FREE PISTON HYDRAULIC ENERGY GENERATOR USING THE STIRLING ENGINE PRINCIPLE

[1]Ionut Tudor Soare[*], [1] Gheorghe-Alexandru Radu, [1] Horia Abaitancei, [1] Sebastian Radu, [1] Aron-Adrian Petric

[1]Transilvania University of Brasov, Romania,

KEYWORDS – free-piston, Stirling engine, hybrid-hydraulic

ABSTRACT – Reducing fuel consumption for vehicles is not only necessary to save energy, but also for drastic reduction of polluting emissions, and for changing the transport system to be more economical and less pollutant.
Hydraulic hybrid systems have the advantage of high power density and the system of recovering the braking energy is able to work at high frequencies of loading/unloading conditions. Nowadays it is known that investigations are made to increase hydraulic efficiency, for example pumps and hydraulic motors with distribution controlled electronic, whose efficiency is 95%. Another direction is the primary source of hydraulic energy. A solution is using a free piston Stirling engine.
In comparison with the free piston Stirling engines, classical Stirling engines are complex, with a need for lubrication, seals and bearings that combined reduces the performance and limits the endurance of the engine. The power produced by the classical Stirling engine is hard to be used for hybrid hydraulic propulsion.
This paper describes simulation results of a free piston Stirling engine that generates the hydraulic energy needed by a hydraulic – hybrid vehicle propulsion. The system analyzed in this paper is a free piston Stirling engine.

INTRODUCTION

Hydraulic pump is one of the most complex elements with low efficiency. Energy transmission is made with heavy losses because the rotational motion s converted into translational motion and then into rotational motion again. To improve these situations, solutions are sought that the transfer system of the chemical energy into mechanical energy to be as close to the fundamental in facts of conversion mechanical energy into hydraulic energy.

The solution of the free piston engine is a way that can simplify the method of energy conversion. Unlike free piston internal combustion engine at Stirling engines which have external combustion is possible manifestation of principled advantages.

ADVANTAGES OF FREE PISTON STIRLING ENGINES

The free piston Stirling engine has numerous benefits over conventional engines and free piston internal combustion engine. First of it is the combustion process which is external and continuous. This advantage allows drastic improvement of the combustion efficiency and reduces the pollutant emissions in comparison with internal combustion engines where the combustion process is rapid and transient. Another benefit of Stirling engines is that because of the external combustion they are silencer than internal combustion engines, which allows them to be used in various applications.

Stirling engines because of its unique characteristic, can be powered by numerous and various types of fuels such as: gasoline, diesel, natural gas, coal. Alternative fuels such as: bio-diesel, ethanol, wood, rice husks can also be used to power the free piston Stirling engine. Stirling engines can run almost from any heat source, meaning that it can be powered directly from the solar energy.

Stirling engines can be classified in kinematic engines and free piston. At kinematic engines the output power is rotational movement and at free piston solution the movement remains linear. Because of that free piston Stirling engine can be used to actuate a hydraulic pump or to act as a linear electric generator [1].

DISADVANTAGES OF FREE PISTON STIRLING ENGINES

Despite continuous researches in this domain Stirling engines have also some disadvantages that made it to become worldwide used. First of all free piston Stirling engines are still expensive to produce, primarily because of the heat exchangers which have to permanently heat and cool the cylinder walls. The power output of the free piston Stirling engine is directly proportional to the gas pressure inside de cylinder. Another problem that shall be still resolved is the frictional loses between the cylinder and displacer, and cylinder and power piston [1].

PRINCIPLE OF OPERATION

The technical solution is considered a hydraulic pump driven by the free piston Stirling engine. The scheme of principle is given in Figure 1.

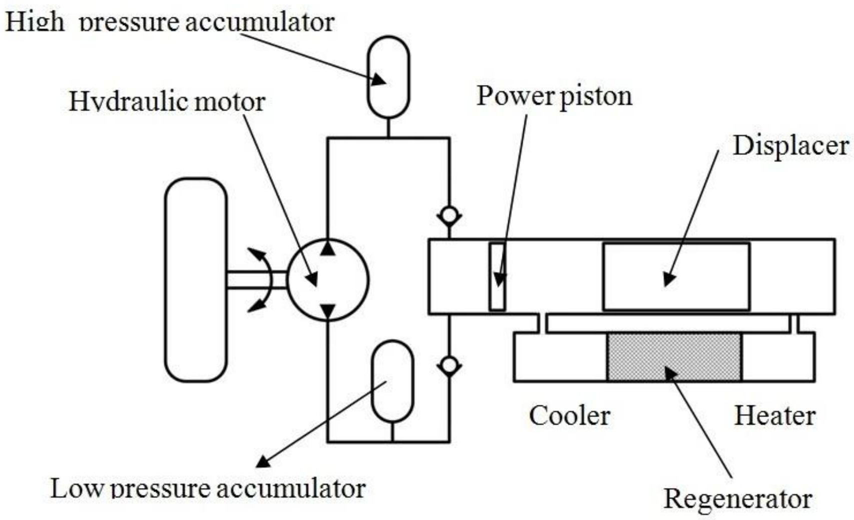

Fig. 1 Schematic diagram of free-piston Stirling engine

The space in the right of the displacer is continuously heated by a heat source and the space on the left side of the displacer is permanently cooled so that always is a difference of temperature between the hot side and the cold one. The displacer moves the air from the hot side to the cold one so that air expands when heated and contracts when cooled and a difference of pressure is created moving the displacer [2].

DISPLACER PISTON

When the temperature in front of the displacer is lower than the one behind it, the engine pressure is changed by the movement of the displacer. The pressure increases when the displacer is to the left side and all of the air is in the hot side. The pressure decreases when the displacer is moving to the right side of the cylinder. The displacer only moves the air back and forth from the hot side to the cold side.

PUMP PISTON

When the engine pressure reaches its maximum because of the motion of the displacer, a power piston is pushed by the expanding gas adding energy to the liquid column that drives the hydraulic motor. The displacer type Stirling engine is operated by the power of the power piston.

SIMULTION AND RESULTS

To realize the analysis of different parameters that influence the functioning of free piston Stirling engine, the formula number (1) presented below was taken into account [3].

$$P = Wn \cdot pn \cdot f \cdot V_0 \cdot \frac{T_H - T_C}{T_H + T_C} \qquad (1)$$

Where: Wn – a constant equal with 0.25, p_n – nominal pressure, f – frequency, V_0 – work volume, T_H – temperature in hot side, T_C – temperature in cold side

After calculation and simulation of the various parameters entered in the composition of the formula (1) the following graphics resulted:

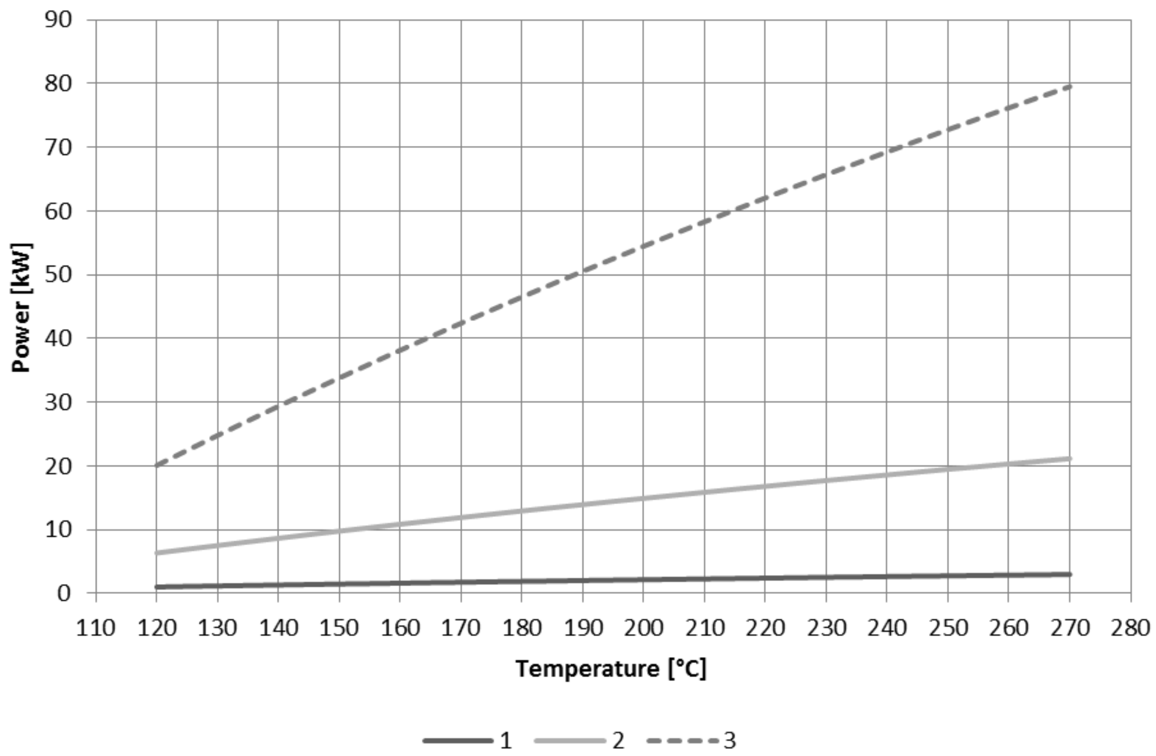

Fig. 2 Variation of engine power depending of temperature

In figure 2 is illustrated the dependency of power versus temperature. In series marked with 1 the volume taken in consideration is 2 dm^3, nominal pressure of 10 bar, frequency of 25 Hz, temperature in cold side of 60 degrees Celsius and the temperature varies between 120 – 270 degrees Celsius. In series marked with 2 the volume taken in consideration is 1.5 dm^3, nominal pressure of 50 bar, frequency of 50 Hz, temperature in cold side of 70 degrees Celsius, and in series 3 the volume taken in consideration is 1 dm^3, nominal pressure of 150 bar, frequency of 100 Hz, temperature in cold side of 80 degrees Celsius.

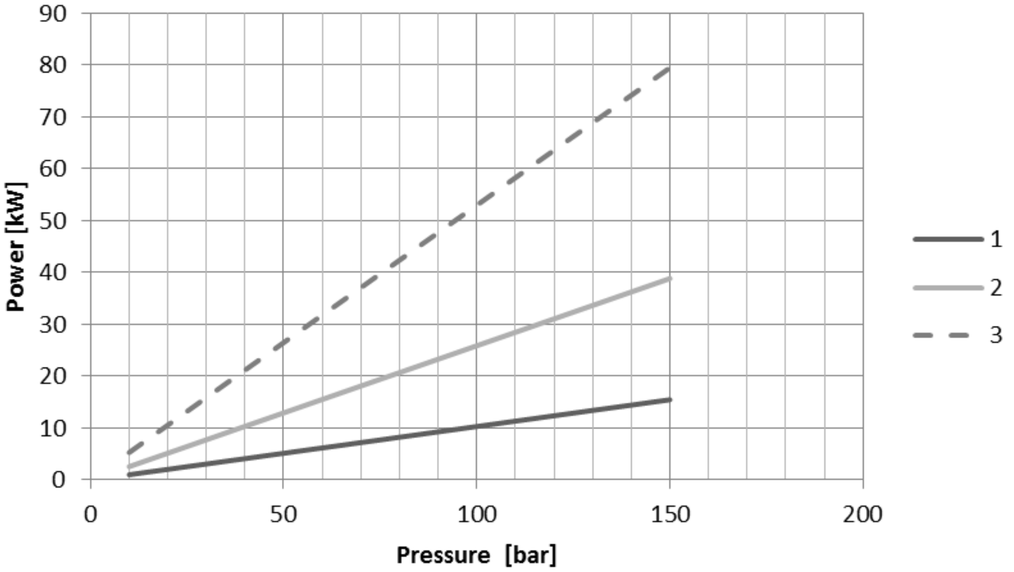

Fig. 3 Variation of power depending on pressure

In figure 3 is illustrated the dependency of power versus pressure. In this chart the pressure varies between 10 to 150 bar. In series 1 the temperature in hot side is 120 degrees Celsius, frequency of 25 Hz, the volume of the cylinder 2 dm^3, temperature in cold side 60 degrees Celsius. In series 2 the temperature in hot side is 180 degrees Celsius, frequency of 50 Hz, the volume of the cylinder 1.5 dm^3, temperature in cold side 70 degrees Celsius, and in series number 3 the temperature in hot side is 270 degrees Celsius, frequency of 100 Hz, the volume of the cylinder 1 dm^3, temperature in cold side 80 degrees Celsius.

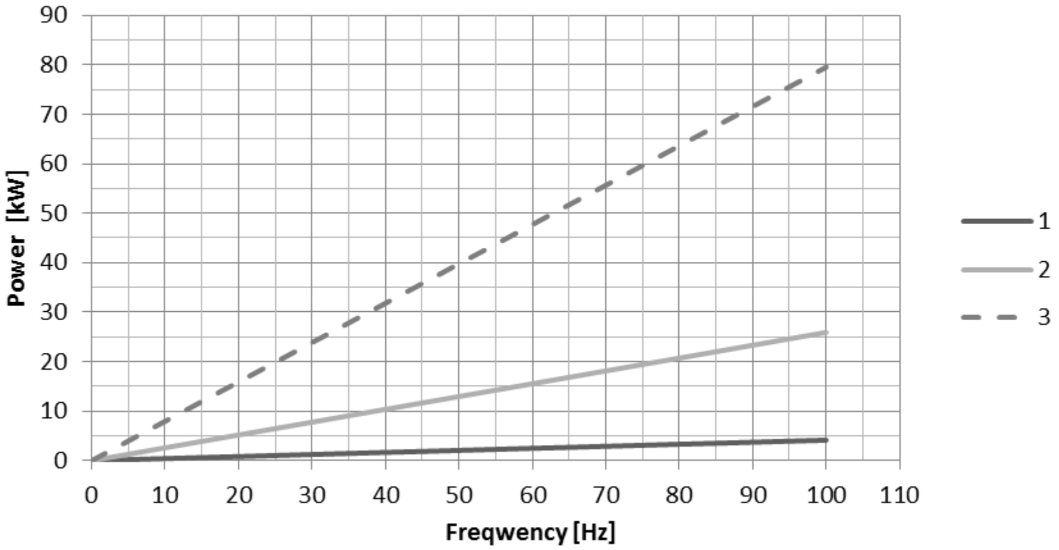

Fig. 4 Variation of power depending on frequency of the displacer

In figure 4 is shown the variation on power depending on the frequency of the displacer. In this figure in series 1 the elements that are constant are: the nominal pressure 10 bar, the temperature in hot side 120 degrees Celsius, volume of the cylinder 2 dm^3 and the temperature in hot cold side 60 degrees Celsius. In series 2 the volume is 1.5 dm^3, pressure 50 bar, the temperature in hot side 180 degrees Celsius and in the cold side 70 degrees Celsius. In series 3 the volume is 1 dm^3, pressure 150 bar, the temperature in hot side 270 degrees Celsius and in the cold side 80 degrees Celsius. The frequency of the displacer varies between 0 to 100 Hz.

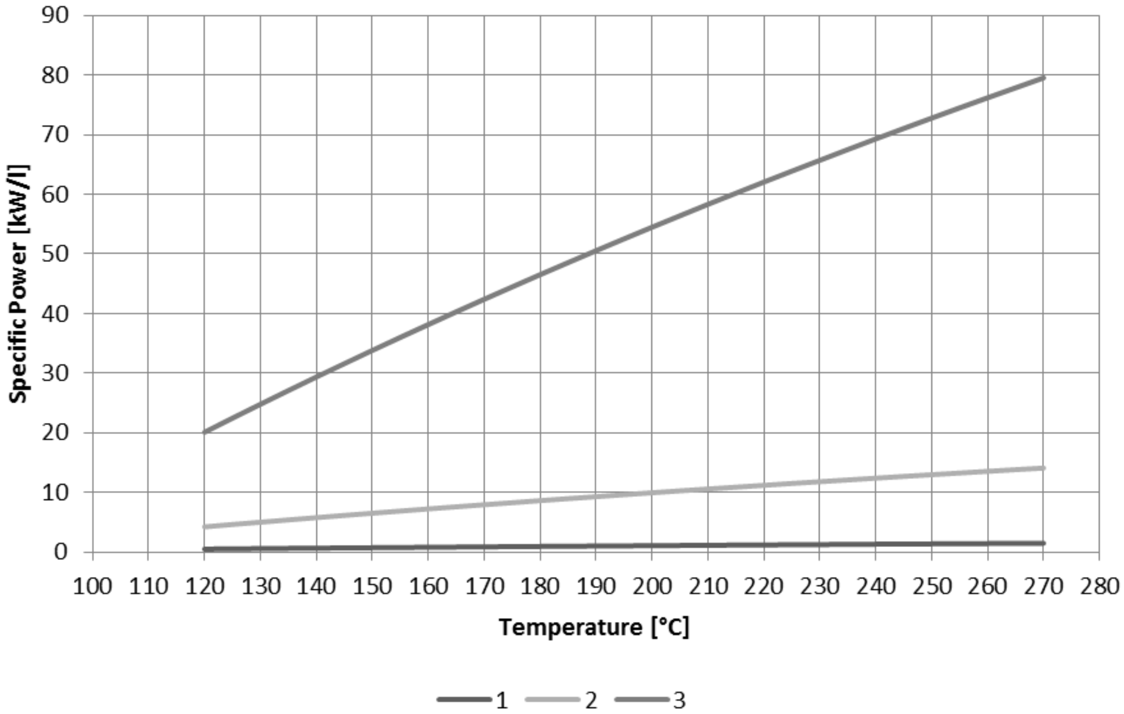

Fig. 5 Variation of specific power depending on temperature

In this chart (fig. 5) is illustrated the dependency of specific power versus temperature. The series marked with 1 the nominal pressure is 10 bar, frequency of 25 Hz, temperature in cold side of 60 degrees Celsius and the temperature varies between 120 – 270 degrees Celsius. In series marked with 2 the nominal pressure is 50 bar, frequency of 50 Hz, temperature in cold side of 70 degrees Celsius, and in series 3 the nominal pressure of 150 bar, frequency of 100 Hz, temperature in cold side of 80 degrees Celsius.

CONCLUSIONS

Pressure influences significantly the power output of free-piston Stirling engine. At high pressure the engine construction is more compact but appears problems at sealing. Once with increasing the frequency a proportional increase of power is obtained. At high frequencies the inertia of masses in motion of translation plays an important role in the evolution of pressure, where in the future requires a dynamic analysis.Acceptable specific power is obtained in free piston Stirling engine resulting that it can be used in vehicle propulsion.

ACKNOWLEDGEMENT

This paper is supported by the Sectoral Operational Programme Human Resources Development (SOP HRD), financed from the European Social Fund and by the Romanian Government under the contract number POSDRU/88/1.5/S/59321.

This paper is supported by the Sectorial Operational Programme Human Resources Development (SOP HRD), financed from the European Social Found and by the Romanian Government under the contract number POSDRU/6/1.5/S/6.

REFERENCES

[1] James D. Van de Ven, Mobile hydraulic power supply: Liquid piston Stirling Engine Pump, Renewable Energy, Issue 34, 2009, pages 2317-2322;
[2] ***, http://www.phy.duke.edu/~hsg/176/answers/how-does-sterling-engine-work.pdf, 09.september. 2010
[3] C. D. West, Stirling engines and irrigation pumping, Oak Ridge National Laboratory, TM-10475, 8 September 1987