TRACTIVE FORCE PROPERTIES OF DRIVE AXLE DEPENDING ON THE DIFFERENTIAL CONSTRUCTION

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ABSTRACT *An analysis of the influence of differential construction upon the total tractive force of drive axle is represented in this article. The influence of the torque distribution between the axle wheels upon the total coefficient of cohesion _(x tot) which depends on the type of the inter-wheels differential, is considered. Mathematical dependencies are deduced, and a mathematical model for calculation and analysis is suggested. The graphic kind of the model gives the opportunity for detailed and adequate comparison of different types and constructions of differentials, which affects the total tractive force as well as the cross-country capability and handling of motor-vehicle as a whole.*

Introduction

The problems concerning the improvement of engines operational characteristics refer to the basic ones in machine building.

One of the effective directions for the increase of fuel economy and decrease of the released toxic substances together with the burnt gases of internal-combustion engines is the use of electric drive. Another direction for the improvement of the operational characteristics of transport engines is the optimal distribution of the force flows upon the driving wheels. In these directions the automation of the processes of control of the force drive is differentiated as a common one.

Statement

The maximum possible moment from the differential drive cannot be greater than

$$M_{max} = 2G_w r_d \varphi_{hast} + M_{fr} \qquad (1)$$

where G_w is the motor-vehicle weight per a wheel (engaged weight)**;** r_d is the wheel dynamic radius; φ_{hast} is the coefficient of cohesion with the road of the hastened up wheel; M_{fr} is the differential friction moment.

The usage of self-blocking differential, which distributes the moments between the driving wheels depending on the cohesion conditions between the wheels and the road, contributes for the improvement of transport machine tractive force characteristics.

The self-blocking differential allows a maximum moment to be realized which is determined by the following equation (2)

$$M_{max} = M_1 + M_2 = M_1(1 + K_{bl}) = G_w r_d \varphi_{hast}(1 + K_{bl}) \qquad (2)$$

where M_1 *is the smaller moment (of the hastened up wheel)*; M_2 is the greater moment (of the lagged wheel);K_{bl} is the coefficient of blocking of the differential.

According to equation (2) the graphics of the maximum possible initial moments of inter-wheels differentials at different coefficients of cohesion between the wheels and the road are represented in Fig. 1.

The characteristics are built for passenger car with weight $G_w = 2604\ N$ and wheel dynamic radius $r_d = 0,281\ m$.
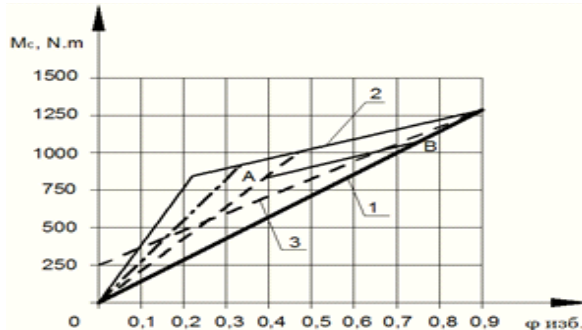

Fig. 1. Graphics of maximum possible initial moments of different types and characteristics inter-wheels differentials at different coefficients of cohesion between the wheels and the road.

Curve 1 corresponds to the maximum possible initial moments at identical coefficients of cohesion φ of both wheels with the road, while curve 2 corresponds to the maximum possible initial moments at coefficient of cohesion of one wheel φ_{hast}. and for the other the coefficient of cohesion is $\varphi = 0,9 = const$.

It is necessary the differential characteristic to be chosen in such a way that during the car motion at good road conditions a friction moment not to be available in the shafts, and the self-blocking differential to operate as an usual differential with coefficient of blocking $K_{bl} = 1$ (curve 3 in Fig. 1).

Fig. 2 shows the dependence of γ_P on γ_G, while Fig. 3 represents the dependence of $\frac{\sum k_\gamma}{\sum k_{\gamma P}}$ on γ_G at the usage of differentials with different coefficients of blocking. The rolling resistance coefficient of the wheel is $= 0,02$ and $\frac{\sum P}{\sum G_w} = 0,2$. Point a_6 (Fig. 3) corresponds to the start of slipping of the internal wheel.
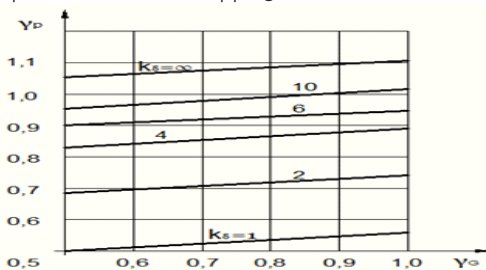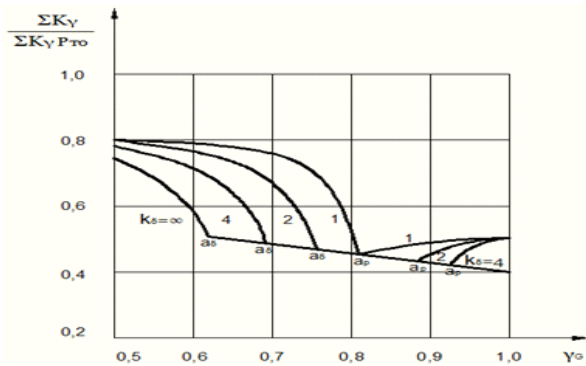

Fig. 2. Distribution of the tractive forces between the wheels of a passenger car with self-blocking differential.

Fig. 3. Change of the total slipping resistance coefficient at self-blocking differential ($\frac{\sum P}{\sum G_w} = 0{,}2;\ \varphi = 0{,}5; f = 0{,}02$).

In the case of a passenger car with symmetrical inter-wheels differential at values of γ_G exceeding the values in the corresponding points a_{bl}, the total tractive force $\sum P$ decreases with the increase of γ_G With regard to this the total slipping resistance coefficient of the wheels of the drive axle starting from point a_{bl} grows up with the increase of γ_G reaching the greatest value for this section at completely unloading of the internal wheel ($\gamma_G = 1$). If the passenger car is with self-blocking differential the values of $\sum P$ could stay constant even after the slipping of the internal wheel has begun. In this case a redistribution of the moments transmitted on the internal and the external wheels occurs. If up to the start of the slipping the internal wheel has been lagged and if a greater part of the moment delivered to the differential body has passed towards it, then after the beginning of the slipping the internal wheel transforms in hastened up wheel, and the greater part of the torque begins to transfer to the external wheel.

The values of γ_G at which exceeding $\sum P$ have to decrease with the increase of γ_G can be calculated from the following equation

$$\gamma_{G_{\text{np}}} = \frac{\varphi(K_{bl} + 1) + fK_{bl} - \dfrac{\sum P}{\sum G_w}}{(\varphi + f)(K_{bl} + 1)} \qquad (3)$$

In this case, after the beginning of wheels slipping at inter-wheels differential with coefficient of blocking $K_{bl} > 1$, the total slipping resistance coefficient does not increase as it is so for symmetrical differential, but continues to decrease up to reaching $\gamma_{G_{\text{np}}}$. In Fig. 3 the abscissa corresponding to $\gamma_{G_{\text{np}}}$· is marked with a_6. If $\gamma_G > \gamma_{G_{\text{np}}}$ along the decrease of the total tractive force the total slipping resistance coefficient grows with the increase of ˙γ_G.

Therefore, the type of inter-wheels differential significantly affects the change of the total resistance coefficient of the drive axle wheels.

Conclusions

The analysis of all built dependences for the influence of inter-wheels self-blocking differential upon the handling and motion stability of passenger car shows, that depending on the traffic characteristics with different coefficients of cohesion, we should dispose of variable blocking devices depending on the outdoor conditions and the differential operational parametres. This allows the following conclusions to be pointed out:

1. The blocking characteristics of the inter-wheels self-blocking differential (ISD) exert greater positive influence on the straight-line motion of passenger car with front-wheel drive, and increase the limits of its stability during constant curvilinear motion;

2. On roads with small coefficient of cohesion is necessary a limitation of the coefficient of blocking of ISD of passenger car up to values of 2,5, and selection of the intensity of the blocking moment increase along with the growing of angular speeds difference of the driving wheels.

3. The influence of blocking characteristics of ISD during constant curvilinear motion on roads with small and as well as with great coefficients of cohesion for cars with rear-wheel drive leads to narrowing of limits of cars motion stability, while for cars with front-wheel drive leads to their extension. The influence of differential blocking upon the car stability during non-uniform curvilinear motion is not synonymous and is determined by the magnitude of the disturbing action. Moreover, the greater values of the coefficient of blocking at all circumstances of curvilinear motion synonymously decrease the handling and motion stability of a passenger car;

4. ICDs with growing internal friction allow fuller realization of tractive force during motion at bad road conditions, but they have unnecessary great blocking characteristics during motion with great load at turn. ICDs with reduced internal friction are necessary for cars with high tractive-speed characteristics, because they allow motion at turn with maximum speed as their characteristics approach to the characteristics of an ordinary differential. Along with that such differential to a small extent is capable to distribute the moment towards the semi-axes, and does not allow to be realized the maximum possible moment during significantly good cohesion of one of the wheels;

5. The combined characteristics of ISD allow fuller realization of tractive force during motion at bad road conditions, and do not reduce the handling and motion stability on roads with great and small coefficients of cohesion.

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