NUMERICAL SIMULATION FOR THE PERFORMANCE ANALYSIS OF A GAMMA STIRLING ENGINE PROTOTYPE

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Abstract

The Stirling engine is a closed-cycle regenerative system that presents good theoretical properties. These include a high thermodynamic efficiency, low emissions levels thanks to a controlled external heat source, and multi-fuel capability among others. However, the performance of actual prototypes largely differs from the mentioned theoretical potential. Actual engine prototypes present low electrical power outputs and high energy losses. These are mainly attributed to the complex interaction between the different components of the engine, and the challenging heat transfer and fluid dynamics requirements. The complexity of the system has heightened the need for engineering tools, such as numerical simulation, that could assess design improvements on the engine components and thus increase the engine performance. Following this trend, the current work aims to analyse the performance of a Stirling engine prototype with the help of simulation tools. The prototype presented very low experimental performance; furthermore, there are no available research studies for the engine. For these reasons, the numerical analysis methodology was selected for the initial identification of possible causes that limited the performance. The analysis is based on a second order Stirling engine model that was previously developed and validated. The simulation allowed to evaluate the effect that different design and operational parameters have on the engine performance, and consequently different performance curves were obtained. These curves allowed to identify ranges for the charged pressure, temperature ratio, heat exchangers dimensions, crank phase angle and crank mechanical effectiveness, where the engine performance was improved. In addition, the curves also permitted to recognise ranges were the design parameters could drastically reduce the brake power and efficiency. The results also showed that the engine could reach a brake power closer to 832 W with a corresponding brake efficiency of 26% when the adequate design parameters were considered. On the other hand, the performance could also be very low; as the reported in some experimental tests, with brake power measurements ranging 52-120 W.

Keywords: Stirling engine; simulation and modelling; thermodynamic analysis; energy technology