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ENERGY RECOVERY SYSTEM FROM THE VEHICLE DAMPERS AND THE INFLUENCE OF THE TANK PRESSURE

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Abstract: There exists the necessity of drastic reduction of the green house gases and fossil fuel but not interacting with the comfort and safety conditions of the vehicles. The vehicles can produce a significant amount of energy by means of a vertical movement which is given by the road profile and the displacement regimes of the vehicles, from which a major part is dissipated in the conventional suspensions. The purpose of our work is to recover this energy having the aim to reduce the fuel consumption of a hydraulic hybrid vehicle.
For evidencing the capacity of such a recovery system, a series of simulations were made by using the AMESim 8.0B software. This helps us further for validating of the energy from the suspensions recovery system simulation models as well for the identification of the way the recovery system realizes the charge of the hydraulic hybrid transmission.
Keywords: *hydraulic , hybrid, recovery , dampers.*

1. INTRODUCTION

Although the hydraulic hybrid technology has so far been aimed at delivery trucks it could make sense for smaller vehicles too.

Design concept of a hybrid hydraulic car is based on a simple working principle: car's diesel or gas engine powers a hydraulic pump motor, which charges the high-pressure accumulator. The accumulator, in turn, drives one or more additional pump motors connected to the wheels. A second lower pressure accumulator completes the hydraulic circuit. [1] Depending on the design, there may be one pump motor to drive a pair of wheels through a differential or one pump motor per wheel for an all-wheel-drive version with independent torque control. [2] During braking, the pump motors on the wheels reverse themselves, re-charging the accumulator and capturing energy that would otherwise be lost to heat. [3]

Operators of truck fleets have recently taken an interest. FedEx, UPS and Waste Management have been evaluating hydraulic hybrids developed by fluid power players such as Parker Hannifin and Eaton Corp. The U.S. Environmental Protection Agency (EPA) has also been involved with the design and testing of these vehicles and even showed a hydraulically driven UPS truck at the International Fluid Power Exposition, which devoted two different technical sessions to hydraulic hybrids in Las Vegas [4].

The simulation results showed the Passat's hydraulic drive train was about 95 percent efficient , once you add in the vehicle's regenerative braking energy. That efficiency is only about 4 percent better than a conventional mechanical drive train. Yet, thanks to the hybrid's engine optimization and engine-off operations, total fuel conversion efficiency jumped from 18 percent with the traditional vehicle to 38 percent with the hydraulic hybrid [5].

The aim of this paper is to present a new hybrid propulsion system, which is based on the recovery of the translation mechanical energy received from the road profile (force x velocity) and transforming it in hydrostatic energy with the help of the recovery cylinders. So this energy is no more dissipated in the vehicle suspension, where it would have been transformed into heat, instead is recovered with the help of the hydraulic cylinders and used further for vehicle propulsion.

2. WORKING PRINCIPLE

Using the AMESim 4.2 and AMESim 8.0B software a virtual model of a recovery system of the energy from suspensions, was realized. Dedicated modules were used for hydraulic, mechanical, powertrain, IFP drive, signal, control and observers with the purpose of having a more realistic image of all the elements that influence the system.

Further the principle scheme of the energy recovery system is presented in Figure 1.

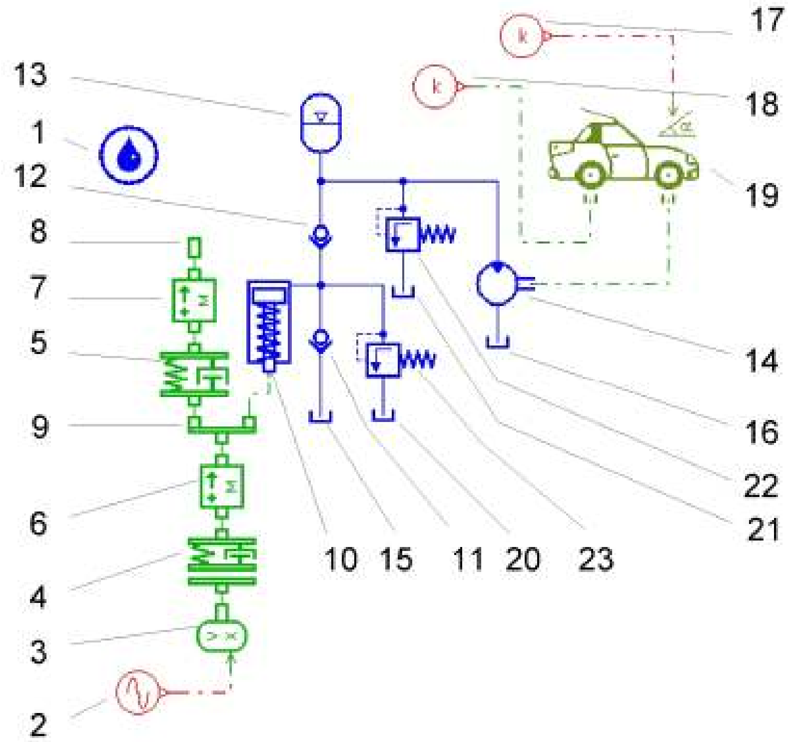

Figure 1: The AMESim model of the energy recovery system

1 – liquid
2 – signal source
3 – signal converter
4 – elastic contact
5 – vehicle damping
6 – wheel mass
7 – vehicle mass (¼ of the total mass of the unloaded vehicle)
8 – zero force source
9 – linear mechanical node
10 – recovery damper
11,12 – one-way valve
13- hydraulic accumulator
14 – hydraulic motor
15,16,20,21 – tank
17,18 – constant signal source
19 – vehicle
22,23 – pressure control valve

The impulses received from the road profile are taken by the tire and transmitted further on to the vehicle suspension system and finally on the car body. Through lever 9 which connects the tire to the suspension and energy recovery dampers, the energy will be recovered. So at passing of a tire over a bump, or unevenness, the wheel will send an impulse to the suspension system of the vehicle and to the recovery cylinder, so that the energy of this impulse will be absorbed. In the same time it is obtained a better damping during crossing over diverse road profiles, correlated with energy recovery from the damper 10. The impulses received by the recovery cylinder 10 will be transmitted to the working fluid.

The recovery damper in the downward stroke creates a depression, opens the valve 11 and the working fluid is absorbed from tank 15. The tank 15 is under pressure especially for avoiding the cavity phenomenon which can occur in the recovery damper. In the upward stroke the valve 11 is closed and the valve 12 opens the fluid being under pressure in the hydraulic accumulator 13. Between the two one-way vales is a pressure control valve 23 for preventing the deterioration of the circuit until the hydraulic accumulator. The valve 23 in case of an overpressure opens and discharges the direct circuit in the tank preventing the deterioration of the system components. The hydraulic accumulator stores the energy stored by element 10 but it also fulfills the function of elimination of the pressure overloads, equalizing the pressure in the circuit. Another pressure control valve is situated between the hydraulic accumulator and hydrostatic motor for avoiding the damage of the motor 14.

The working fluid reaches the hydraulic motor under pressure provides the necessary energy required in the rolling resistance. With the help of element 19 in the system are introduced all the studied vehicle proprieties (mass, tire radius, frontal surface of the vehicle etc) as well as the wind velocity, rolling resistance coefficient. With element 17 it can be simulated the ramps climbing or slope descending. The element 18 allows us the introduction of a braking moment on the rear axel. After the simulation we can interpret the parameters of the damping of the suspension system as well as the behavior of the vehicle.

3. FUNCTIONING CHARACTERISTICS OF THE RECOVERY SYSTEM

The aim of the work is to study the influences of pressure from oil tank of the recovery cycle. Tests were conducted which should demonstrate the displacement capacity of the vehicle with hybrid-hydraulic propulsion system. As input data used for the simulations are presented in Table 1.

It has been studied the oil tank pressure when the vehicle rolls with a set of Bridgestone Turanza RFT tires with a stiffness coefficient of 322 000N/m and when rolling with Michelin Radial tires with a stiffness coefficient of 874 000N/m [6].

The simulation lasted for 800 seconds on an uneven road and the frequency induced by the rolling path is of 30 Hz and the average amplitude is 5mm. The results of the simulations are presented next in Figures 2…5. The four main parameters presented are: recovered speed (see Figure 2), installation pressure (see Figure 3), outlet flow (see Figure 4) and vertical displacement of the vehicle (see Figure 5). A significant difference between the two tires used can be observed, which help us further in choosing the right type of tire.

Table 1:

Bumper frequency	30 Hz;
Bumper height	0,005m;
Tire mass	37Kg;
Tire damping degree	560 N/(m/s) ;
Tire elasticity coefficient	322 000N/m Bridgestone Turanza RFT 874 000N/m Michelin Radial 11R22.5 XZA
Stiffness coefficient of the spring	39170 N/m;
Damping coefficient of the suspension C	2000 N/(m/s) ;
¼ of the vehicle mass	400 Kg;
Recovery pistons diameter	45 mm;
Tank pressure	20 bar; 30 bar; 40 bar;
Accumulator pressure	100 bar;
Hydraulic accumulator volume	7,5L ;
Hydraulic motor deployed volume	33 cc/rev;
Tire radius	0,3 m;
Advancement resistibility (for speed of 22 m/s)	868 N;
Vehicle frontal surface	3 m².

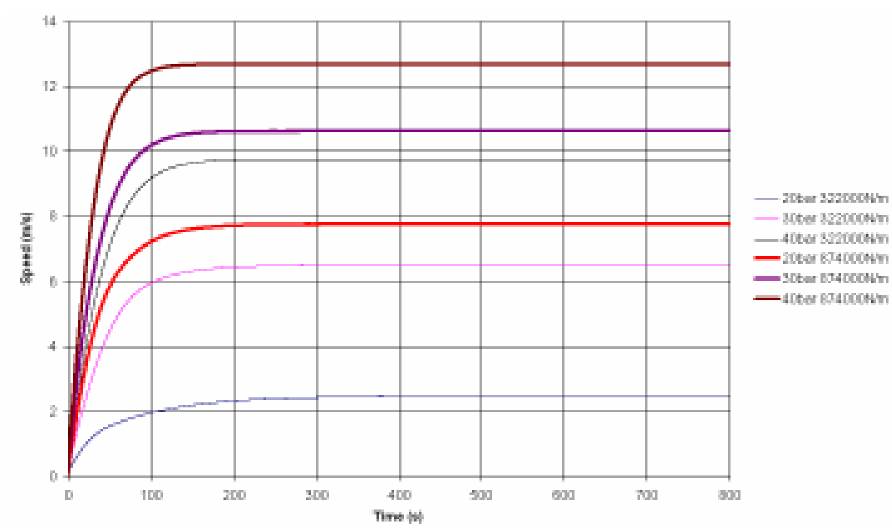

Figure 2: Speed of hybrid hydraulic vehicle

In Figure 2 it can be observed that a high coefficient of the vertical stiffness of the tire benefits the energy recovery and in combination with a pressure of 40 Bar in the hydraulic tank a speed of 12.7 m/s can be obtained while by using a vertical coefficient of the tires of 322000N/m a speed of 9.8 m/s is obtained. It was observed that at a pressure of 20 bar in the hydraulic tank the recovery speed difference when it rolls with a set of tires with a low vertical stiffness is with 325% lower than when it rolls with a set of rigid tires.

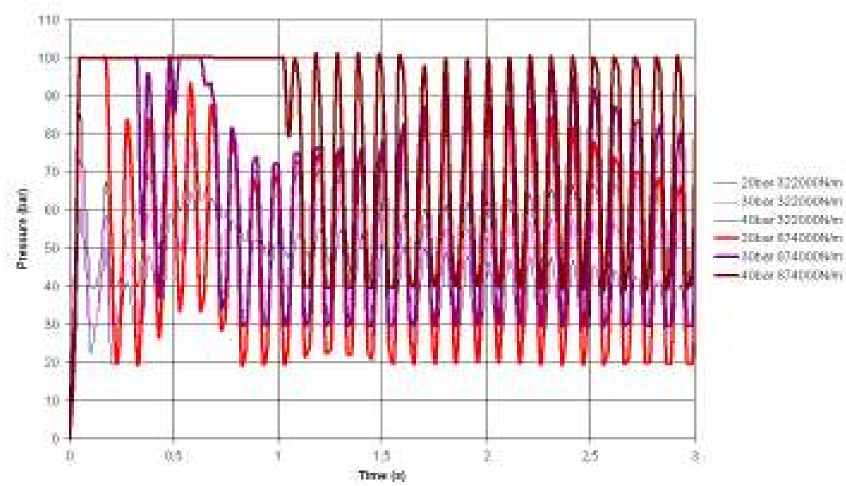

Figure 3: Pressure of hydrostatic motor

It can be observed that with the increase of the vertical stiffness increases the pressure from the installation from the maximum 80 bar in case of Bridgestone Turanza tires, to 100 bar when using tires with the highest vertical stiffness. (see Figure 3)

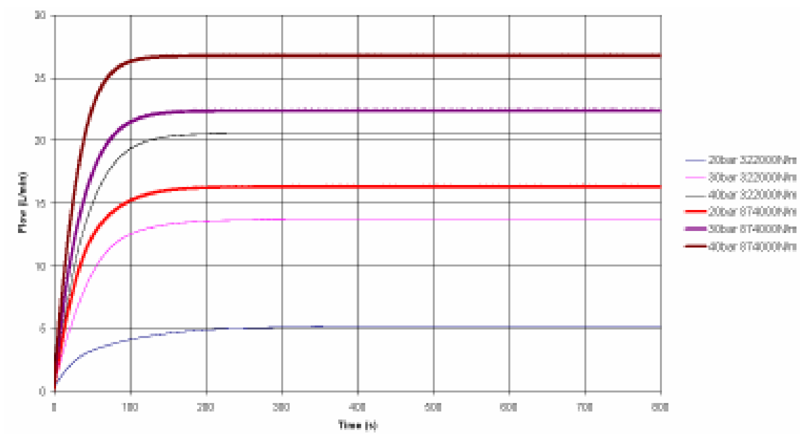

Figure 4: Flow of hydrostatic motor

As can be observed from Figure 4 the fluid flow in the recovery installation is directly proportional to the increase of the recovery speed, for a 12.7m/s speed, the installation will debit 27L/m of hydraulic liquid for a vertical stiffness coefficient of 87400N/m and a tank pressure of 40 bar. Compared with this value it can be seen that if rolled with a set of Bridgestone Turanza RFT tires with a vertical stiffness coefficient of 322000m/s teh recovery speed will be only 2.4 m/s and the flow is only 5L/min.

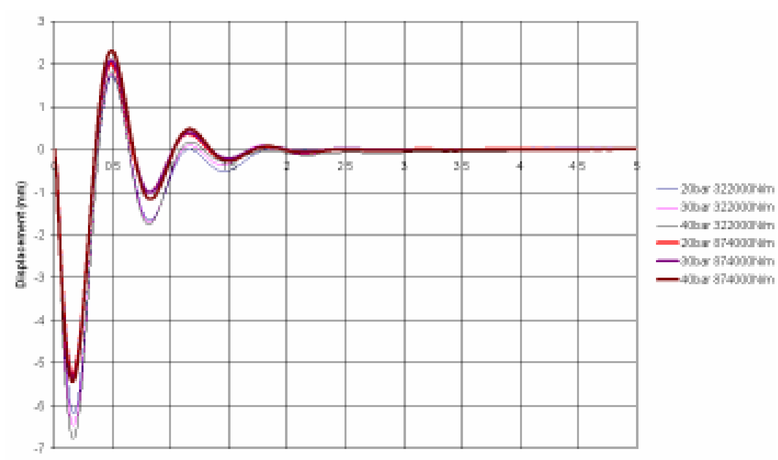

Figure 5: Vertical displacement of the vehicle

The vertical displacement of the vehicle is influenced in small extend by the vertical stiffness coefficient of the tire, and this because almost all the received energy from the unevenness of the road is captured with the help of the recovery system and transformed in mechanical work. At a pressure fluctuation in the tank with ± 10bar from the reference pressure of 30 bar, a oscillation of ±5% can be observed in the vertical displacement of the car body. (see Figure 5)

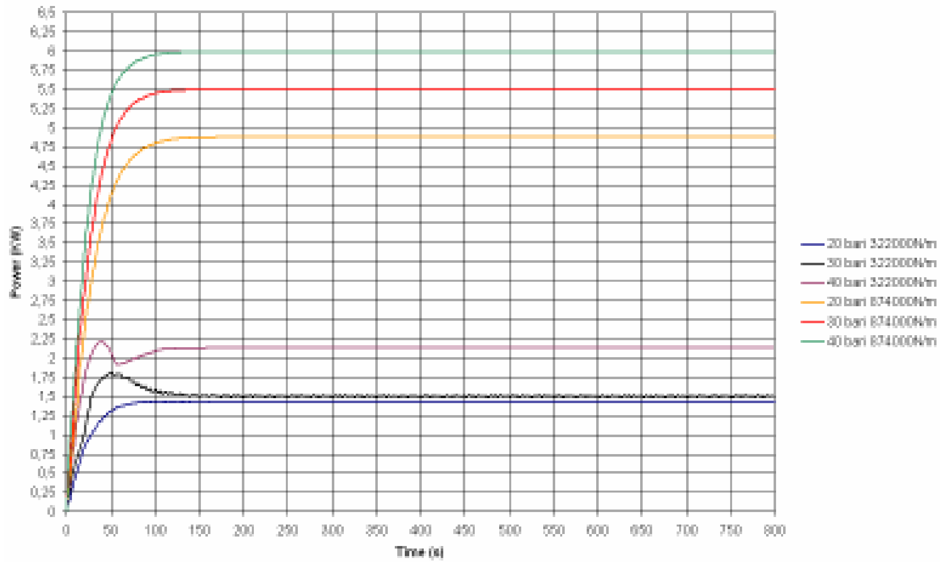

Figure 6: The power developed by the hydraulic recovery system

The recovery power of a single cylinder is shown in Figure 6. It can be observed that the pressure in the hydraulic tank and the vertical stiffness coefficient of the tire influence the recovery power. So, if it is used a tire with a vertical stiffness coefficient of 874000N/m at a tank pressure of 30 bar, the system generates 5.5kW. At an increase of the tank pressure of 10 bar, we obtain a rise of the power with 9.5%, and at a decrease of 10 bar of the pressure, the recovery power decreases with 11%.

3. CONCLUSION

Based on the simulations it can be observed that by increasing of the pressure in the hydraulic tank the cavity phenomenon can be avoided, phenomenon that can occur during the functioning of the recovery cylinder at high frequencies but a better filling of the hydraulic installation is obtained.

By using two different vertical stiffness coefficient tires it was observed that the difference between the recovery speeds in the case when the tank pressure is 40 bar for a tire with vertical stiffness coefficient of 322000N/m the value of the recovered speed is of 9.8 m/s and for a rigid tire the speed is 12.7m/s, 30% more. When using a tire with the vertical stiffness coefficient of 322000N/m, the maximum pressure in the installation is of 80 bar, while using a rigid tire the pressure increases with 25%, reaching 100 bar. This pressure represents the maximum accepted pressure in the hydraulic accumulator.

By means of comfort it can be said that the pressure in the hydraulic tank, influences the vertical displacement of the car body only with a ratio of ±5%, related to a 30bar tank pressure.

The energy recovery system presented in this paper represents a new step in the development of the hybrid hydraulic transmission vehicles, having the capacity of recovering more energy from the suspensions, energy that would have been dissipated into heat at conventional cars.

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