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THEORETICAL METHOD FOR DETERMINING PARAMETERS OF THE VACUUM BOOSTER (VB) IN AUTOMOBILE BRAKE SYSTEMS

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Abstract: Nowadays, with the increase in the number of vehicles, the demand for traffic safety is also rising. One of the ways to reduce the number and consequences of traffic accidents is to improve the technical condition of the vehicle's braking system. As a result, the use of tuning services (modification of components) is becoming more common, especially in vehicles. For instance, analyzing and selecting boosters, and determining the feasibility of installing them into other vehicles, has become a current and significant issue.

Keywords: Vacuum booster, membrane surface, push rod

Introduction: Today, to ease the driving process for the driver, boosters are being widely used. To theoretically justify the parameters of the vacuum booster (VB), mathematical calculations were conducted to determine the VB membrane surface and radius.

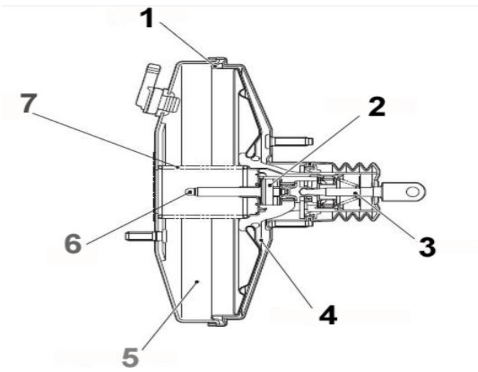

Figure 1. Vacuum booster diagram

1 - diaphragm; 2 - buffer of rod; 3 - push rod; 4 - atmospheric chamber; 5 - vacuum chamber; 6 - rod; 7 - return spring of the valve body.

The force at the vacuum chamber entrance (at the booster push rod) is determined as follows [1]:

$$P_T = P_p * U_p \qquad (1)$$

Where: P_p – force on the brake pedal, N (P_p<500 N)

U_p – transmission ratio of the brake pedal (U_p = 3.2)

The force at the vacuum booster rod (output of the vacuum chamber) is calculated as:

$$P_r = P_T + P_M \qquad (2)$$

Where: P_m – force generated by the booster membrane, N

$$P_m = (\rho_a - \rho_b) * S_m \qquad (3)$$

Where: ρ_a – pressure on the left side of the membrane, MPa

ρ_b – pressure on the right side of the membrane, (0.065 + 0.003 MPa)

S_a – membrane surface area (0,32 m²)

During braking, the force between the tire and the road is calculated as:

$$P_s = M_a * g * \varphi \qquad (4)$$

Where: M_a – vehicle mass, kg
g – gravitational acceleration (9.81 m/s²)
φ – coefficient of adhesion
The rolling resistance moment of the car wheel is:

$$P_s = M_a * g * \varphi \qquad (5)$$

Where: r_w – wheel radius, m

Force applied to the brake pad:

$$P' = \frac{M_S}{2 * \mu * r_d} \qquad (6)$$

Where: μ – friction coefficient

r_d – distance from the wheel axle to the brake pad, m

$$P' = P_r * U_{t.r} \qquad (7)$$

Force on the booster rod is calculated as:

$$P_r = P'/U_{t.r} \qquad (8)$$

The transmission ratio of the master brake cylinder is:

$$U_{t.r} = \frac{S_{w.c}}{S_{m.c}} \qquad (9)$$

From the formula above, the surface areas of the master and working cylinders are:

$$S_{w.c} = \frac{\pi * d_{w.c}}{4} \qquad S_{m.c} = \frac{\pi * d_{m.c}}{4} \qquad (10)$$

Where: $d_{w.c}$, $d_{m.c}$ – diameters of the working and master cylinders

Equating formulas (2) and (8):

$$\frac{P'}{U_{t.r}} = P_T + P_M \qquad (11)$$

Substituting formulas (1), (3), (7), (9) into (11), the membrane surface area (S_m) of the vacuum booster is determined as:

$$S_M = \frac{M_a * g * \varphi * r_w * S_{w.c} - 8 * P_p * U_p * \mu * r_d * S_{m.c}}{8 * \mu * r_d * S_{m.c} * (\rho a - \rho b)} \qquad (12)$$

From this formula, the radius of the vacuum booster membrane is calculated as:

$$R_M = \sqrt{\frac{M_a * g * \varphi * r_w * S_{w.c} - 8 * P_p * U_p * \mu * r_d * S_{m.c}}{8 * \pi * \mu * r_d * S_{m.c} * (\rho a - \rho b)}} \qquad (13)$$

Table: Vehicle Mass and VB Radius

№	Vehicle Mass	VB Radius
1.	1072	0.31
2.	1460	0.36
3.	1650	0.38
4.	2100	0.43
5.	2880	0.50

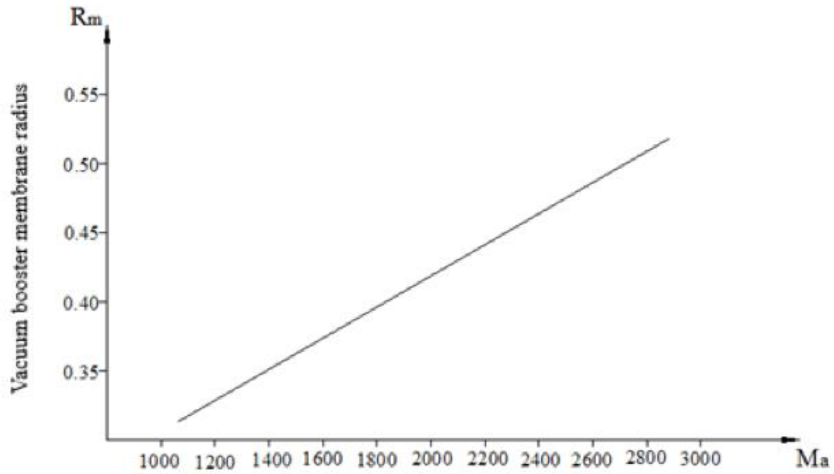

Figure 2. Graph of vacuum booster membrane radius as a function of vehicle mass

Using formula (13), the VB radii of different light vehicles can be calculated, and graphs relating membrane radius to vehicle mass can be constructed. Based on theoretical calculations with different vehicle masses, VB membrane radii were determined using formula (13), and a graph was constructed from the table above.

Thus, using the above method, the vacuum boosters in light vehicles' braking systems were theoretically analyzed and mathematical parameters were derived. With this method, parameters of vacuum boosters (membrane surface area, membrane radius, and pressure difference) of various light vehicles can also be recalculated by altering these variables.

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