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Influence of The Blocking Coefficient of Differential Upon The Motor-Vehicle Delay Without Motion During Turn And Longitudinal Road Slope

KEYWORDS: differential, coefficient of blocking, motion in turn, motion at slope, resistant forces during motor-vehicle motion

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ABSTRACT *The influence of magnitude of blocking coefficient of differential upon the motor-vehicle delay possibility without motion during turn and longitudinal road slope without another means of stopping and delay is discussed in this article. The case of motor-vehicle with wheel formula 4x2, rear axle and front driving wheels is considered.*

Introduction

The motor-vehicle differential is a mechanism with two degrees of freedom which distributes the incoming torque towards wheels (or axles), and allows them to rotate with different angular speeds. Furthermore we will consider inter-wheel differential in a motor-vehicle with wheel formula 4x2, rear axle and front driving wheels. The motor-vehicle is situated on a straight road section down the slope with an angle of longitudinal slope α (Fig. 1).

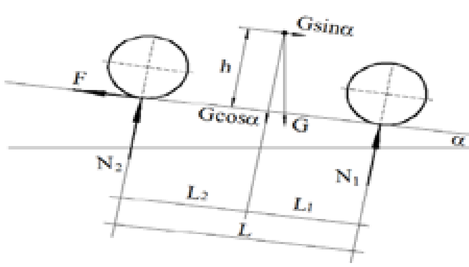

Fig. 1.A scheme of the force in respect to the model.

The problem to be solved is as following: How does the magnitude of blocking coefficient of a motor-vehicle differential influence upon the angle of the road longitudinal slope at which the motor-vehicle is not able to be set in motion by its own weight with lead away from the zero position driving wheels to extremely left or extremely right direction?

Mechano-mathematical model

The solution describing the differential kinematics is of the form:

$$\omega_1 - p\omega_2 = (1 - p)$$

Taking into account the relations between the forces in the differential the coefficient of blocking could be defined in two ways.

A) The ratio of the moment of the slow shaft to the moment of the speed up shaft characterizes the distribution of the moments between the semi-shafts or the axles, and is termed a coefficient of blocking:

$$K_b = M_1/M_2$$

whereM_1 is the moment of the slow shaft, and M_2 is the moment of the speeding up shaft.

According to the differential type,$K_b = 1 \div \infty$

$K_b = 1$at$M_1 = M_2$and $K_b = \infty$at $M_2 = 0$.

B) Sometimes the coefficient of blocking is defined as the ratio of the moment of friction in the differential (internal friction) to the moment of the differential body (the incoming moment) - $K_b = M_r/M_д$. At such definition $K_b = 0 \div 1$, because if there is no internal friction and$M_r = 0$, then$K_b = 0$, and if $M_r = M_d$, i. e. the total incoming moment is transformed in friction moment, then $K_b = 1$.

For the purposes of this investigation we use the second definition, namely:

$$K_b = M_r/M_d. \qquad (1)$$

Taking into account the first definition of the coefficient of blocking for the friction moment in the differential we can write:

$$M_r = M_1 - M_2 \qquad (2)$$

As furthermore we accept $M_1 > M_2$.

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In the considered case of the moment that is delivered to the differential body we can write:

$$M_d = F_b \cdot r_w = G(\sin\alpha - f\cos\alpha) \cdot r_w \qquad (3)$$

where F_b is the total force that strives to shift the motor-vehicle down the slope; r is the radius of the driving wheels; G is the weight of motor-vehicle, and f is the resistance coefficient of rolling.

The friction moment in the differential (2) has to oppose to the moment created by F_b in order the motor-vehicle to be hold up on the slope. Thus M_d from (3) will represent M_r from (1), and M_d is the maximum possible moment which can be delivered to the differential body on the conditions of normal reaction and a friction coefficient between the wheel and the road φ_{max} :

$$N_2 = \frac{G(cos\,\alpha \cdot L_1 - sin\,\alpha \cdot h)}{L}$$

$$M_d = \frac{N_2}{2} \cdot r_w \cdot \varphi_{max}$$

where N_2 is the total normal reaction of the rear wheels, and φ_{max} is the maximum coefficient of friction between the road and the wheel. At real road circumstances $\varphi = 0{,}2 \div 0{,}8$.

Using the upper dependences we obtain:

$$M_d = \frac{G(\cos\alpha \cdot L_1 - \sin\alpha \cdot h) \cdot r_w \cdot \varphi}{2L} \qquad (4)$$

Having in mind of (1), (2), (3) and(4) we can write:

$$K_b = \frac{2(\sin\alpha - f\cos\alpha)}{(A\cos\alpha - B\sin\alpha)\varphi} \qquad (5)$$

where: $L_1 = 0{,}5L = A; h = 0{,}3L = B; \varphi = 0{,}2 \div 0{,}8$

Numerical experiments

Equation (5) represents the dependence of the necessary coefficient of blocking of the differential on the angle of the road longitudinal slope at which will hold immovable on the slope without additional breaks and delaying devices.

The numerical experiments are carried out at the following input data:

$A = 0{,}5L$ и $B = 0{,}3L$, а $\varphi = 0{,}2 \div 0{,}8$; $\alpha = 0 \div 16°$; $f = 0{,}018$

Three variants are used:

1. $A = 0{,}5$; $B = 0{,}3$; $\varphi = 0{,}8$
2. $A = 0{,}5$; $B = 0{,}3$; $\varphi = 0{,}5$
3. $A = 0{,}5$; $B = 0{,}3$; $\varphi = 0{,}2$

The results are presented graphically in Fig. 2, Fig. 3, and Fig.4.

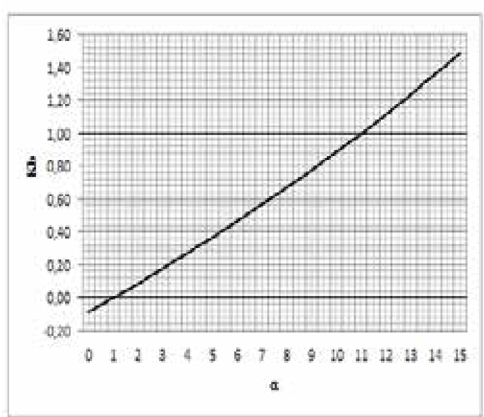

Fig. 2. A dependence of coefficient of blocking in the differential K_b on the slope angle α at $\varphi = 0{,}8$.

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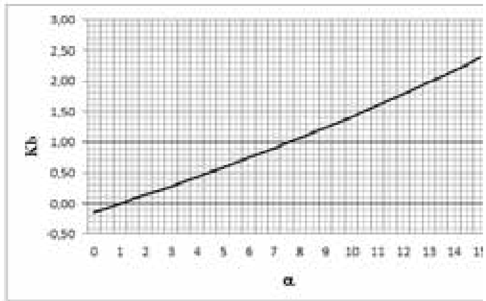

Fig. 3. A dependence of coefficient of blocking in the differential K_b on the slope angle αat $\varphi = 0{,}5$.

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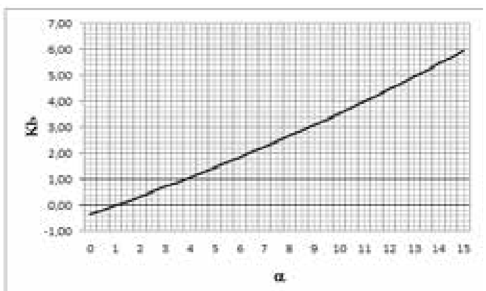

Fig. 4. A dependence of coefficient of blocking in the differential K_b on the slope angle αat $\varphi = 0{,}2$.

Conclusions

1. The graphic dependences have a physical meaning at $K_b = 0 \div 1$.
2. $K_b = 0$at$\alpha = arctg\ f = 1{,}03°$, if$f = 0{,}018$
3. With the increase of road slope α a greater coefficient of blocking K_b is necessary in order the motor-vehicle to be hold without motion.
4. With the decrease of friction coefficient φ the necessary coefficient of blocking K_b decreases.

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