Conception, fabrication and characterization challenges of a Stirling cycle micro-motor for thermal energy harvesting.

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Currently, production, consumption and energy saving are major issues in our society. Since 2014, the Institut Interdisciplinaire d’Innovation Technologique (3IT) at Université de Sherbrooke (UMI-LN2) has been collaborating with several partners on the Micro Stirling Cluster (MISTIC) project in the design and development of free-piston Stirling engine, dedicated to heat energy harvesting on low temperature heat dissipating systems (< 200 °C) [1]. The mechanical properties of a polymeric piston membrane assembly were favorable for the micro-engine’s startup, according to the MISTIC project’s Stirling engine model [2] [3]. However, the previous version of the prototype was not able to start by itself in its operating environment, specifically with a temperature differential of 180 °C between the cold exchanger and the hot exchanger. In this study, we worked on several aspects of the micro-engine to make it start; fig.1 shows its new design. In fact, the prototype is made of three sub-assemblies: the hot exchanger, the cold exchanger and the core that is composed of the hot membrane, the cold membrane with strain gauges, the hot baseplate, the cold baseplate, the frame, the three pistons and the 6 kapton shims. The fluid used inside the working chambers is helium. When heated, the fluid applies a pressure force on the hot membranes, which pulls the pistons toward cold chambers. Cold side fluid flows through the regenerators in the hot chambers and over time, the pistons synchronize with each other with a phase of 120°. This paper shows how the prototype was improved. Firstly, we rebuilt the geometry and improved the fabrication method. Secondly, in order to help the micro-engine to reach its resonance frequency for optimal operation, we dimensioned and fabricated an external electromagnetic actuator. To allow us to observe the membranes evolution after the operation, we made a non-permanent assembly. To ensure that the sealing is strong enough to sustain five bar of He, we spin-coated a PDMS thin layer on the membranes. They were dimensioned to be permeable enough to let us the possibility to fill the micro-engine through them, and at the same time, to be hermetic enough to avoid any leakage while the core is compressed between the two exchangers. We dimensioned and fabricated a test bench specifically for the micro-engine. Finally, to observe and characterize the dynamic behavior of the membranes during the operation, we developed a strain gauge technology, which could also measure the temperature inside the working chambers.

Fig. 1. Exploded schematic representation of the developed Stirling micro-engine

REFERENCES