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ALGORITHM FOR COMPUTING SPACE IN FREE RUNNING

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ABSTRACT

The paper presents a modality of determination by computation of the space covered by a vehicle which is rolling freely from its launching with a certain speed and up to its stopping. There are presented the design assumptions, the values which influence the analysed process and it is established a relationship to determine the space for free rolling. Starting for the data of some concrete vehicles there are presented some results of the calculus.

The paper allows the establishment of the free rolling space value and,by comparison with that obtained expermentally, the appreciation of the general technical estate of the vehicle. Through the analysis of the influences of different factors it can be determined the precision of measurement necessary, so that the results of the test might be concludent.

In the same way, there can be determined with precision the road resistances in case there exist experimental data.

ALGORITM DE DETERMINARE PRIN CALCUL A SPAȚIULUI DE RULARE LIBERĂ

REZUMAT

Lucrarea prezintă o modalitate de determinare prin calcul a spațiului parcurs de un autovehicul care rulează liber de la lansarea lui cu o anumită viteză și pînă la oprire. Se prezintă ipotezele de calcul, mărimile care influențează procesul analizat și se stabilește o relație pentru determinarea spațiului de rulare liberă. Pornindu-se de la datele unor autovehicule concrete, se prezintă cîteva rezultate ale calculului.

Lucrarea permite stabilirea valorii spațiului de rulare liberă și, prin compararea cu cel obținut experimental, aprecierea stării tehnice generale a autovehiculului. Prin analiza influențelor diferiților factori se poate determina precizia de măsurare necesară pentru ca rezultatele încercării să fie concludente. De asemenea se pot determina cu bună precizie rezistențele la înaintare în cazul în care se dispune de date experimentale.

Free running is one of the most frequent tests for motor vehicles. The conditions under which these take place are standardized. The test is run to determine some possible anomalities in the running of some subansamblies of the motor vehicle. To establish whether the vehicle is acceptable from a technical point of view in order to achieve some other, more complex tests, the value of space in free running is compared to values corresponding to some similar or closely related types of vehicles.

But these data are not always at hand, especially when testing new models, which led to the idea of determining the value of space in free running by computation. What follows is a briefing of the procedure that generated the initiation of a program, written in FORTRAN and developed on a computer M 118. The results of the program were confronted with the experimental results, the model, as well as the adopted hypothesis being satisfactory. As a greater, as well as more complex amount of data is accumulated, the algorithm is likely to be improved.

The dynamic pattern adopted is simple taking into consideration that the motor vehicle is made of:

- mass in translatory motion m;
- equivalent flywheel I_{Rn}, corresponding to wheels kinematically unconnected to transmission;
- equivalent flywheel I_{Rm}, corresponding to wheels kinematically connected to transmission and integral parts with them up to the housing of the differential driving gear inclusive;
- equivalent flywheel I_S, corresponding to the secondary shaft of the gear box and the parts kinematically connected to it up to the differential bevel drive gear inclusive.

With the free running test, the wheels are not loaded with heavy moments which agrees with the simplifying hypothesis that the turning radii are constant and equal to the dynamical ones:

$$r_r = r_d = r \qquad (1)$$

further defined as computation radii.

To determine the value of the instantaneous acceleration that the motor vehicle will have while free running, one writes the general equation for motion particularly applied to free running:

$$a = \frac{dv}{dt} = -\frac{(R_r + R_p + R_a + R_f)}{m\,\delta}, \qquad (2)$$

where Rr, Rp, Ra and R_f are the road resistances of the motor vehicle (viz. the motion resistance, the slope resistance, the air resistance and the resistance equivalent to the transmission friction values), v - the car velocity, m - car mass, δ - influence coefficient of rotating masses and $m\,\delta$ is its reduced mass.

The influencing coefficient of rotational masses is given by relation:

$$\delta = 1 + \frac{I_{Rn}}{m\, r_n^2} + \frac{I_S\, i_0^2 + I_{Rm}}{m\, r_m^2} \qquad (3)$$

where:

i_0 is the ratio of the main drive;

I_{Rn} - the inertia moment of the non-driving wheels;

I_{Rm} - the inertia moment of the transmission elements reduced to the secondary shaft of the gear box.

The road resistance is:

$$R_r = f\,G\cos\alpha \qquad (4)$$

where:

f is the coefficient of road resistance;

G - weight of the motor vehicle;

α - longitudinal slope angle of the road.

As the driving speed - while testing the free running - is relatively low, resistance coefficient will be taken into consideration [2], [4]:

$$f = f_0 + f_1 \cdot v \qquad (4')$$

where f_0 and f_1 are coefficients.

The slope resistance is computed by the well known relation:

$$R_p = G\,\sin\alpha \qquad (5)$$

For the aerodynamic resistance, the wind velocity component w was also considered along the running direction:

$$R_a = \frac{1}{2}\rho \cdot c_x \cdot A(v + w)^2 \qquad (6)$$

where ρ is air density;
c_x - drag coefficient of the motor vehicle;
A - surface of maximum cross section;
v - running speed of the motor vehicle;
w - wind velocity.

As while performing the test of free running - the atmospheric conditions are also specified, the density of the air is determined according to them:

$$\rho = \rho_0 \cdot \frac{p}{p_0} \cdot \frac{t_0 + 273}{t + 273}, \qquad (7)$$

where $\rho_0 = 1.225$ kg/m^3 is the density of the air under standard conditions ($p_0 = 760$ mm Hg and $t_0 = 15$°C);

p [mm Hg] and t [°C] are the pressure and the environement temperature respectively.

The present form of the general motion equation - rel.(2) - differs from those generally known in the introduction of R_f to the expense of the overall efficiency of transmission. The use of efficiency in computing the space in free running was given up because in this case it cannot be defined.

That is why one preferred to determine a low resistant force R_f (equivalent) corresponding to all frictions among parts in relative motions of the transmission (the engine being out of gear), to the running system and to the suspension. This force is determined by relation:

$$R_f = \frac{M_{fm}}{r_m} + \frac{M_{fn}}{r_n} = \frac{M_f}{r}, \qquad (8)$$

where M_f is the reduced moment of the frictions.

The friction moment inside the wheel bearings is dependent on loading Z, on the average arrangement radius for the rolling bodies r_1, as well as on their types through the rolling friction coefficient μ_{frr}:

$$M_{frr} = \mu_{frr} \cdot Z \cdot r_1, \qquad (9)$$

By noticing that at low rotational speeds μ_{frr} has high values but drops nonsymptomatically towards a value at increased rotational speeds, the authors suggest the following relation to compute the value for the coefficient of rolling friction:

$$\mu_{frr} = C_1 + \frac{C_2}{v + C_3}, \qquad (10)$$

where C_1, C_2, C_3 are constants.

To determine the constants above, the values of μ_{frr} shown in [2] and found again in [3] were used.

Underlining that in the case of wheel bearings the full load is:

$$Z = G \cos\alpha \qquad (11)$$

(the buoyant force of air was neglected), the moment of losses by frictions in the wheel bearings can be determined.

The moment of friction in the transmission is dependent on the frictions in the bearings, in the gearings, in the sealings as well as on the consumed energy for oil bubbling. As the loading of bearings and gearings is reduced, the authors suggest a constant value for the moment of resistance corresponding to the first three types of friction shown.

For the moment of losses by bubbling, there is the suggestion of a dependence linear to the square of the angular speed ω_S of the driven shaft (the impulse transferred to a certain amount of oil is proportional to the speed of revolutions and the amount of oil driven):

$$M_{ftr} = (C_4 + C_5 \cdot \omega_S^2) \cdot i_0, \qquad (12)$$

where C_4 and C_5 are constants.

Values C_4 and C_5 depend on the type of the motor vehicle, on the quality of production and assembling, on its total range of running as well as on the servicing.

The determination of constant C_4 (N·m) can be achieved by measuring the necessary torque to be applied to the collar of the cardanic transmission on the drive shaft of the gear box for its slow turning when the driving axles are suspended and the wheels are free. Under the above mentioned conditions, using for engaging the same flywheel a power P_{tr} corresponding to a constant angular speed ω_S, the same collar constant C_5 (N·m/s^2) can be determined.

This manner of determination is difficult to achive, but P_{tr} could be determined as a sum of necessary powers to drive off, by the same angular speed ω_S the driving axles, the driven shaft of the gear box in free position and possibly the cardanic transmission when they are disassembled.

$$C5 = \frac{\dfrac{Ptr}{i_0 \cdot \omega_S} - C4}{\omega_S^2}, \qquad (13)$$

The moment of friction in the suspension depends on the quality of the road and on the suspension as well as on the degree of motor vehicle loading. In [4] these losses are equivalent to climbing up an equivalent ramp p_{susp}, the greater the road is more uneven:

$$M_{f\,susp.} = r \cdot p_{susp.} \cdot G \cos\alpha \qquad (14)$$

Under these conditions the reduced moment of the total losses by friction becomes:

$$M_f = M_{frr} + M_{ftr} + M_{f\,susp.} \qquad (15)$$

and it will be assimilated to (8).

According to these remarks, the general equation of motion (2) becomes:

$$a = \frac{dv}{dt} = -(K_0 + K_1 \cdot v + K_2 \cdot v^2 + \frac{K_3}{v + C_3})(16)$$

where constants K_0, K_1, K_2 and K_3 are determined by relations:

$$K_0 = \frac{(f_0 + C_1\frac{r_1}{r} + p_{susp.})G\cos\alpha + G\sin\alpha + \frac{1}{2}\rho c_x A w^2 + C_4\frac{i_0}{r}}{m \cdot \delta}$$

$$K_1 = \frac{f_1 \cdot G\cos\alpha + \rho \cdot c_x \cdot A \cdot w}{m\delta}$$

$$K_2 = \frac{\frac{1}{2}\cdot\rho\cdot c_x \cdot A + C_5\left(\frac{i_0}{r}\right)^3}{m\delta} \qquad (17)$$

$$K_3 = \frac{C_2 \cdot \frac{r_1}{r} \cdot G\cos\alpha}{m\delta}$$

The space for free running becomes:

$$s = \int_{v0}^{0} \frac{v}{a} \cdot dv = - \int_{v0}^{0} \frac{v \cdot dv}{K_0 + K_1 \cdot v + K_2 \cdot v^2 + \frac{K_3}{v + C_3}} \quad (18)$$

The above integral was computed by a numeric method of approximation (Runge-Kutta of range IV).

By making use of the experimental values obtained in the testing of two motor vehicles (the auto-truck DAC 19.280 F and the tanker 10 AV 1) to determine the influence of different factors on the space of free running, some conclusions can be drawn.

A longitudinal sloping of the road p =0,022 influences by 2 % the space of free running. The determination of sloping p was possible because the test was fulfilled in both directions. An error of measurement of the initial speed of 2 km/h modifies the results of testing by 5 %. A front wind with a speed of 2 m/s influences the result of the determination by (5...6) %.

In case of the first motor vehicle, fitted with tyres 12 R 20, having the operating pressure of 8,5 bars on the front and 7 bars on the rear, the coefficient for running resistance can be considered:

$f = (7.6 + 0.2013\ v) \cdot 10^{-3}$, recommended at [4] (speed is in m/s).

In the case of the second motor vehicle fitted with tyres 11 R 20, operating pressures of 7 bars and 6.5 bars, front and rear respectively, one obtained:

$f = (9.1 + 0.2013\ v) \cdot 10^{-3}$.

The drag coefficient of the first motor vehicle fitted with spoiler, deflector and well stretched canvas hood is reduced as far as this category of motor vehicles is concerned, its value being: $c_x = 0.515 + 0.05$ (one took into consideration a space measurement error of maximum 2 %).

A change of the drag coefficient by 5 % leads to a change by 1.3 % of the space in free running. The frictions within the radial-axial bearings of the wheels represent 1.3 % from the total of average resistances to motion and the frictions in the transmissions (0.5 ... 1) %.

The program achieved allows the easy determination of different influences for other types of motor vehicles too, as well as for other degrees of loading.

By making use of this program, the main sources of error that occur when determining the space in free running can be pointed out, allowing for decisions to be taken in order to reduce them.

By making some recordings with the help of an apparatus of the fifth wheel type that makes it possible to find the instant values of deceleration, the test of free running performed under different conditions might permit, by very simple means, the quite accurate determination of resistances in driving, also permitting the improvement of the adopted model.

REFERENCES

1. * * * *Contract de cercetare nr. 69/1987*, Universitatea din Braşov.

2. MITSCHKE, M., *Dinamik der Kraftfahrzeuge*, Springer Verlag, Berlin, 1982.

3. OLARIU, V. et.al., *Mecanica tehnică*, Editura Tehnică, Bucureşti, 1982.

4. * * * *Truck Ability Prediction Procedure*, SAE J 688, 1963.