THE FREE PISTON ENGINE AS PRIME MOVER FOR CONVERTER BASED VEHICLE PROPULSION SYSTEMS

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ABSTRACT – The vehicle transmission, as a complex system, need to adapt chemical and thermal conversion processes of fuel to mechanical running conditions. Research done by the Romanian Researcher on the mechanical converter has demonstrated that it is a device that can be considered for vehicle propulsion. It is based on transferring energy using oscillations of mechanical coupled systems or hydraulic systems. Energy is provided usually using a rotational device like electrical motor or conventional internal combustion engine. It is necessary in these cases to adapt a device that converts rotational to translational movement in order to generate the necessary oscillations. To overcome these devices, the free piston principle is considered. A multi-domain model is build in order to evaluate the possibility of adapting the free piston device to generate the oscillations in both mechanical and hydraulic converter. Results and computation were done for an ATV. It was found that free piston engine allows a much compact technical solution then conventional engines, adapted to the oscillation based principle.

INTRODUCTION

The free piston engine is a device that converts the chemical energy of a fuel into mechanical translational energy that can be used to compress a gas (gas generator) (1), to displace a liquid (piston pump) (2) or to generate electrical energy (linear electrical generator) (3).

The free piston device was considered for some advantages: a direct linear connection of the engine piston to the piston of the actuation device, avoiding a dissipating mechanism to convert translational to rotational movement and vice-versa. This conversion steps are made with devices that are exposed to wear due to the lateral forces that generate friction. The control of the piston stroke is easily done at a free piston configuration. The effects are an improved thermal efficiency and lower part load consumption due to the variable compression ratio. In this paper only the hydraulic use of free piston energy is considered.

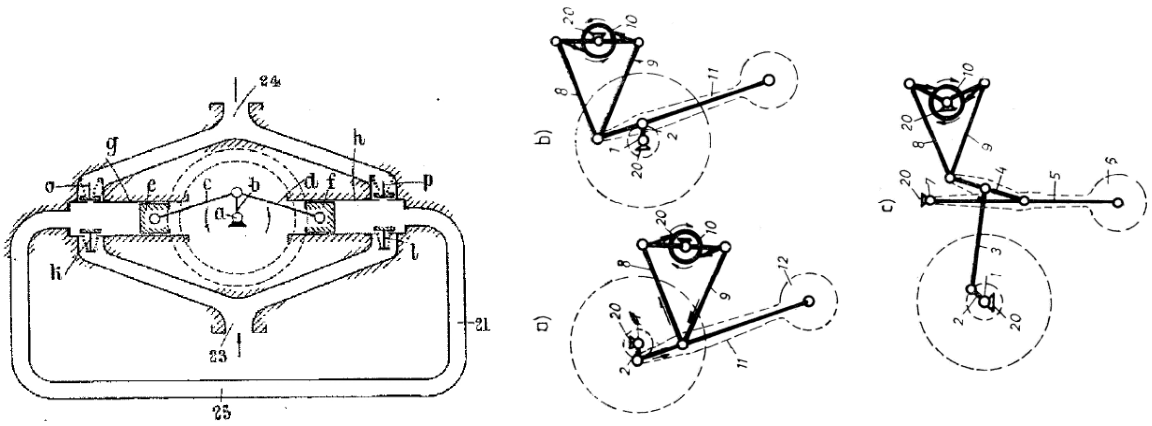

Fig. 1. Volumetric pump with variable flow and convertor – principle scheme: a), b), c) – functional variants

On the other hand the converter is a system that transfers energy using hydraulic or mechanical oscillations. The masses exposed to an alternative movement have a frequency dependent displacement due to inertial effects, accumulating and releasing energy because of these effects. High power densities are achievable in this way. Gogu Constantinescu (4) developed a hydraulic and a mechanical device base on this principle.

THE CONSIDERED SYSTEM

In figure 2 is presented the principle of the free piston – converter system. The main piston of the free piston engine converts the thermal energy into translational mechanical energy. The first consumer attached to the working piston is the compression piston that feeds the accumulator via a directional control valve, using a part of the expansion energy to compress the gas in the accumulator. The stored energy is used to compress the gas in the main cylinder in order to prepare a new combustion cycle. This process is controlled via the directional control valve. It can be seen that diverse functions of the compression stroke can be actuated, having effects on thermal efficiency, considering the time available for wall heat transfer (5).

A variable stroke can be easily obtained by controlling the moment of cutting the actuation energy from the accumulator. Part load efficiency can be improved by a very simple mechanism. The second user of the work available at the engine piston is the main piston of the converter. This piston feeds via a set of check valves the hydraulic motor that drives the vehicle wheels. In parallel to the main converter piston is connected another piston that actuates an external inertia, represented here as a rotational one.

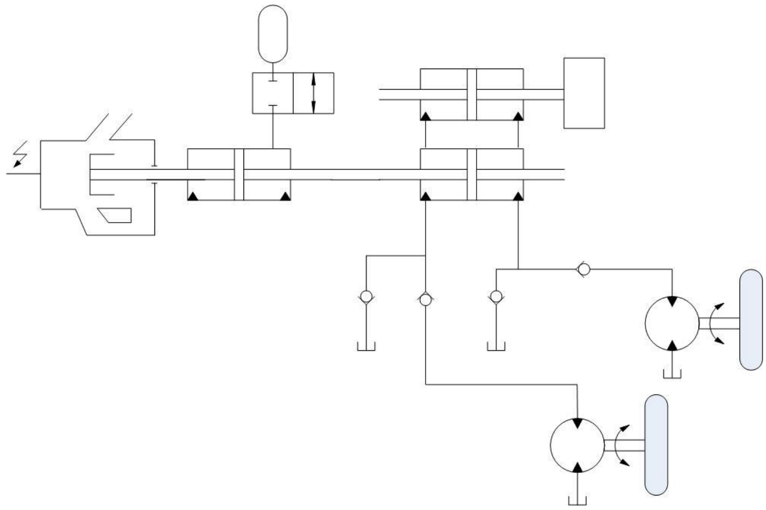

Fig.2. The working principle of the free piston engine coupled whit the hydraulic converter

In figure 3 is presented a solution of the mechanical converter, after (4) that is connected with the free piston engine. The working piston of the converter actuates the oscillating lever of the mechanical converter. The mechanical links actuate the lever of a freewheel mechanism that drives the vehicle wheels.

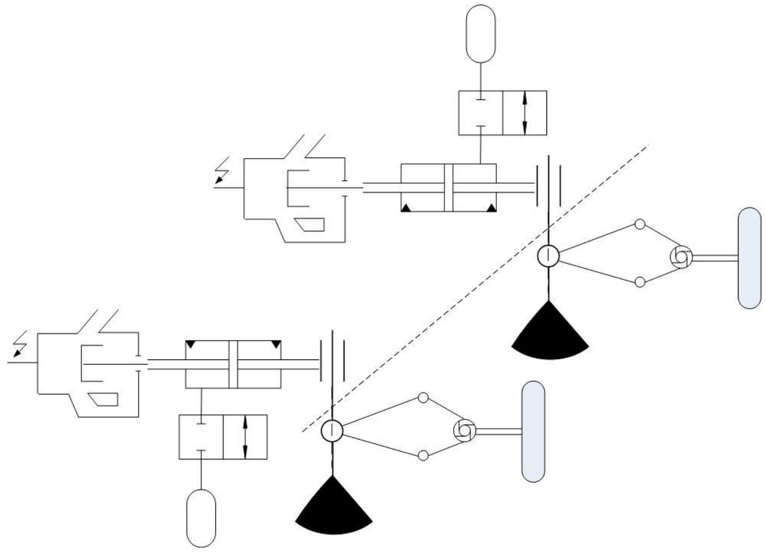

Fig.3. The free piston engine coupled with the mechanical converter

THE SIMULATION MODEL

In order to get an image of the performances of such a device, a multi-domain model of the propulsion system based on a free piston engine – hydraulic converter configuration has been made (fig.4.). The single cylinder model is coupled with a double acting piston as prime mover of the converter. The hydraulic system is modeled to propel a conventional 2 tones vehicle.

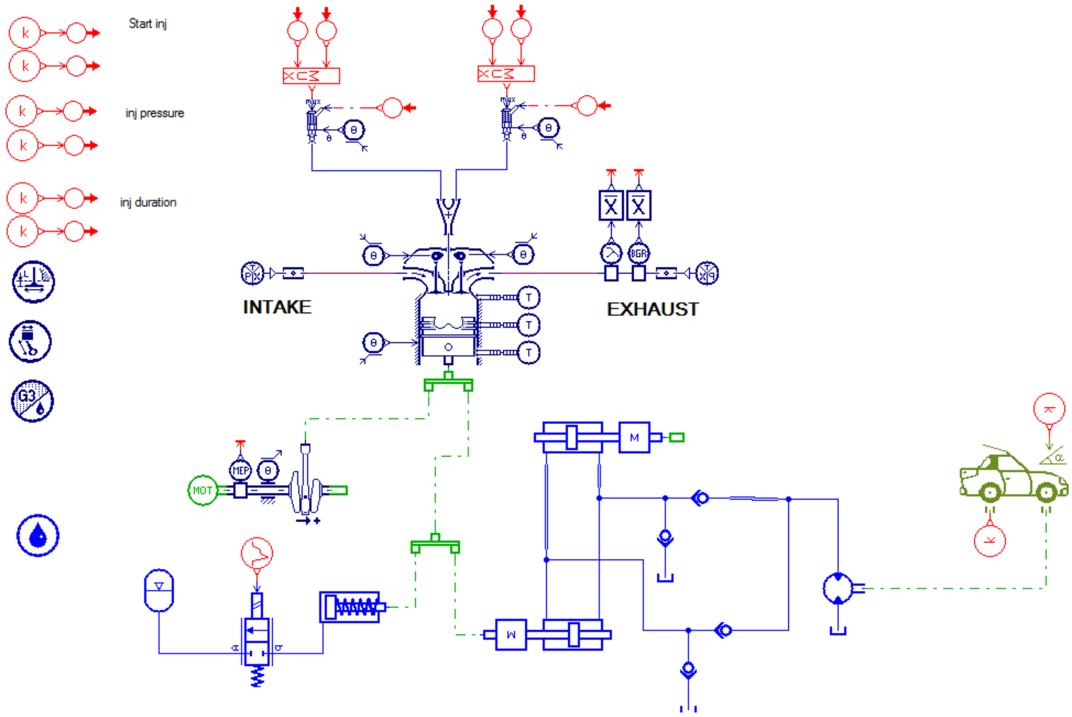

Fig.4. The free piston engine – hydraulic converter

RESULTS AND DISCUSSIONS

Numerous influences can be observed using this model. The main purpose of the simulations was to demonstrate the viability of the system. Simulations were done for a 25 and 50 Hz actuation frequency of the converter driving masses of 1, 3, 5, and 10 kg. The results of the simulation, considering the vehicle speed as main parameter to describe the vehicle performance, are presented in figure 5 for 25 Hz and figure 6 for 50 Hz.

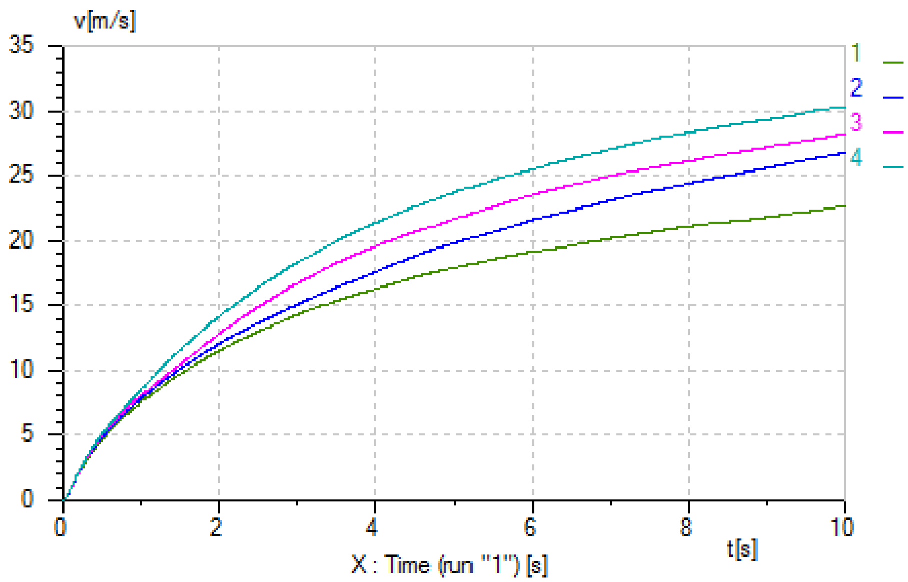

Fig.5. The vehicle speed for 25 Hz

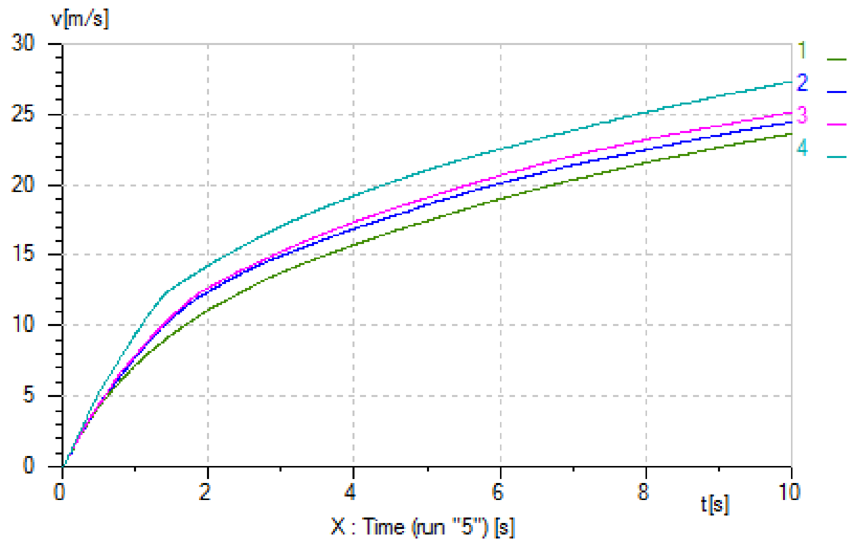

Fig.6. The vehicle speed for 50 Hz

It can be observed in figure 7, the acceleration of the vehicle, induced by the same mass of 5 kg actuated at 25 Hz, curve 1 and 50 Hz, curve 2, that there is an important difference in dynamical performance.

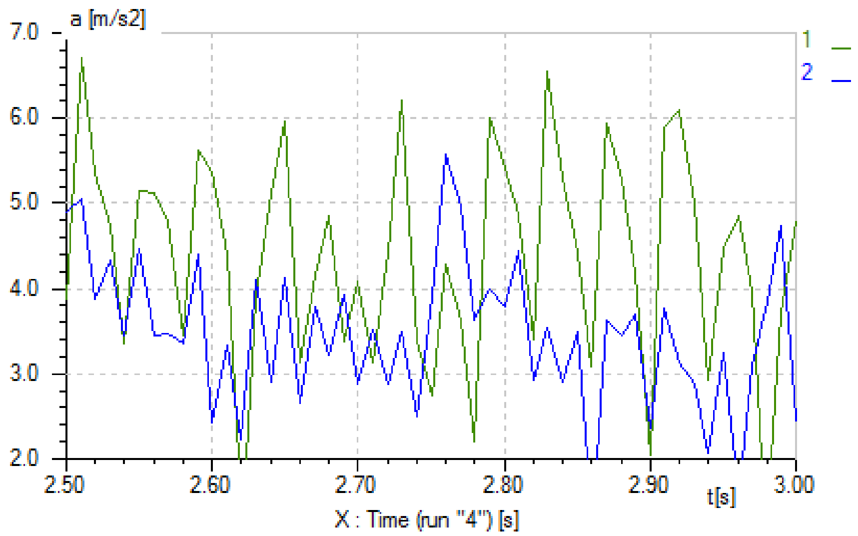

Fig.7. The acceleration of the vehicle

The dynamical performances of vehicle speed and acceleration are obtained at high performance, but conventional pressures as it can be seen in figure 8. As expected the pressure has important oscillations, but these oscillations are not propagated to the vehicle speed.

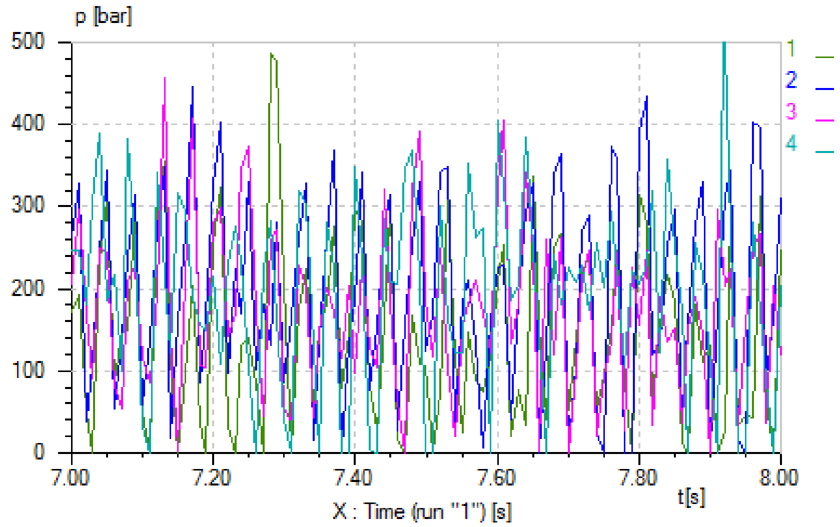

Fig.8. The pressure of the vehicle

CONCLUSIONS

The main purpose of the paper results were to identify the possibility of coupling a free piston structure with a hydraulic accumulator with a converter based hydrostatic propulsion system. A multi-domain model was used to simulate the system behavior.

It could be observed that high dynamical performances, like vehicle speed and acceleration, can be obtained for the vehicle at acceptable pressure levels. Additional advantages result in using a single cylinder structure that may run at constant speed.

The mass and frequency parameters have to be accorded each to other. Simulation results have clearly shown that a higher frequency hasn't as result a high vehicle speed. Also a higher mass that is displaced increases the vehicle speed, but the differences are in much closure intervals then the input values of the displaced mass.

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