Influence of the drawbar pull over the power flux within the automotive transmissions

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Abstract. This paper performs an analysis of the drawbar pull influence over the power flow within the automotive transmissions. First part of the work presents a serial of theoretical approaches with respect to the analyzed elements. Second part of the paper reveals the vehicle's instrumentation to achieve the experimental data and some of the research results as well. The final part of the paper draws a series of conclusions with respect to mode the power loop's magnitude is influenced by the general drawbar pull. Last, but not least, technical solutions are introduced to decrease the power loops and contribute to the fuel savings.

1. Introduction

The paper approaches a special problem of the military wheeled vehicles that have classical transmissions. By power loop flow one could understand the power flow with negative value (it won't contribute to the vehicle motion) that is nor generated by the vehicle's engine; mathematically speaking, it is the gain between the self-generated torque and the element's angular speed (usually, the transmission shafts) the power is computed for. Many papers have developed studies with respect to the analyzed problem [1], [2], [3], [4], [5]. What we meant was to study the influence of the road's overall drawbar pull over these vehicles' power flow within their transmissions. This topic becomes even more interesting since the military vehicles need a serious bunch of improvements to enhance their dynamic parameters, to increase their operational status, to increase their survivability in combat and improve their technical resource. In this respect, the specialized structures of the Ministry of Defense aim at replacing or improving already existing organs to achieve the dynamic and protection parameters required by the battle field, thus the survivability of the vehicle would improve.

Taking into account the budget cuts with respect to the acquisition of new vehicles, Ministry of Defense has to increase the already existing military equipment's performance and operational features. Compromise solutions need to be born to achieving a good balance between the imposed tasks in performance and the available financial resources. Thus, the present study could become a technical foundation that would lead to replacing of an organ of the vehicle's transmission, so decreased values of the power loops would occur at the longitudinal level. The study only followed the influence of the drawbar pull over the power loop circulation, although this kind of power loops strongly influenced by a different series of parameters as well, such as different tire radii, different travel lengths of the wheels and so on.

The study will reveal the need to replace the transfer case. This replacing, along with other ones, could lead to a positive impact over the regional development.

2. Power loop flow and gauging the tested vehicle

The study developed within this article considers a classical, all-wheeled vehicle, working with its inter-axle differential in the locked mode. In the same time, the wheels have different tire radii from front to rear. In the situation below, the front wheels are the same size or smaller than the rear wheels in their radii.

Taking into account the previous hypothesis, within the transmission's elements two fluxes of power are to be met (figure 1 [4]):

- the first: engine - clutch - gearbox - transfer case - rear axle;
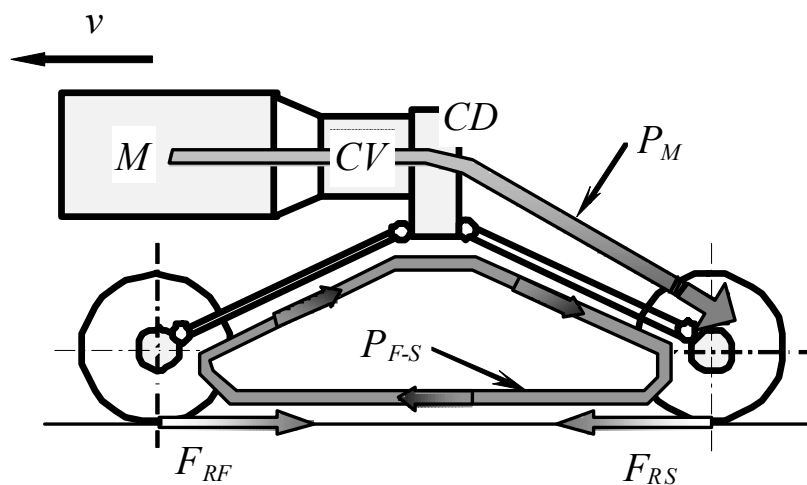- the second: front axle - transfer case - rear axle.

Figure 1. The power fluxes within a 4x4 vehicle with loop power circulation.

The abbreviations in fig. 1 mean: M - engine; A - clutch; CV - gearbox; CD - transfer case with lockable differential; v - vehicle's velocity; P_M - engine's output; P_{F-S} - power flow between axles; F_R - traction forces at front/rear wheels.

To perform the tests, a military vehicle has been used.

Finding the power flux loops needed some gauges placed on the longitudinal shafts, between engine and transfer case, between transfer case and axles. They measured torque and angular speeds. The drawbar pull was generated by towing a 20-ton vehicle. Towing force's variation has been achieved by progressively braking the towed vehicle, up to its full stop.
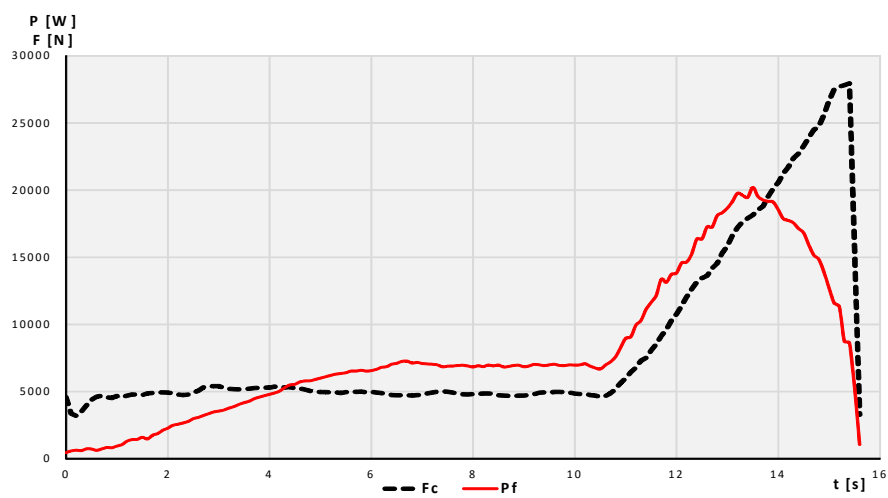
The magnitude of the drawbar pull was measured with a resistive transducer, both for stretching and compressing. The transducers was placed between the tested vehicle and its trailer.
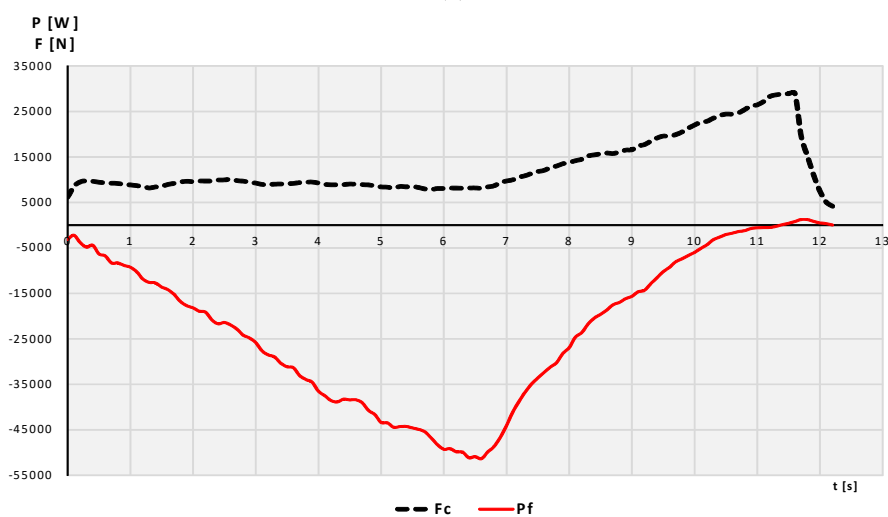
3. Experimental results

The experimental research were carried on with no difference in tire radii (Dr = 0 mm) and with a tire radii difference of Dr = 30 mm between the front and rear axle's wheels. The inter-axle differential was locked. The road surface was made of concrete and the vehicle moved straightly.

To analyzing the power fluctuation at the front axle's level (loop power) versus the overall drawbar pull, we will refer the graphics in figure 2 [5].
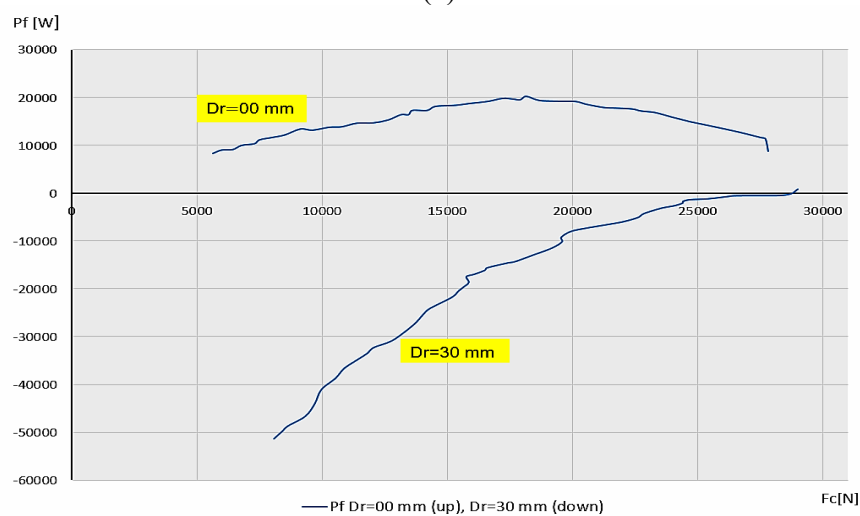
Figure 2 depicts the time histories of the fluctuations of the power reaching the front axle (loop power) and the towing force (F_c).

(a)

(b)

(c)

Figure 2. The fluctuations of the power reaching the front axle (Pf - loop power) and the towing force (Fc) for Dr=00 mm (*a* and *c*) and Dr=30 mm (*b* and *c*).

In these graphics, the following parameters should be introduced: P - power; F - force; t -time; Pf - the power output of the transfer case to the front axle; Fc - traction force (simulated drawbar pull).

Further explanations are needed to a better interpretation of the graphics:

- A positive value of the power means it contributes to the vehicle motion. No loop power involved.
- A negative power means it doesn't contribute to the vehicle's motion. Power loop occurs.
- The fluctuation and the magnitude of the power directly depends on the gain between the torque and the angular speed of the tested longitudinal shaft.

Analyzing the graphics depicted in figure 2, one could reveal three major stages in the evolution of the researched parameters.

The first stage consists of the vehicle take-off and, if occurs, moving with a constant speed. The second stage involves a significant increase of he drawbar pull (Fc). The last stage comes with a significant diminishing of the analyzed parameters till they reach null and the vehicle's comes to a full stop.

In the analyzed graphics, during the first stage of the test, one can notice that, even the value of the towing force is relatively constant, the power on the front axle (Pf) is featured by a rather constant increase of its absolute value (Ministry of Defense). In this situation, the increase of the power is explained by the increase of the vehicle's speed (take-off process) and, hence, an increase of the angular speed of the shafts (ω).

During the second stage, one could notice that, along with the increase in drawbar pull, the power at the front axle's level (Pf) also proportionally increases. Nevertheless, after the value of the drawbar pull reaches a certain value ($F_c \approx 20.000$ N), the rate of the front axle's power increase is diminished. Even a slight decrease can be noticed. This behavior is explained by the decrease of the vehicle's speed as a result of the increasing drawbar pull, hence a decrease of the angular speeds of the shafts (ω).

Eventually, in the final stage, a decrease of the parameters (Pf, F_c) is noticed, down to null, when the vehicle stops. This stage isn't important for the present study.

Beside the above-mentioned issues, some further explanations should be given. Analyzing the drawings above one could notice that they have several offsets from the linear behavior. Nevertheless, the general linear trend of the phenomenon should be concerned. These observations lead to the conclusion that other factors are influencing the behavior and they are independent with respect to the concerned parameters. In other words, these deviations (offsets) from the ideal linear evolution could be generated by some shocks and working inconsistency due to the rolling surface and driver. Since the complete elimination of the disturbing factors is impossible, a perfect linear evolution isn't achievable under real circumstances. Hence, we think that minor deviations can be neglected and the evolution can be considered as linear.

4. Conclusions

With respect to the technical analysis in the present paper: Increasing the towing force induces a proportional decrease of the power on the front axle's shaft (loop power); thus, its value tends to cancel with the drawbar pull increase (i.e. towing force); at a certain moment it really vanishes then it turns into active power (for high level of the drawbar pull); The loop power, vanishes when the towing force reaches Fc=25000 N; For an average 10.000 N variation in the towing force, an average variation of about 25.000 W in front axle's power occurs.

5. References

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