A POSSIBLE ENERGY RECOVERY SYSTEM USED AT AUTOTRUCKS WHICH MOVES WHITOUT EFFECTIVE LOAD

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Abstract: In this paper we develop a system which is relative easy to made. This system is made of a container with wheels of small size (maximum load 400 kg), fixed with joints of the rods of some plunger pumps. When the auto-truck moves on the road, these pumps can deliver oil under pressure to a hydraulic accumulator fixed on the auto-truck's platform. The stored energy can be used for different purposes like: tyre inflation; to screw in/out the wheel's screws with hydraulic pistols; the actuation of a rotary hydraulic engine coupled with the transmission, which will supplement engine's power when climbing a road, etc. The article presents constructional elements and calculations of such a recovery system.

Keywords: hydraulic, piston, pump, accumulator, centrifugal.

1. INTRODUCTION

In most situations when merchandises are transported with auto-trucks having the charging floor closed, there are usually transports without effective load from the beneficiary's delivered merchandises to the supplier or to the employed transport firm which has to accomplish the necessary transport. At the transports without effective load it is good to use a partially recovery-accumulation system of the energy consumed through the fuel burning necessary to the movement.

In this paper it is presented the utilization of a small size tank having the total mass of about 400 kg, with limited displacement possibilities controlled by some hydraulic cylinders with plunger pumps, fixed by the charging floor with articulations, figure 1. Through the limited displacement of this tank fixed on wheels at braking, or in curves or slopes displacement, the plunger pumps will pump oil under pressure from a tank opened at the atmospheric pressure into a hydraulic accumulator (or air cushion reservoir) which has to accumulate energy as mechanical work of the elastic forces, into an air cushion.

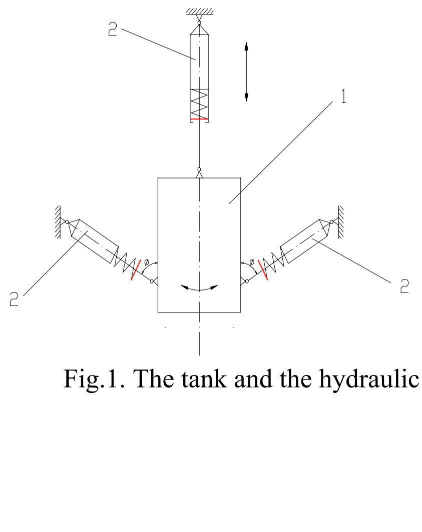

Fig.1. The tank and the hydraulic cylinders.

1 – tank having the total mass of about 400 kg, with wheels which makes it mobile on the auto-truck's platform;
2 – hydraulic cylinders with plunger pumps of high pressure.

On the plunger pump's rods are fixed displacement limiting devices, disc shaped (circular metallic plates), which acts over some short spiral springs, mounted between these limiting devices and the hydraulic cylinder's heads. These short spiral springs do an elastic damp combined with displacement limitation without shock of the mobile tank.
The mobile container C is supported by the wheels, which permit the plan displacement in all directions, their axis being mounted in the console regarding the vertical axis which has an axial bearing, as figure 2 shows:

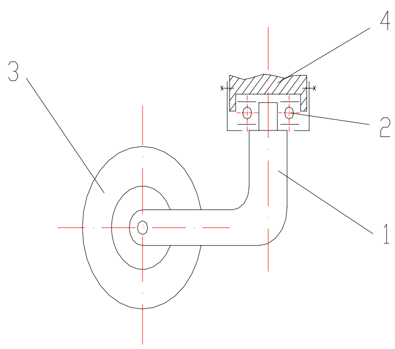

Fig.2. The wheel.

1. Wheel's arm, which has on the upper side a vertical axis, mounted in an axial bearing;
2. Axial bearing;
3. Rubber wheel;
4. The mobile tank's body C;
5. Sheet-metal cover.

The hydraulic oil circuit from the plunger pumps with pistons to the hydraulic accumulator, respectively the feeding with oil from the tank opened at the atmospheric pressure and the discharging of the energy accumulated through a rotary hydraulic engine, optional coupled (controlled) with the auto-truck's transmission can be seen in figure 3:

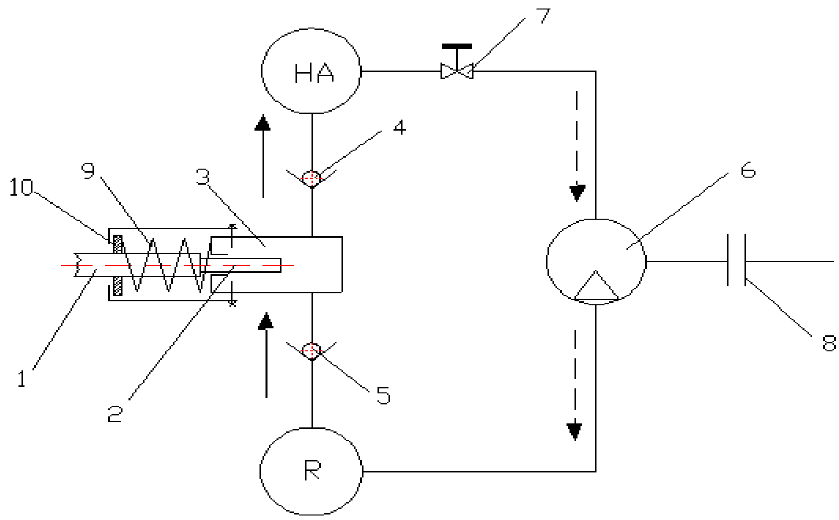

Fig.3. The hydraulic oil circuit.

1. The hydraulic cylinder's rod (plunger pump);
2. Plunger pump's piston;
3. Plunger pump's cylinder;
4, 5. One-way valves with hydraulic control;
6. Rotary hydraulic engine;
7. Electro-valve (tap controlled electric);
8. Coupling connected of the hydraulic engine's shaft, which makes the connection with the auto-truck's transmission;
9. Spiral spring for the shocks absorption;
10. Metallic disc, the limiting device of the plunger pump's piston rod.

The connection between the plunger pump's and the hydraulic accumulator, respectively to the tank opened at the atmospheric pressure, can be made with high pressure flexible pipes having metallic insertions used in hydraulic actuation. For the discharge hydraulic circuit through the rotary hydraulic engine can be used fix metallic pipes.

2. THE HYDRAULIC PISTON ACCUMULATOR

Piston accumulators provide a means of regulating the performance of a hydraulic system. They are suitable for storing energy under pressure, absorbing hydraulic shocks, and dampening pump pulsation and flow fluctuations. The simple, compact, cylindrical design of piston accumulators ensures dependable performance, maximum efficiency, and long service life [1].

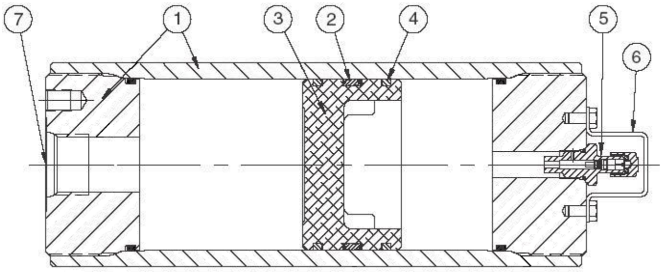

Fig. 4. The hydraulic accumulator.

1 – cylinder (steel shell);
2 – piston seal;
3 – piston;
4 – PTFE glide rings;
5 – gas valve;
6 – gas valve protector;
7 – input port.

Piston type accumulators are designed with compact, rugged steel shell and caps. The steel shell allows heat to dissipate effectively. The piston seal consists of a unique, patented five bladed V-O-ring with back-up washers. This design eliminates seal roll-over and ensures total separation of fluid and gas under the most severe operating conditions. The V-O-ring also holds full pressure throughout long idle periods between cycles, providing dependable, full pressure storage of hydraulic energy.. The piston seal design helps to prevent sudden failure of the accumulator. The lightweight piston design allows fast response to reduce shock in rapid cycling applications. The dished profile of the piston provides extra gas capacity and greater useable volume of fluid. PTFE glide rings eliminate metal-to-metal contact between the tube and piston, reducing wear and extending service life. All piston accumulators are fitted with a standard designed gas valve for ease of gas pre-charging. The steel gas valve protector reduces the risk of damage to the gas valve from external impact.

3. CALCULUS ELEMENTS

When the auto-truck's moving, the energy accumulated as mechanical work of the elastic forces of pressure in the air cushion, which is under pressure, of the hydraulic accumulator can be calculated using the theoretical

mechanical work relation for the isothermal case of the air cushion compression and expansion or for the polytropic case.
For the isothermal case we consider that this compressions or expansions of the air cushion from the hydraulic accumulator are developing without temperature modification [2]. So, the relation for this case is:

$$L_{iz} = p_1 \cdot V_1 \cdot \ln \frac{p_1}{p_2} \tag{1}$$

where:
p_1 - the maximum pressure in the air cushion;
V_1 - the minimum volume of the air cushion;
p_2 - the minimum pressure in the air cushion at the limit expansion.
For the polytropic case, when the temperature is modifying, for the compression and expansion cases, having also heat exchange with the environment, the same accumulated energy can be written:

$$L_{pol} = \frac{n}{n-1} \cdot p_1 \cdot V_1 \cdot \left[1 - \left(\frac{p_2}{p_1} \right)^{\frac{n-1}{n}} \right] \tag{2}$$

In this situation we notice the polytropic exponent *n*.
The plunger pumps attached to the mobile tank works when the auto-truck's in acceleration, in deceleration but also in curves (sinuous road), or in grade and slope roads.
So, in the case of decelerations, figure 5, the force exercised on the plunger pump's piston rod can be calculated with the following relation:

$$F = m \cdot a_d \tag{3}$$

where:
m – the mobile tank's mass;
a_d – the deceleration (braking acceleration)

$$a_d = \frac{\Delta V}{\Delta t} \tag{4}$$

where:
ΔV – the speed variation from the cruise value (the speed of the auto-truck) till the complete stop of the auto-truck;
Δt – the time interval necessary to stop completely the auto-truck.

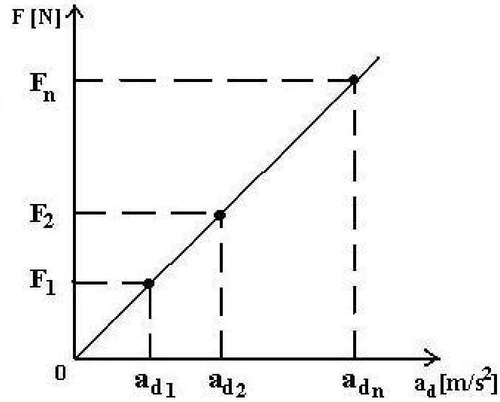

Fig.5. The force on the plunger pump's function of the deceleration.

In curve traveling the centrifugal force which acts over the plunger pump's piston rod can be calculated with the following relation, considering also figure 6:

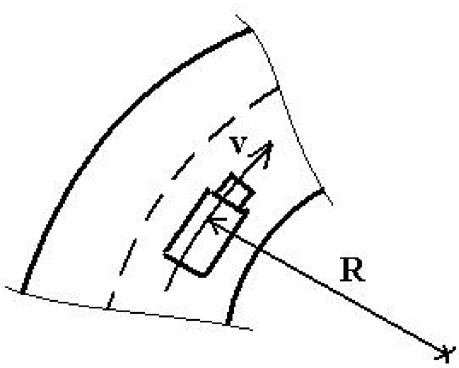

Fig.6. The auto-truck in a curve of radius R.

$$F_c = m \cdot \omega^2 \cdot R \qquad (5)$$

where:
F_c – the centrifugal force which acts over the plunger pump's piston rod because of the mobile tank's mass;
m – tank's mass;
ω - the angular speed in curve.

$$\omega = \frac{v}{R} \qquad (6)$$

where:
v – displacement (traveling) speed;
R – curve's radius on the road.

In the case of traveling with different speeds, the variation of the centrifugal force can be seen in figure 7:

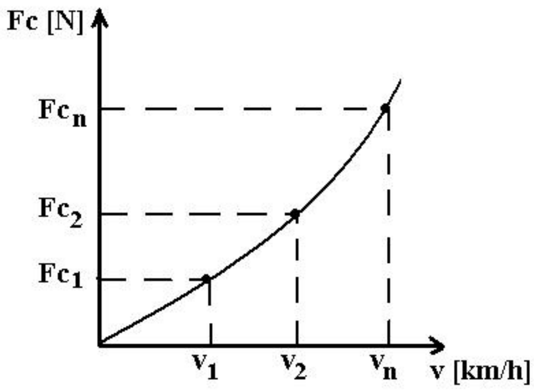

Fig.7. The variation of the centrifugal force at different speeds.

The theoretical energy consumed for climbing a hill in the case of the auto-truck without effective load, when we neglect the frictions, can be estimated using the relation:

$$E = m \cdot g \cdot \Delta A \tag{7}$$

where:
m – the auto-truck's mass without effective load;
g – the gravitational acceleration;
ΔA – the level difference from the base of the hill to the top.

4. NUMERICAL CALCULUS

In the case of a hydraulic accumulator for which the volumes ratio is $\frac{V_2}{V_1} = 10$, knowing that $V_2 = 1.5 \cdot 10^{-4}$ [m³], and $V_1 = 1.5 \cdot 10^{-5}$ [m³], in the case when the pressure $p_1 = 60at = 60 \cdot 9.81 \cdot 10^4 \frac{N}{m^2}$ and the pressure p_2 at the total expansion of the air cushion of the accumulator is $p_2 = 9.81 \cdot 10^4 \frac{N}{m^2} \cong 10^5 \frac{N}{m^2}$ in the situation of isothermal evolution is:

$$L_{iz} = 60 \cdot 9.81 \cdot 10^4 \cdot 0.015 \cdot \ln 10 = 2.034 \cdot 10^5 J \tag{8}$$

When climbing a hill with a level difference of $\Delta A = 50m$, the theoretical energy consumed for a auto-truck having it's mass of $m = 10000kg$ would be:

$$E = 10^4 \cdot 9.81 \cdot 50 = 4.9 \cdot 10^6 J \tag{9}$$

In percentage, the accumulated isothermal energy is about 4.16% from the energy necessary to climb a hill of 50m. If the evolution in the case of the accumulator is polytropic, in the same conditions (equal volumes and pressures) for a polytropic exponent $n = 1.3$ results:

$$L_p = \frac{1.3}{0.3} \cdot 60 \cdot 9.81 \cdot 10^4 \cdot 0.015 \cdot \left(1 - 10^{\frac{0.3}{1.3}} \right) = 6.4965 \cdot 10^5 J \tag{10}$$

This energy represents about 13.2581% from the necessary energy to climb a hill with a level difference of 50m, which can not be neglected.
At some time intervals, when we notice through special indicators on auto-truck's board that the hydraulic accumulator is under load, the driver can command the electro-valve from the hydraulic circuit to open, acting on the hydraulic engine which transmits the accumulated energy to the power circuit (auto-truck transmission).

5. CONCLUSIONS

In this paper it is presented a method to recover energy that can be used in auto-truck's traveling such as to reduce the fuel consumption, or can be used at the garage in other purposes, such as:

- tyres inflation;
- screwing up or down the wheel's screws;
- the actuation of a rotary hydraulic engine coupled with the transmission, such as to supplement the engine's power when climbing a hill;
- using the pressure from the accumulator's air cushion by connecting it to a tank with water, the auto-truck can be washed;

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