determine the moment of inertia, the vehicle is mounted on a spring-loaded oscillating platform, Figure 7.

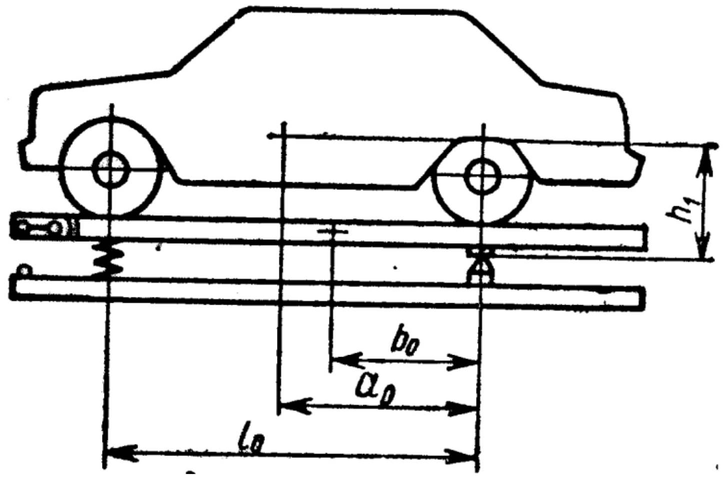

Figure 7. The scheme of determining the moment of inertia of the car

During the test, the "vehicle-platform" system is vibrated relative to the axis of the platform. The moment of inertia relative to the transverse axis of the car is determined by the following formula

$J = T_a cl_o{}^2 / 4\pi^2 – M a_0{}^2 – J_{pl} – mb_0{}^2$, (21)

where, $J_{pl} = T_p cl_o{}^2 / 4\pi^2 - mb_0{}^2$;

T_a and T_p are vibration periods of the platform with the car and the platform in the appropriate state and without the car (determined in the experiment);

s is the stiffness of the suspension spring;

l_o is the distance from the axis of the spring to the axis of vibration;

M and m are the masses of the car and the platform in the appropriate state;

b_0 – from the axis of vibration to the center of gravity of the platform the distance

a_0 - from the axis of vibration to the center of gravity of the car the distance

Jpl $_{is}$ the moment of inertia of the platform.

When choosing the stiffness and position of the spring, it is desirable if the oscillation period is equal to or greater than one second. The mass and moment of inertia of the platform should be as small as possible.

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