The Advancement of Stirling Cycle Engines

C. Clanachan, A. Knox

Progress towards the advancement of Stirling Engines by adjustment of the phase angle between the engine pistons is described. Included is an introduction to Stirling engines and their potential role in on site energy generation, an outline of the project aims and a guideline for future investigation and proposed techniques

The Stirling cycle is a closed loop thermodynamic cycle which can be used to produce power from a heat differential and the cyclic compression and expansion of a working fluid. To illustrate the basic concept Figure 1 shows the layout of a simple beta type Stirling Engine (S.E.):

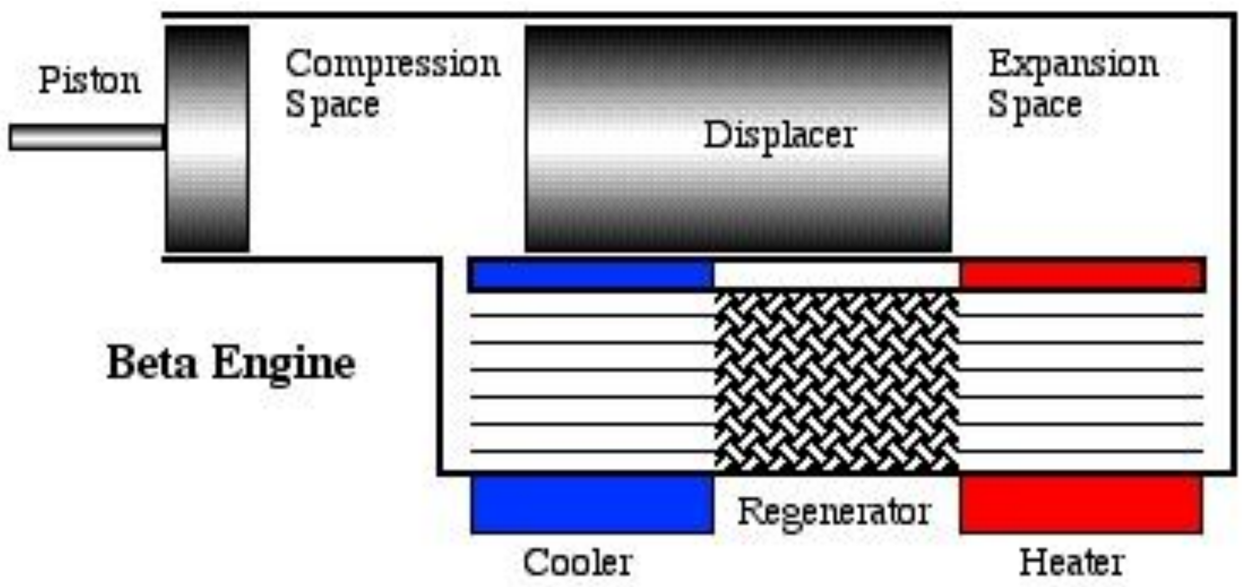

Figure 1 – Diagram of a beta type Stirling Engine

Recent investigations have found Stirling Engines can be used to provide the electrical component of on site heat and power generation units. Combined heat and power generation (CHPG) reduces the transmission losses and supply—demand irregularities associated with off sight generation as well as potential CO2 reductions of up to 20%[1]. CHPG units can have overall efficiency ratings of up to 85% however practical Stirling Engine efficiencies are rarely above 15% and need drastic improvement.

The main **aim** for this research project is to identify ways of increasing the power output and efficiency of a S.E by varying the phase angle between the two pistons of the engine. The phase angle is the angle which represents the offset between the displacer piston and the power piston. In a conventional Stirling configuration the phase angle is fixed at approximately 90°; experimental work will characterize performance at other angles.

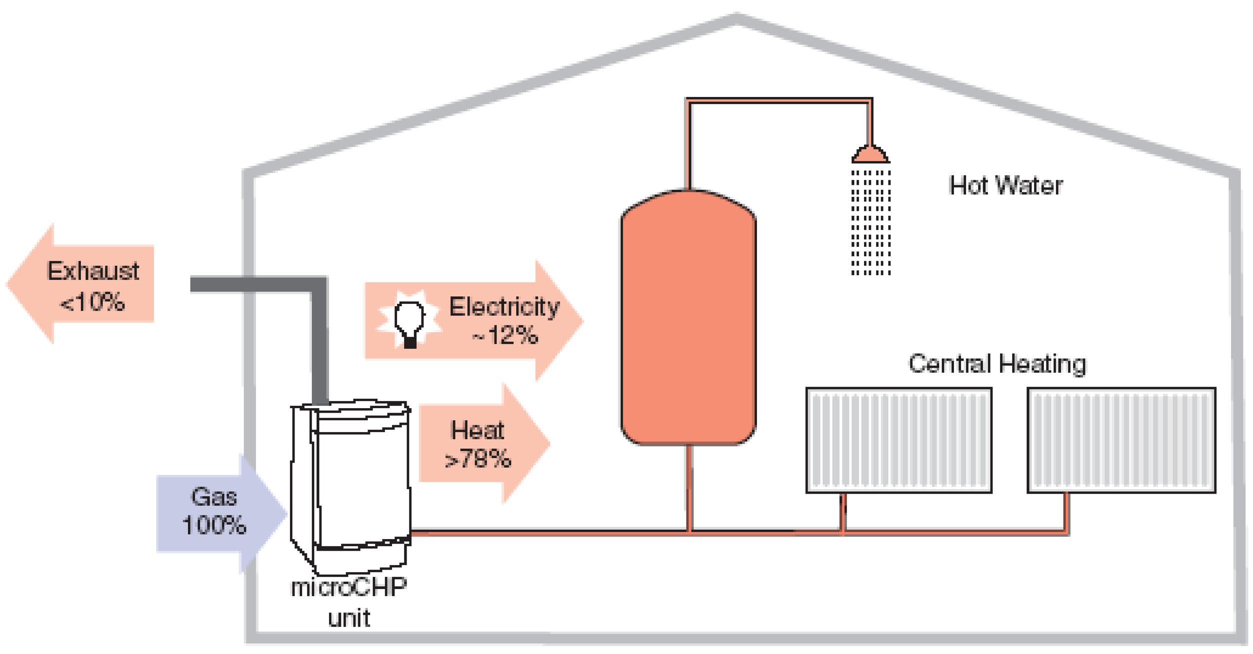

Figure 2. Micro-CHP in the heating and hot water system (Whispergen design manual)

The ability to **change the phase angle** would allow a number of benefits. C. Cinar[2] has shown that in terms of power output, the optimum phase angle for the Stirling engine varies between the expansion chamber, the heating and cooling chambers, and the compression chamber - the optimum value ranging between 80° – 100°.

Additionally, the power output waveform of the engine is currently sinusoidal and is constrained to periods of reduced power production. If the **phase angle** can be controlled and the duration where the peak power output occurs can be extended the overall mean power can also be increased. An example of the desired waveform is shown in Figure 3.

Due to the absence of test data it was deemed advantageous to build an experimental engine. This engine is a 0.5 watt mechanical output displacer Stirling Engine with a wire heating element and water cooling, shown in figure 4.

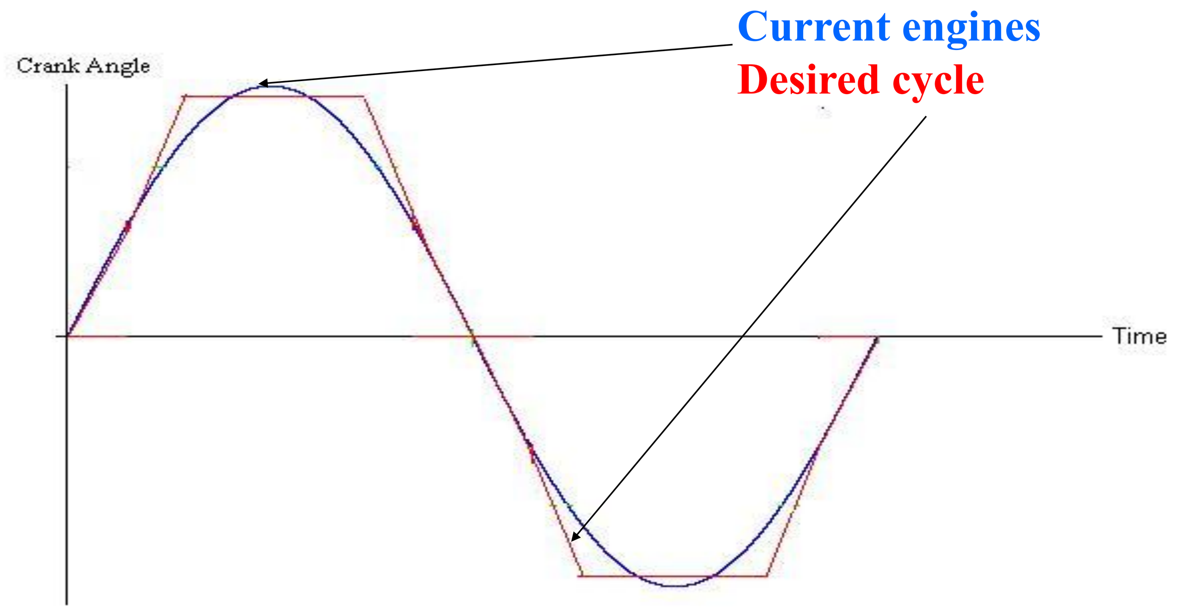

Figure 3:- current sinusoidal phase angle and desired controlled phase.

Initial tests have been performed and a working state has been achieved using propane gas as the heat source. The engine, however, suffered from large losses due to friction and gas leaks and a larger experimental engine with a much great projected power output is currently in development. This engine should provide a greater margin for error in terms of losses and will encompass the lessons learned during the manufacturing of the first engine. It will also allow the effects of changing the phase angle to be analysed over a wider temperature and speed range.

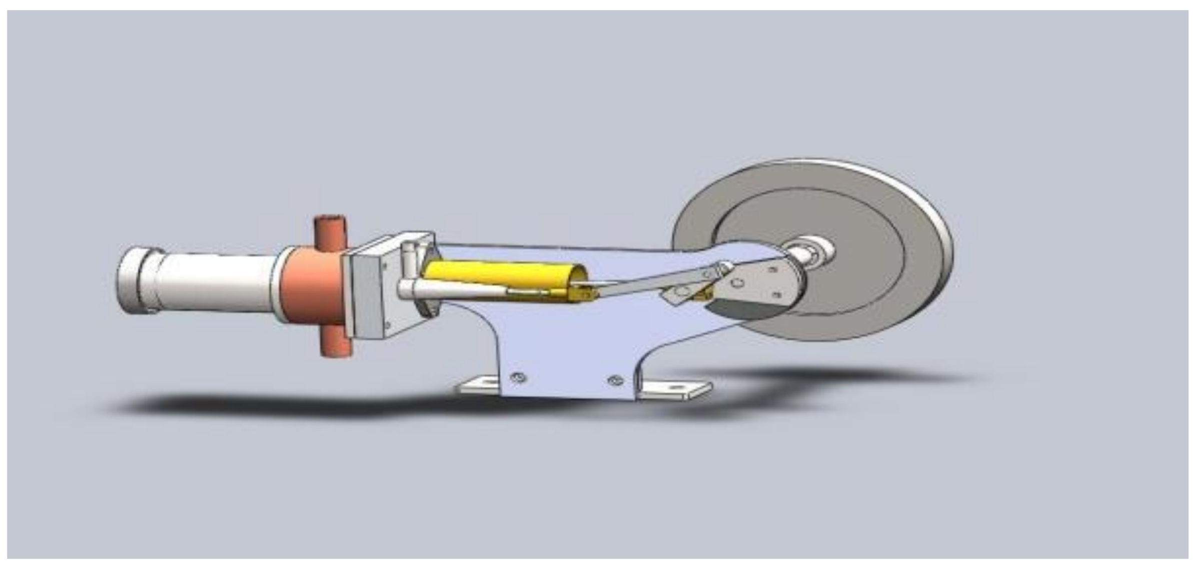

Figure 4. Experimental Model Stirling Engine - Fizgig

Future investigations will include the practical consequences generated by changing the phase angle such as induced vibrations and mechanical stresses. Additionally, general Stirling Engine optimization is planned, bringing together some of the latest material and gas flow knowledge to create a more efficient and competitive energy production unit.

For more information, please contact Craig Clanachan (c.clanachan.1@research.gla.ac.uk) or Professor Andrew Knox (Andrew.Knox@glasgow.ac.uk)

References

[1] Alanne, K *et al*. *Techno-economic assessment & optimization of Stirling Engine micro-cogeneration systems in residential buildings.* Journal of Energy Conversion and Management, (2009)

[2] C. Cinar. *Thermodynamic analysis of an alpha type stirling engine with variable phase angle*. Journal of Mechanical Engineering Science, 221(3):949{954, 2007.