The Application of Microcontrollers Diagnostic System for Evaluation of Stirling Engine

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Abstract. The article presents the microcontroller system for diagnostic and evaluation of the Stirling engine performance. For this purpose the model for the prototype engine analysis has been developed, to present the engine’s improved benchmarking results. The most relevant objective in this respect was to achieve a uniform heat transfer across each tube of the hot gas heat exchanger. The functioning of this engine has been analyzed with the aim to find and optimize the main working parameters. To obtain this goal the Stirling engine has been equipped with different kinds of electronic sensors. A microcontroller testing circuit has been designed, which uses the acquisition of data from the data module. One of the important tasks of testing a Stirling engine is to present a model, which is able to represent the dynamics involved in all essential processes of the engine.

Keywords: Stirling engine, heat transfer, regenerator, performance.

1 Introduction

A Stirling engine is an external combustion engine based on the Stirling Cycle. Developed first in 1816 by Robert Stirling, this engine produces power from differences in temperature. The working fluid inside the engine, typically air, hydrogen or helium, is heated on one end and cooled on the other, consequently causing the gas to expand and compress, respectively. In addition, the expansion and compression of the working fluid moves two pistons within the engine cylinder, which in turn are depending on the configuration, coupled in some manner with a drive mechanism to produce a net power output [16]. The Stirling engine requires a sufficient temperature difference \((T_{\text{max}} - T_{\text{min}})\) to operate. The low temperature Stirling engine operating on small temperature differences was studied in 1991 by Senft [5]. This machine runs with a temperature difference of only 0.4 °C. In this construction was used a glass cylinder and a graphite piston, and it is not easy to manufacture such a system locally. A PTFE (PolytetraFluoroEthylene) cup was developed using 0.2 mm thick pure PTFE sheet.

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The manufacturing method was complex and this engine performance was not as good as reported but the Stirling machine run continuously for several months and has started and run only from the heat of a human hand.

The maximum temperature difference is limited by the heat sink temperature, usually atmospheric and by the temperature limit of the hot end material. The heat source can be chemical, solar, nuclear or some other one, typical for thermal storage. By the use of heat pipe technology the heat source does not have to act directly on the hot end of the heat exchanger (Hargreaves, 1991) [6]. This can allow a more conventional heat exchanger design and much higher rates of heat transfer.

As stated by the Second Law of Thermodynamics, heat must be dissipated from the Stirling engine. Considerable heat is discharged from an internal combustion engine by the exhaust directly to the atmosphere. For example, in a Diesel engine about 30 % of the heat supplied by combustion is dissipated by the exhaust and almost 35 % by the radiator. With the Stirling engine heat rejected by the exhaust has not gone through the engine cycle and is wasted. To maintain a high efficiency of an engine, more heat must be dissipated by the radiator. This puts about twice the thermal load on the radiator than in a comparable Diesel engine (Walker) [7]. This is less of a concern with marine engines but can add considerable expense and bulk when the heat is dissipated to the atmosphere via radiator. Stirling engines lack a throttling method inherently built into other engines. One method of changing power output is to change the diameter of the choke point of the engine, which is the point at which the hot air flows from the heat transfer to the engine cylinder. Choke points are often specifically designed to work optimally at one setting. A choke point that can be varied is advantageous, because power output can be altered on the fly. The goal of this project is to develop a simple variable choke point for use in a small Stirling engine. Originally, types of Stirling engines were classified into three groups, according to the Kirkley-Walker classification system: Alpha, Beta, and Gamma [9], depicted on Fig. 1.

Fig. 1. Stirling engine types: Alpha, Beta, and Gamma [8]