FUNCTIONALITY OF THE STIRLING ENGINE WITH NONCONVENTIONAL MECHANISM FIK

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Abstract: At the design of heat engines like Stirling engines are, it is possible to use not only classical crank mechanisms, but also non-conventional mechanisms. Engines with non-conventional mechanisms may have several advantages when used in practice, but the design calculation model is often more difficult [6]. This paper deals with the design of the measuring system for the measurement and diagnostic of basic parameters of the thermal cycles in Stirling engine with nonconventional FIK mechanism, which was solved in the project VEGA: Nonconventional engine FIK – Stirling. The measuring system concept is applied to a special type of piston machines with swinging mechanism that is used in this instance of a Stirling engine type. Stirling engines are currently usually used as a drives of machines for production of the electricity [2]. There are several types of mechanisms, which are suitable by design for use in a Stirling heat engine. FIK mechanism is a swinging system, which is characterized by circular motion of the central point of the swinging plate during the rotation of the shaft. Proposed measuring systems allows to confirm the functionality of the structural design of Stirling engine with a swinging plate and examine the thermodynamic phenomena conducted in the engine cylinders.

Keywords: *FIK MECHANISM, SENSOR, DESIGN, MEASUREMENT*

1. Introduction

Stirling engines are currently used in the production of electricity. There are several types of mechanisms, which by design are suitable for use in a Stirling heat engine [1]. In the case of prototype devices of Stirling engines, which verifies the functionality of the machine is necessary to determine the progress of thermodynamic phenomena taking place at the premises of the rollers and therefore need to create and implemented on a machine measuring system [3] [4].

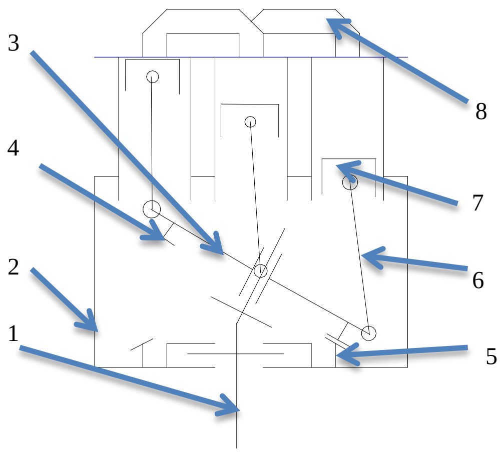

Fig.1 Schematic model of the nonconventional design FIK:
1- Crankshaft, 2- crankcase, 3- swinging plate, 4- bevel wheel (part of swinging plate), 5 bevel wheel (part of crankcase), 6- ball joint segment, 7- piston, 8- head cylinder and regenerator pipe

Fig.2 Mechanism FIK virtual model without cylinders and head valves

2 Measuring system

The measuring system (Fig. 3, Fig. 4) consists of pressure and temperature sensors, RPM sensor and the cooling cylinder is provided through non-return valve inlet pressure [5].

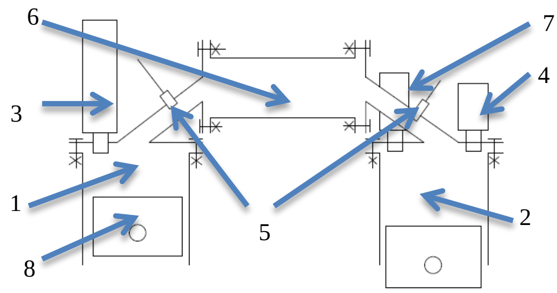

Fig.3 Schematic representation of the measurement system in head cylinder: 1- Heat cylinder, 2- cooled cylinder, 3- Heat cylinder pressure sensor, 4- Cooled cylinder pressure sensor, 5- Temperature sensor, 6- regenerator, 7- Non-return valve, 8- Piston

RPM sensor (Fig.4) is connected with a rubber coupling on the output shaft. This sensor is located at the bottom of the flywheel [5].

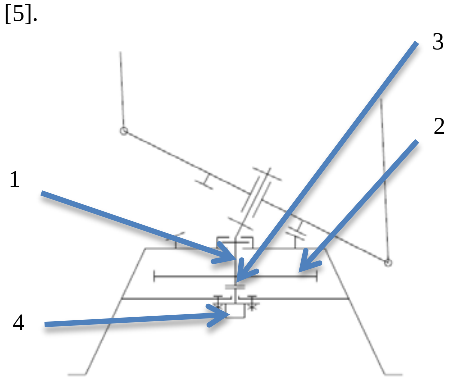

Fig.4 RPM sensor: 1- Output shaft (crankshaft), 2- flywheel, 3- rubber coupling, 4- RPM sensor

3 Virtual and real models

The exact location (Fig. 5) of each sensor was designed in CAD software. In this case, the pressure sensors are located in the cylinder heads and the thermocouples are attached with connections screws in the interconnecting pipes. Supercharging system (Fig. 6, 7) consists of non-return valve and pneumatic distributor [5].

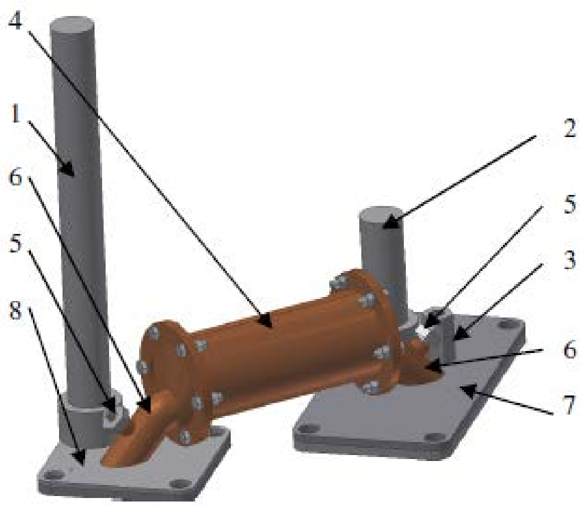

Fig.5 Virtual model of head valves, interconnection pipes (one pair) and regenerator pipe with sensors: 1- Heat cylinder pressure sensor, 2- Cooled cylinder pressure sensor, 3- Non- return valve (Supercharging system), 4- Regenerator pipe, 5- Temperature sensor connection 6- Interconnection pipe, 7- Cooled cylinder head valve, 8- Heat cylinder head valve

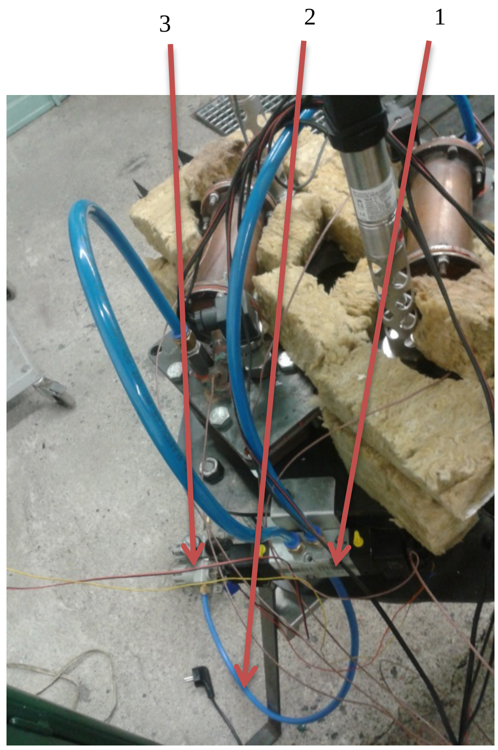

Fig.7 Part of supercharging system: 1- Pneumatic distributor, 2- Rubber hoses (outlet from the compressor), 3- Water separator- oil lubricator

RPM sensor (Fig. 8) is attached to the aluminum console that is fixed to the engine block.

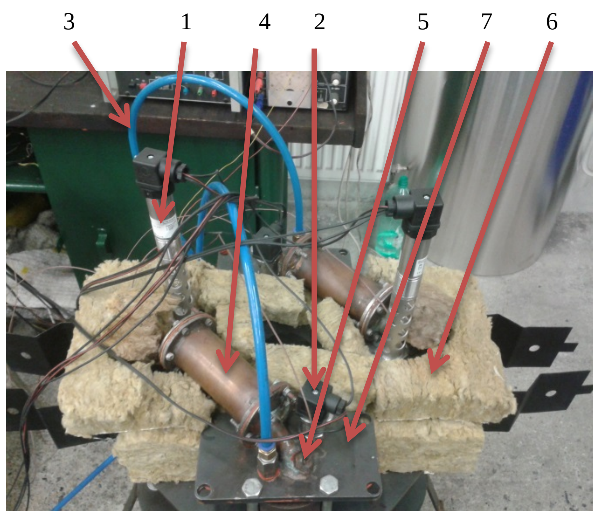

Fig.6 Real model of head valves interconnection pipes and regenerator pipe with sensors: 1- Heat cylinder pressure sensor, 2- Cooled cylinder pressure sensor, 3- Pneumatic rubber hose (Supercharging system), 4- Regenerator pipe, 5- Temperature sensor (thermocouple) connection 6- Thermal isolation, 7- Cooled cylinder head valve

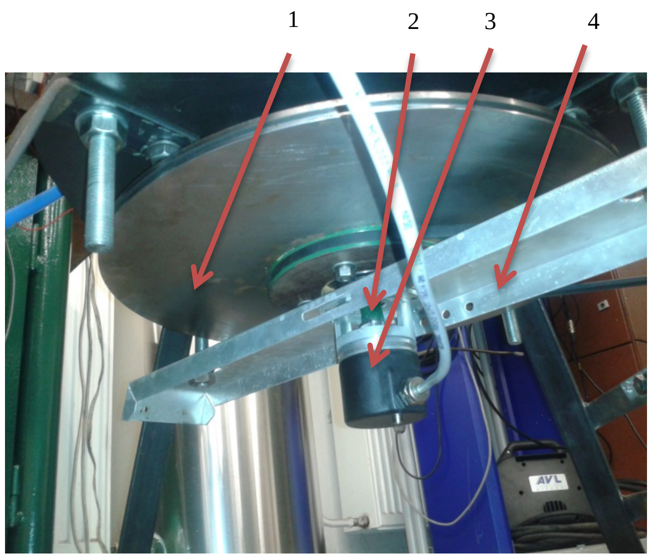

Fig.8 Design of RPM sensor connection: 1- Flywheel, 2- Rubber coupling, 3- RPM sensor, 4- Aluminium console

4 Static pressure test

Initial test, which was performed on the engine was tightness test. In this case, the tightness was tested by pressurizing of one pair of interconnection pipe to 3.4 bar and it was measured time for which the pressure drops to atmospheric pressure. The pressure was measured simultaneously by two sensors, one to be heated cylinder heads, on the other side of the cooled cylinder. Turbocharging system is integrated into the head of cooled cylinder and therefore the measured values between the sensors slightly delayed onset of pressure in the space heating of the cylinder (Fig. 9). For measurements we used a measurement card NI USB 6211. The measured values are processed in LabVIEW environment.

Initial conditions:

- time range 30 second

- pressure range 0- 10 bar

- output voltage signal 0-5 Volts

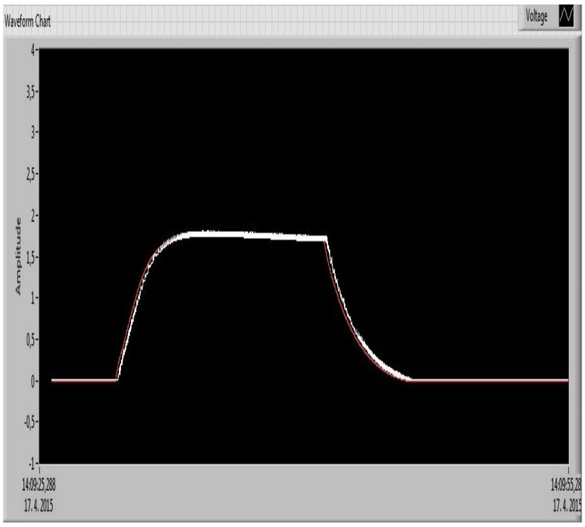

Fig.9 Progress of pressure: cooled cylindersensor- red curve, heat cylinder white curve

To measure the of pressures was created a simple enviroment (measuring system) in LabVIEW (Fig. 10).

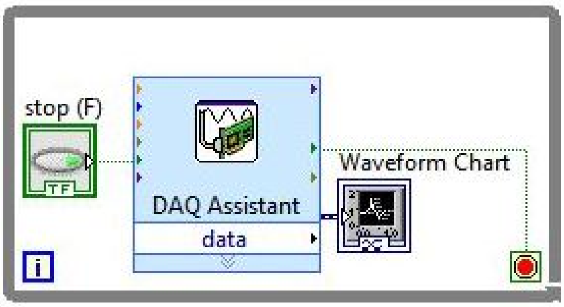

Fig.10 Virtual enviroment in LabVIEW

5 Results

The measured values were exported to Microsoft Excel. As can be seen in Figure 10 the system cannot keep the pressure even at still supercharging.

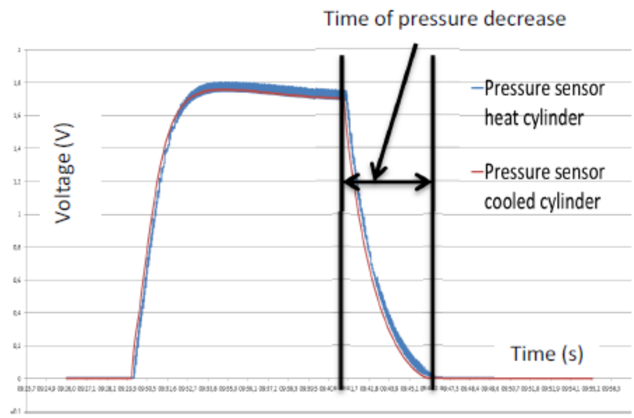

Fig. 11 Progress of pressure in excel

The time of pressure decrease is about 4.5 second. Measurement was done several times on both pairs of interconnection pipes. Waveforms of pressure drop in the two pairs did not differ significantly and their values when calculating of the average values of time decrease were negligible difference.

6 Conclusion

Problems of Tightness in engine FIK can be divided into two parts:

- tightness of Solids engine (this is a leaks of air between the connected parts mainly cylinder heads, cylinders and interconnecting pipelines, regenerator and interconnecting pipelines and integrated sensors),

- tightness of the moving parts of the engine (this is a leaks of air between the cylinder and piston).

The tightness of brazed joints (it is a test using soapy water) showed a small leak incurred in the manufacturing process. The tightness of brazed joints (it is a test using soapy water) showed a small leak (Fig. 12) incurred in the manufacturing process. This problem can be solved by re-melting the solder in the assembled state of the engine.

The tightness between cylinders and pistons can be improved by using suitable piston rings.

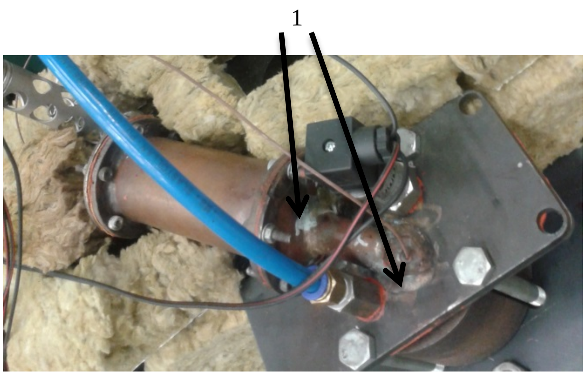

Fig.12 Head valve with interconnection pipe system: 1- soldered joints

5 Literature

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