ANNALS of the ORADEA UNIVERSITY.
Fascicle of Management and Technological Engineering

ON THE POWER CIRCULATION IN LONGITUDINAL PLAN AT A FOUR WHEEL DRIVE VEHICLE

Drd.ing. Gheorghe BECHERU
Directia Audit Intern a M.A.I., membru AGIR, membru ARTENS
Prof.dr.Eur.ing. Tiberiu BABEU
Universitatea “Politehnica” din Timisoara, vicepresedinte AGIR, presedinte filiala AGIR Timis
Prof.dr.ing. Adrian CHIRIAC
Universitatea “Politehnica” din Timisoara, membru AGIR

Key words: four wheel drive vehicle, rectilinear motion, power circulation, parasitic power

Abstract. In the paper it is studied the dynamics of a four wheel drive vehicle (“4x4” road vehicle), performing a rectilinear motion. It is determined the power circulation in longitudinal plan (between the front and rear driving axles), tacking into account the slipping of wheels. Firstly, it is made a cinematic study of the vehicle rectilinear motion, in order to establish the conditions in which the power circulation in longitudinal plan appears. Then, by applying the graphs of nodal theory, a dynamic study is made, in order to effect the power balance of vehicle and to put in evidence the power circulation in longitudinal plan (longitudinal parasitic power).

1. INTRODUCTION

The relevant cases of apparition of the power circulation in longitudinal plan, (longitudinal parasitic power), i.e. the power circulation between the front and rear driving axles are as follows:

- inequality of radii of rolling of the wheels of the front driving axle, in relation to the ones of the rear driving axle;
- displacement in turn.

2. CINEMATIC STUDY

In order do not have circulation of power between the driving axles, (in longitudinal plan), it is necessary that the peripheral velocities of wheels of the two driving axles, in rectilinear motion, to be equal:

$$\omega_{d_F} r_{r_F} = \omega_{d_S} r_{r_S} . \qquad (1)$$

In the relation (1), the signification of notation is as follows:
- ω_{d_F} - angular velocity of differential case, of the front driving axle;
- ω_{d_S} - angular velocity of differential case, of the rear driving axle;
- r_{r_F} - rolling radius corresponding to the wheels of the front driving axle;
- r_{r_S} - rolling radius corresponding to the wheels of the rear driving axle.

It is made the hypothesis of inexistence of the longitudinal differential gear (or of its complete blocking).

In order to evaluate, from the cinematic point of view, the conditions of apparition of longitudinal circulation of power, it is introduced the notion of cinematic non-concordance,

[1],[2]. For its study, it is used the index of cinematic non-concordance in the rolling system of vehicle, given by the relation

$$K = \frac{1 - s_S}{1 - s_F}. \quad (2)$$

In the formula (2),

$$s_S = 1 - a_S \quad (3)$$

is the average skidding of wheels of the rear driving axle, where

$$a_S = \frac{v - v_{tS}}{v_{tS}} \quad (4)$$

is the slipping of wheels of the rear driving axle, in which:
- v - real velocity of center of the wheels, i.e. the speed of vehicle;
- v_{t_S} - theoretical velocity of center of the wheels of the rear driving axle.

The theoretical velocity of center of the wheels of the rear driving axle has the expression

$$v_{t_S} = \omega_{r_S} r_{r_S}, \quad (5)$$

where:
- ω_{r_S} - angular velocity of the wheels of the rear driving axle;
- r_{r_S} - dynamic radius of rolling of the wheels of the rear driving axle.

In an analogous way, it is defined the average skidding of wheels of the front driving axle, respectively with the help of a_F (skidding of wheels of the front driving axle) and v_{t_F} (theoretical velocity of center of the wheels of the front driving axle). From the formula (3), it results that the slipping can be also considered as a negative skidding.

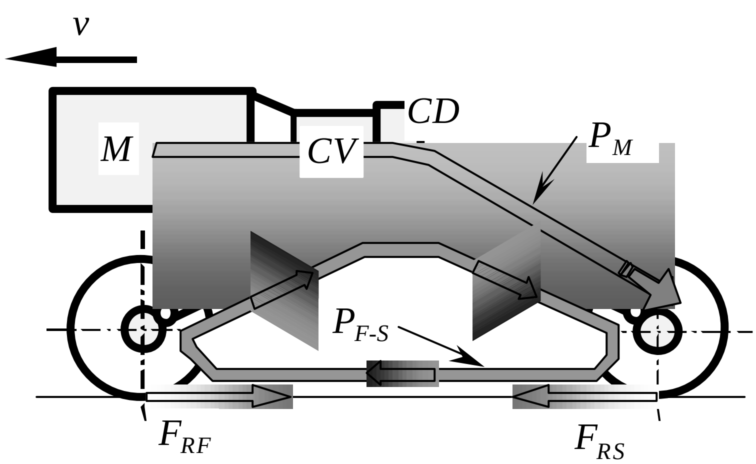

Fig. 1. Power fluxes in the transmission of a 4x4 vehicle with circulation of power in transmission

3. DYNAMIC STUDY BY APPLYING THE GRAPHS OF NODAL THEORY

The circulation of power in longitudinal plan can be put in evidence, in a suggestive way, with the effecting of the balance of powers, by applying the graphs of nodal theory, figure 2, which represents the nodal schema of the transmission, affected by the parasitic circulation of power, in figure 1.

The notations used in the two figures have the following significations:

- *M* – engine;
- *CV* – gear box;
- *CD* – slide box;
- *RK* – conical group;
- *F* – front pair of wheels;
- *S* – rear pair of wheels;
- P_τ - lost power by friction between different organs of the transmission.

If there are also taken into consideration the losses in the organs of the transmission, expressed with the help of the mechanical efficiency, the power which arrives to the slide box, from the part of the front driving axle has the expression

$$P_F = F_{R_F} r_{r_F} \omega_r \eta_{T_{F-CD}}, \tag{6}$$

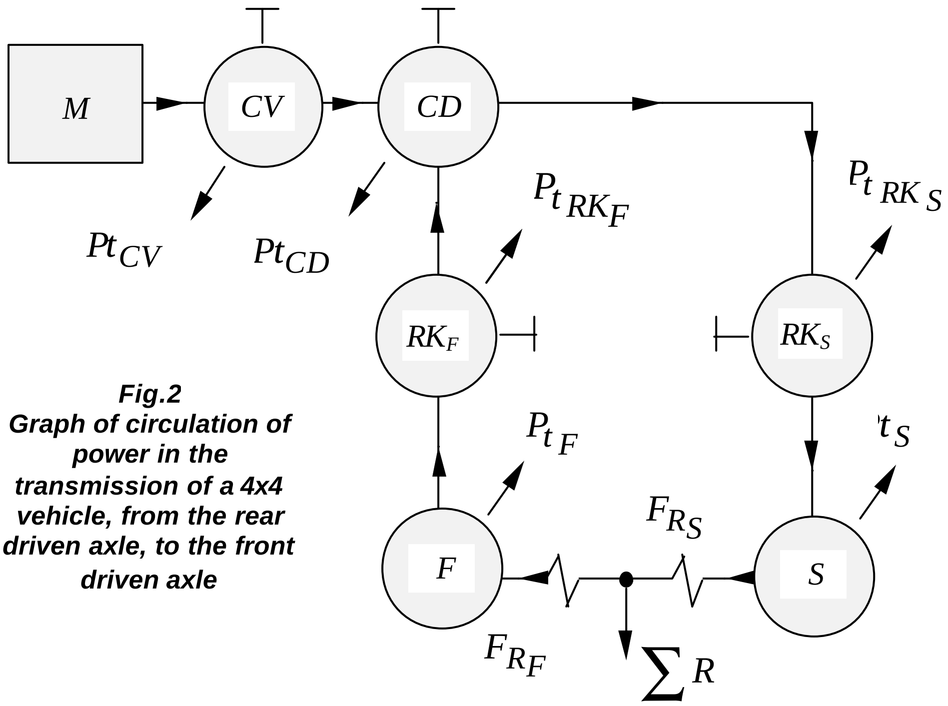

Fig.2
Graph of circulation of power in the transmission of a 4x4 vehicle, from the rear driven axle, to the front driven axle

where

$$\omega_r = \omega_{r_F} = \omega_{r_S} \tag{7}$$

because the transmission is rigid, and $\eta_{T_{F-CD}}$ is the efficiency of the transmission on the tract from the wheels of the front driven axle, to the driven shaft, to the rear driven axle of the slide box.

Another flux of power also arrives to the gear box from the part of the driving engine, which can be determined with the relation

$$P_M = P_{mot}\,\eta_{T_{M-CD}}, \tag{8}$$

where:

- P_{mot} – power from the driven shaft of engine (crankshaft);

- $\eta_{T_{M-CD}}$ - efficiency of the transmission on the tract from the engine, to the driven shaft of the slide box, to the rear driven axle.

Consequently, on the driven shaft of the slide box, there are totalized the two powers, expressed by the relations (6) and (7):

$$P_S = (P_F + P_M)\eta_{T_{CD-S}} = \left(F_{R_F} r_{r_F} \omega_r \eta_{T_{F-CD}} + P_{mot}\eta_{T_{M-CD}}\right). \quad (9)$$

This power is consumed for the overcoming of resistance to motion, from the part of the wheels of the rear driven axle, $P_{R_S} = F_{R_S} r_{r_S} \omega_r$; for $F_{R_S} = \varphi Z_S$, it has the expression

$$P_{R_S} = \varphi Z_S r_{r_S} \omega_r . \quad (10)$$

By equalizing the last two relations, it is obtained the balance of powers, corresponding to the level of the zone of contact between the ground and the wheels of the rear driven axle:

$$\left(F_{R_F} r_{r_F} \omega_r \eta_{T_{F-CD}} + P_{mot}\eta_{T_{M-CD}}\right)\eta_{T_{CD-S}} = \varphi Z_S r_{r_S} \omega_r . \quad (11)$$

The term in the left side represents the flux of power which comes by the transmission to the wheels, and the term in the right side, corresponds to the limit of adherence.

Finally, for the considered case, the force F_{R_F} is given by the equation

$$\sum R + F_{R_F} = F_{R_S} , \quad (12)$$

from which it is obtained

$$F_{R_F} = \varphi Z_S - \sum R , \quad (13)$$

that is introduced in the equation (11). After this substitution, the equation of balance of powers is transferred from the zone of contact with the ground, to the level of the driven shaft of the slide box (where there are meeting the flux of power which comes from the engine and the parasitic power which comes from the rear driven axle). After the separation of the two fluxes of power, the equation of balance of powers becomes

$$P_{mot}\eta_{T_{M-S}} = \varphi Z_S r_{r_S} \omega_r - \left(\varphi Z_S - \sum R\right) r_{r_F} \omega_r \eta_{T_{F-CD}} . \quad (14)$$

The convenient grouping of the terms permits the separation of different categories of powers in the equation of balance, as fallows:

- $P_{mot}\eta_{T_{M-S}}$ - power which arrives from the engine;
- $\varphi Z_S r_{r_S} \omega_r$ - power corresponding to the limit of adherence;
- $\left(\varphi Z_S - \sum R\right) r_{r_F} \omega_r \eta_{T_{F-CD}}$ - parasitic power.

4. CONCLUSIONS

From the equation (14), it is easy to deduce the conclusion that, if the resistance to the vehicle displacement increases, the parasitic power decreases as value, becoming null for

$$\sum R = \varphi Z_S \,. \tag{15}$$

By inverting the reasoning, the coupling of the integral traction, together with the blocking of the longitudinal differential gear, in the case of the displacement of vehicle on the roads of good quality, leads to the apparition of important values of the parasitic power.

REFERENCES

1. Gorianu, M., Influenta diferentialelor cu frecare marita asupra progresiunii automobilelor, Buletinul Academiei Militare, nr. 6, 1992.
2. Macarie, T., Influenta tractiunii integrale cu legatura cinematica rigida asupra stabilitatii automobilului, RIA, nr. 1, 1995.