SOLAR STIRLING ENGINE – INTRODUCTION AND CONFIGURATION

Introduction

Due to pressing political and environmental factors, the entire world is looking for alternative energy sources. For decades scientists have been researching everything from photovoltaic cells to solar troughs in an effort to find ways to use clean, renewable resources to generate power. Many of these breakthroughs can be expensive and difficult to maintain for such little power output compared with traditional power generation. Finally, an invention that is over 100 years old may provide a solution – the Stirling engine combined with solar power. (Shown on the right is a picture of the future solar plant)

Stirling Engines

A typical stirling engine consists of a reciprocating piston/cylinder arrangement in a closed regenerative cycle. Sealed inside the cylinder arrangement is a pressurized gaseous “working fluid” which follows ideal gas laws. The fluid flows back and forth between a hot heat exchanger, a regenerator (or temporary heat store) and a cold heat exchanger. Though usually hydrogen, the fluid can be helium, nitrogen, air, methane, or even ammonia. The fluid is heated by an external source, and the increased pressure in the heated cylinder pushes on the power piston. The movement of the piston turns a crankshaft which produces work. Materials with low coefficients of friction are used in the construction of the engine, and some designs eliminate sliding altogether by using diaphragms instead of pistons.

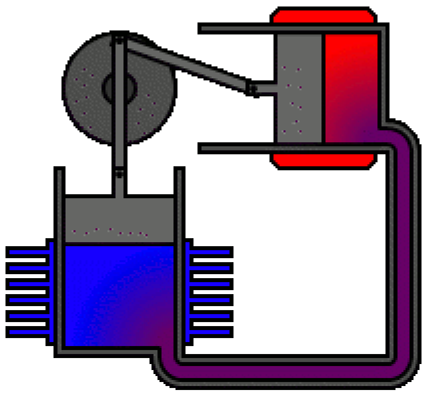
Theoretically, the stirling engine can perform to full Carnot Cycle efficiency, but there has been no success in practice. Depending on the configuration, efficiency typically hovers around 25-30%. It can run on a temperature difference as little as 7°C, with diminished power output, of course. The engine can also be supplied with mechanical power to reverse its cycle and be used as a heat pump.

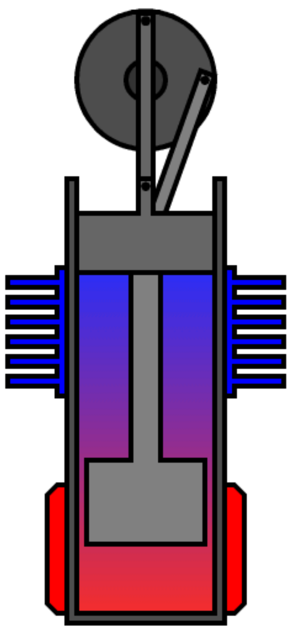
Cycles

The stirling cycle has four steps involved in its operation, illustrated in the animation below.
1. *Heating*: Energy is transferred from the heat source to the working fluid through the hot heat exchanger. This causes the pressure of the working fluid to increase within the fixed volume contained by the piston. The bulk of the fluid is contained in the hot cylinder at this time.
2. *Expansion*: At a certain point, the pressure within the cylinder becomes high enough to displace the power piston. The power piston turns the crankshaft which results in a power output. The working fluid will continue to expand until the pressure inside the cylinder reaches equilibrium with the pressure applied by the piston.
3. *Cooling*: On the cold side, energy is transferred from the working fluid to a heat sink through the cold heat exchanger. This causes a pressure decrease in the cold side. At this point, the working fluid is mostly inside the cold cylinder.
4. *Compression*: At a certain point, the pressure within the cylinder becomes low enough to displace the displacement piston, sending the cooled fluid back to the hot cylinder. The working fluid will continue to compress until the pressure inside the cylinder reaches equilibrium with the pressure applied by the piston.

Configurations

The presence of the regenerator is really what distinguishes a Stirling engine from a simple hot air engine. There can be many different piston/cylinder configurations. Here are the three most common types:





Alpha: The alpha configuration consists of two connected cylinders (shown left) – one housing the power piston and one housing the displacement piston. The working fluid flows between the two cylinders during operation. This configuration yields a high power to volume ratio, but it can have some maintenance problems with the durability of the seals in the hot cylinder.

Beta: The beta configuration consists of two pistons moving within the same cylinder (shown right). This configuration is also known as displacement. The power piston is tightly fitted in the cylinder, while the displacement piston is loose

Gamma: The gamma configuration is basically the beta configuration with the power piston mounted in a separate cylinder. This configuration provides lower compression, but is mechanically simpler – so it is used more frequently in multi-cylinder engines.

There are also several other configurations that are less widely used. Sometimes a diaphragm is used instead of a piston in an effort to eliminate moving parts. A typical rotary engine qualifies as a Stirling engine. Even a thermoacoustic refrigerator is a Sterling engine – the device is different, but the gas still follows the Stirling cycle.

Benefits/drawbacks

The Stirling engine has many benefits, most notably its ability to run on any available heat source. This fact alone makes it eco-friendly. It typically runs between 15% and 30% efficiency, and Stirling electricity generation is cost-competitive with traditional generation up to 100kW. It's quieter, more reliable, and lower maintenance than an internal combustion engine – which is why it has been used to power submarines and some aircraft.

Unfortunately, the Stirling engine has a high capital cost as well as a high cost per unit power. Though it can operate on as little as a 7˚C temperature difference, it needs a large difference to be efficient. It's larger and heavier than a traditional internal combustion engine. The system cannot start instantly – it needs time to warm up and build momentum. By the same token, the power output is relatively steady and cannot be changed quickly.

Source : http://me1065.wikidot.com/solar-stirling-engine