ON SOME SPECIAL TRANSVERSAL DIFFERENTIAL GEARS FOR OFF ROAD VEHICLES

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Abstract. In the paper it is studied the behavior of some special differential gears, for off road vehicles, in the conditions when the two driven wheels are submitted to very different rolling resistances. The special character of these differential gears consists in the fact that they have a complex construction, which leads to an important increasing of internal friction. For the studied types of differential gears, the torque of internal friction is established and, on its basis, the coefficient of self blocking is calculated.

1. INTRODUCTION

In the practice of operation of the off road vehicles, there are situations when the existing differential gears in the transmission hinder the displacement on very heavy ground, because they allow the slipping of a wheel or even of the whole driving axle. In order to avoid this phenomenon, the differential gears are endowed with the possibilities of commanded blocking or self blocking.

After the passing over the ground obstacle, if the differential gear remains in blocked state, it appears the power circulation (parasite power), with an unpropitious effect on the energetic balance of vehicle (increasing of fuel consumption). In relation to the longitudinal axis of vehicle, the power circulation can be of transversal type, i.e. between the two planetary shafts of the same driven axle, or of longitudinal type, between the front driven axle and the rear driven axle. In order to diminish the circulation of parasite power, the off road vehicle must obligatory have both axles as driven axles (equipped with transversal differential gear) and also, a longitudinal differential gear, between the two driven axles.

The efficiency of working of a differential gear is quantitatively evaluated with the help of the coefficient of self blocking, c_b

Supposing, for example that, within the framework of a transversal differential gear, the planetary shaft no.1 is retarded and the no.2 one is accelerated, then the coefficient of self blocking is defined as, [2],

$$c_b = \frac{M_1}{M_2} = \frac{\frac{M_0}{2} + M_f}{\frac{M_0}{2} - M_f}. \tag{1}$$

where:
- M_1 - moment of the torque, acting on the planetary shaft no.1;

- M_2 - moment of the torque, acting on the planetary shaft no.2;
- M_0 - moment of the torque, acting on the differential case, from the part of the vehicle engine;
- M_f - moment of the torque of internal friction in the differential gear.

By blocking an ordinary differential gear, with the aim of increasing of capacity of passing over obstacles, the coefficient of blocking (an ordinary differential gear has not the facility of self blocking, so that its blocking is realized by a special device, as consequence of a command from the part of the vehicle driver) becomes infinite, and the power from the engine is equally divided on the two planetary shafts.

On the other hand, after the passing over the obstacle, the ordinary differential gear must be immediately unblocked, because if not, on rolling tracks of good quality (with normal adherence), the magnitude of the parasite power can reach very high values; in this situation, the vehicle transmission and tires are strongly solicited and can be rapidly deteriorated. In order to avoid this kind of situations, there were designed differential gears with increased internal friction, endowed with the facility of automatic self blocking and also, the facility of automatic self unblocking. This category of differential gears do not eliminate the apparition of circulation of parasite power, but leads to an important increasing of capacity of passing over obstacles, maintaining the circulation of parasite power at a low value.

2. SELF BLOCKING DIFFERENTIAL GEAR WITH CONICAL TOOTHED WHEELS AND DISCS

A first solution of increasing of internal friction is the supplementation of the friction

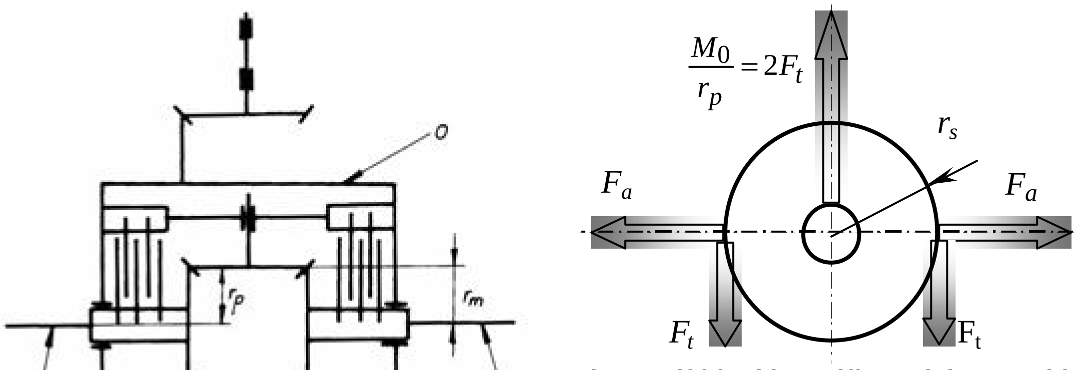

Fig.1 Self blocking Differential gear with conical toothed wheels and discs (in right side, the schema of loading of satellite)

surfaces in an ordinary differential gear, by introducing of some packages of discs, mounted like in figure 1, [1].

The forces that appear in the gearings between the satellites and planetary pinions produce pressings which generate important frictions in the packages of discs.

The moment of the torque of internal friction in this differential gear is given by the expression

$$M_f = \mu F_a r_m z = \frac{M_0}{2r_p} \mu r_m z \cdot tg\alpha \sin\delta, \qquad (2)$$

and its coefficient of self blocking is

$$c_b = \frac{1+\mu\dfrac{r_m}{r_p}z \cdot tg\alpha sin\,\delta}{1-\mu\dfrac{r_m}{r_p}z \cdot tg\alpha sin\,\delta}. \tag{3}$$

In the expressions (2) and (3), the quantities which intervene have the following significations:

- F_t - tangent force to the planetary wheel (generated by all satellites);
- a - angle of gearing;
- d - half angle of the cone of division of the planetary wheel;
- r_p – radius of the circle of division of the planetary wheel;
- m - coefficient of friction of the discs;
- z – number of the pairs of surfaces of friction;
- r_m – average radius of the friction discs.

3. SELF BLOKING TRANSVERSAL DIFFERENTIAL GEAR WITH DISCS AND FLOATING PINS

The solution in fig.2 is similar to the previous one, the difference consisting in the way of mounting of the satellite axles in the differential case, [1]. For the realization of progressivism of the variation of the coefficient of self blocking, in relation to the difference of moments on the planetary shafts, the pins are floatingly mounted in the differential case. The pin can be half floating or floating, in accordance to the details in the mentioned figure.

In the case of this construction of differential gear, the moment of the torque of internal friction has the expression

$$M_f = \frac{M_0}{2}\left(\frac{tg\alpha sin\,\delta}{r_p} + \frac{1}{Rtg\beta}\right)r_m z\mu, \tag{4}$$

and the coefficient of self blocking is

$$c_b = \frac{1+\left(\dfrac{tg\alpha sin\,\delta}{r_p} + \dfrac{1}{R\,tg\beta}\right)r_m z\mu}{1-\left(\dfrac{tg\alpha sin\,\delta}{r_p} + \dfrac{1}{R\,tg\beta}\right)r_m z\mu}. \tag{5}$$

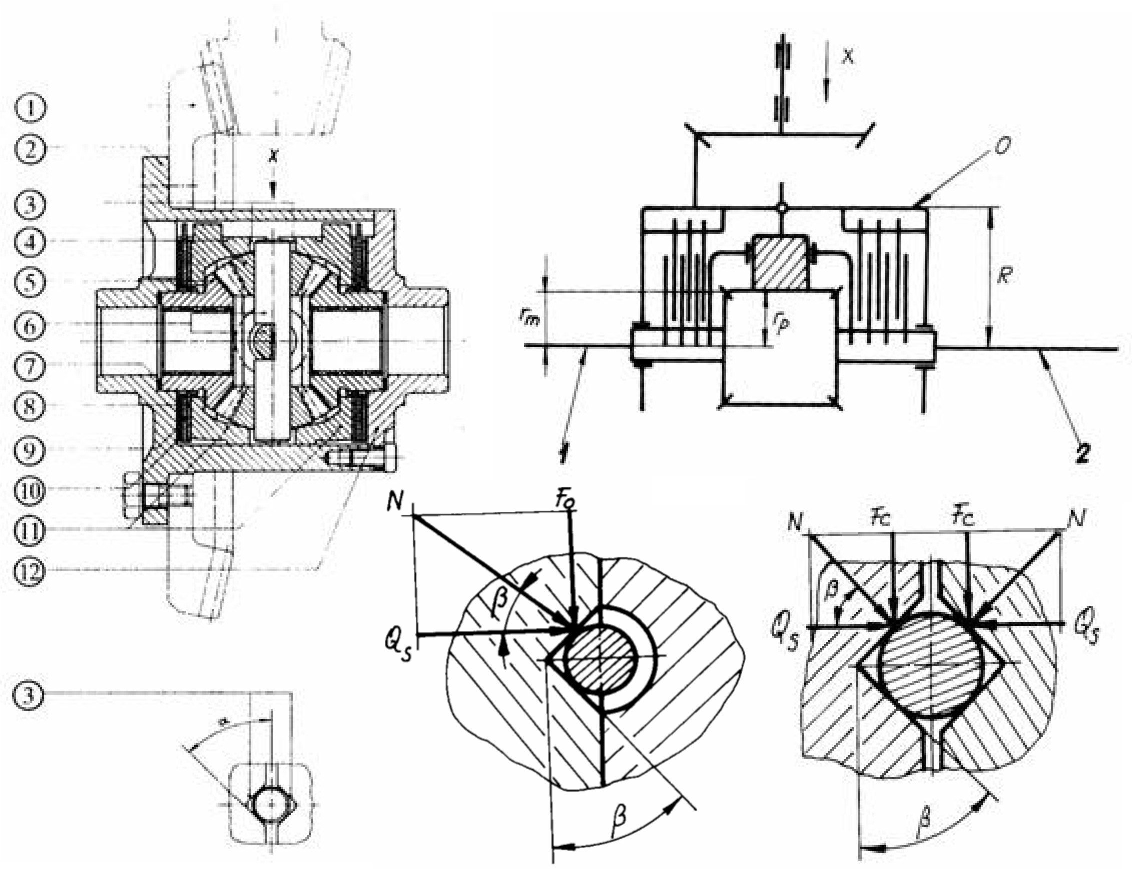

Fig.2 Self blocking transversal differential gear with discs and floating pins

In the above relations, in addition to the quantities whose signification was explained at the type of differential gear, previously presented, it also intervenes the angle β, which is the angle of prismatic groove recess in the contact zone " pin – half differential case".

4. DIFFERENTIAL GEAR WITH CAMS AND RADIAL PUSHERS

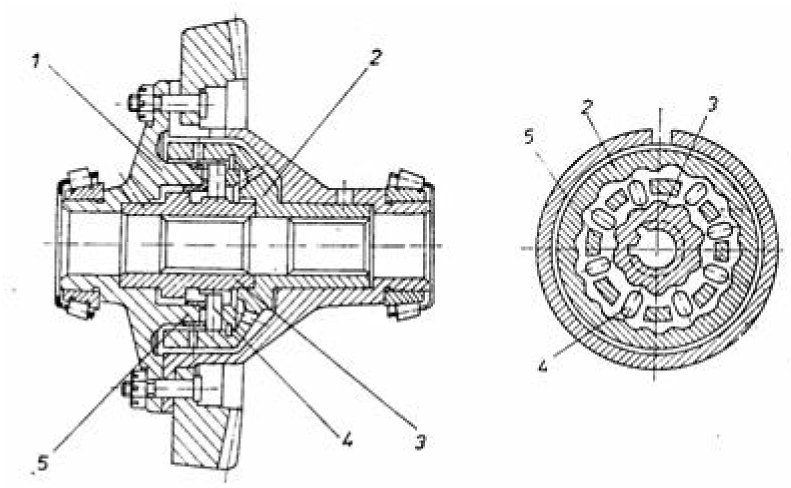

Fig.3 Differential gear with cams and radial pushers

Another type of self blocking differential has a totally different construction, [1]. This one has not planetary wheels and satellites, but it benefits of two wheels of special profile, one at the interior and the another one, at the exterior, between them working a set of pushers, radially mounted in one or two rows, as in figure 3. It is mentioned that it also exists an axial variant of disposure of pushers, but this one is no more utilized because of the constructive and working complications.

In order to determine the moment of the torque of internal friction, it is considered the schema of loading of the elements of this differential gear, presented in figure 4.

The main special characteristic of this type of differential gear is the fact that it is

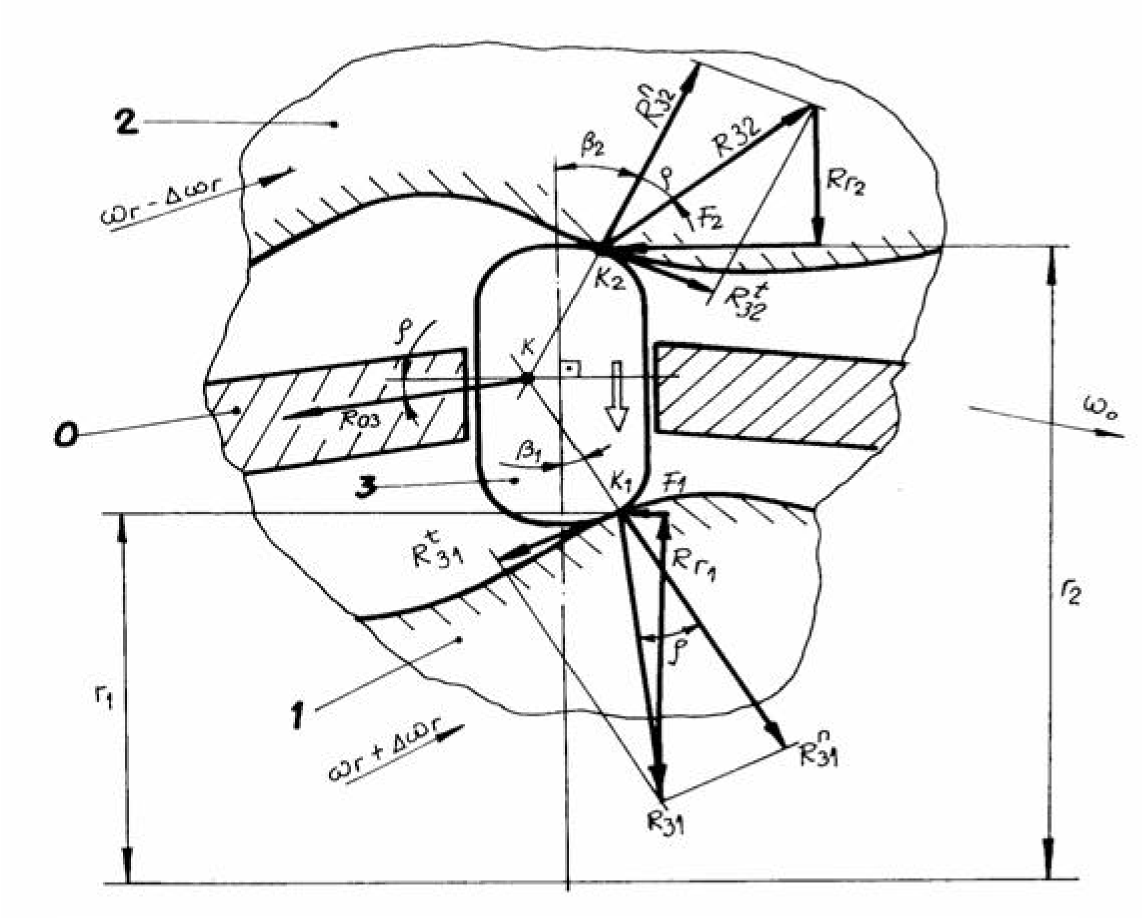

Fig.4 Schema of loading of the differential gear with cams and radial pins

relatively asymmetrical, from the point of view of the value of the coefficient of self blocking. Thus, for the situation in the figure above, the coefficient of self blocking, in the case $w_2 < w_1$, has the expression

$$c_b = \frac{r_2}{r_1}\frac{\sin(\beta_2+\rho)\cos(\beta_1-2\rho)}{\sin(\beta_1-\rho)\cos(\beta_2+2\rho)}, \tag{6}$$

and, for $w_2 > w_1$, it has the expression

$$c_b = \frac{r_1}{r_2}\frac{\sin(\beta_1+\rho)\cos(\beta_2-2\rho)}{\sin(\beta_2-\rho)\cos(\beta_1+2\rho)}. \tag{7}$$

In the above relations, in addition to the geometrical dimensions which can be observed in the figure, it is notated by r = *arctgm*, the angle of friction between the cams and pins.

It can, also, make a few remarks:

- the left-right coefficients of self blocking are different;

- the value of a coefficient of self blocking is variable in relation to the angles b_1 and b_2 and the radiuses r_1 and r_2;

- in order to avoid the complete self blocking of the differential gear ($c_b = \infty$), it must be accomplished (constructively) the conditions $90^0 - 2r < b_{2,3} < r$.

5. CONCLUSIONS

As conclusions of the above study, it can be mentioned the following aspects:

- the “off road” vehicles or, more suggestively called, “4x4” vehicles, i.e. “four wheel drive” vehicles must obligatory have both axles as driven axles (equipped with transversal differential gear);
- in addition of this demand, the transversal differential gears on the two driven axles must not be ordinary, but special differential gears, with increased internal friction, which assure the facility of automatic self blocking in the conditions when the vehicle must run on heavy conditions of ground;
- even if the two driven axles of vehicle are equipped with special transversal differential gears, there are very heavy situations on ground when the existence of a longitudinal differential gear between the two driven axles is the only solution to make possible the vehicle to pass over some obstacles; thus, the endowment of the off road vehicles with a longitudinal differential gear becomes, also, an obligatory demand.

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