Stirling Engine and Heat Pipe Combination

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1. Introduction

Energy recovery is an ever expanding industry. Demand continues to grow yet resources diminish. Alternatively, renewable energy sources, such as solar and wind, have low efficiencies but are available to all at no cost. The Stirling engine and heat pipe combination uses the same concept and is geared towards harnessing the waste heat discarded from many industrial processes.

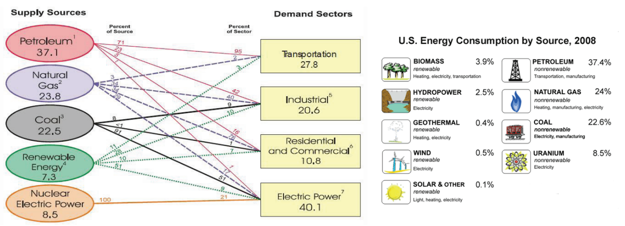
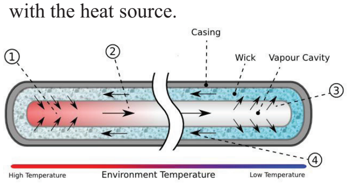


Figure 1 U.S. Energy Usage (2008)

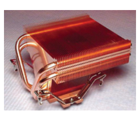
2. Heat Pipes

A heat pipe is a heat transfer device. It allows the transfer of heat from one location to another. In this project it is used to transfer waste heat to the Stirling engine without requiring the engine to be in physical contact with the heat source.



1) Working liquid evaporates, absorbing thermal energy.
2) Vapour migrates along the cavity to lower temperature end.
3) Vapour condenses and is absorbed by wick, releasing thermal energy.
4) Working liquid flows back to higher temperature end.

Figure 2 Heat Pipe



CPU Cooler

Satellite

Solar Dish

Alaska Pipeline

Figure 3 Applications of Heat Pipes

3. Stirling Engines

The Stirling engine (SE) is an external heat source engine. A SE contains a sealed gas and relies on heat transfer to create work through the expansion and compression of the gas. Hundreds of designs of the Stirling engine have been created and these can be classified into three categories. They are Alpha, Beta, and Gamma engines. Schematics are shown in Figures 4-6. Each engine operate on the same principles, but have different piston and displacer locations.

4. Engine Configurations

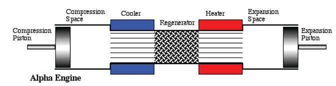


Figure 4 Schematic Alpha Engine

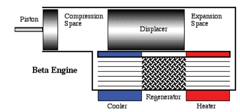


Figure 5 Schematic Beta Engine

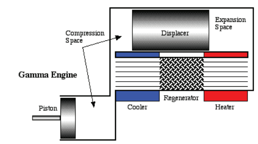


Figure 6 Schematic Gamma Engine

5. Stirling Cycle

1 → 2 Isothermal Expansion
2 → 3 Isovolumetric Heat Removal
3 → 4 Isothermal Compression
4 → 1 Isovolumetric Heat Addition

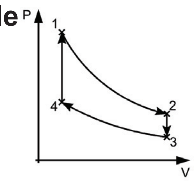


Figure 7 The Stirling Cycle

Work is only created during the expansion portion of the cycle. This means that for the remainder of the cycle, another way of conserving energy, such as a fly-wheel, is required. The cycle can repeat indefinitely as long as the conditions are favourable.

6. Objectives

The goal of this project was to design and construct a Stirling engine which can be coupled to a previously designed heat pipe. This heat pipe – Stirling engine (HP-SE) combination will then be used to capture, concentrate, and convert (3 C's) low grade waste heat to electricity.

7. Design

The most important factors to consider in the design of a Stirling engine are the sizing parameters, sealing, volume ratios, crank mechanism, temperature differential, and type of engine. Originally, with a previous student, a twin opposing piston engine (alpha type) was constructed. Unfortunately, this engine was not suitable for the applications envisioned. Thus, a new engine (gamma type) was designed rectifying the problems encountered in the previous model.

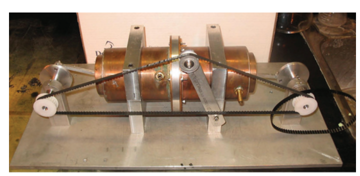


Figure 8 Original Engine (Alpha)

Figure 9 New Prototype (Gamma)

8. Construction

During the design process it was decided that the engine should be easily disassembled and modified with a single hex key. The image below illustrates the initial design. The base is 14 inches (~0.35m) and the height (excluding the fly wheels) is 6 inches (~0.15m). Most of the engine is made of aluminum except for the power piston (graphite), the displacer (plastic), the displacer rod guide (graphite), and the screws (stainless steel). In addition to being easily modified, the engine has a variable crankshaft which allows for a change in stroke length (compression ratio).

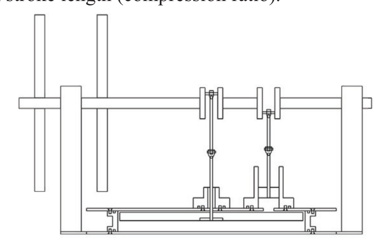


Figure 10 Schematic Design Drawing

As of August 4th, 2010 the engine is still under construction.

9. Testing

Once the engine is complete, testing will begin. Simple tests will be used to tweak the design. Temperature differential, rpm, and torque will be measured. Initially, boiling water and air cooling will be used to create a temperature differential. Once the design is proven, the jackets will be attached and the tests in conjunction with the heat pipe will commence.

10. Acknowledgements

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Picture Sources

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