A Review of Heat Engines

Aman GUPTA[1], Sunny NARAYAN[2]

[1] Indus University, India, sn2008@rediffmail.com

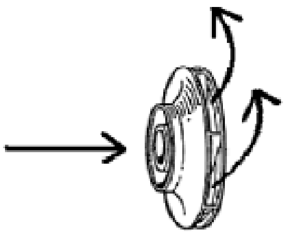
[2] Indus University, India, rarekv@gmail.com

Abstract: *Engines are common engineering devices which have become essential to the smooth running of modern society. Many of these are very sophisticated and require infrastructure and high levels of technological competence to ensure their correct operation, for example, some are computer controlled, others require stable three phase electrical supplies, or clean hydrocarbon fuels. This project focuses on the use of novel Stirling engine which can be used to pump water up to certain distance without use of expensive material. Some models working on this model have also been discussed.*

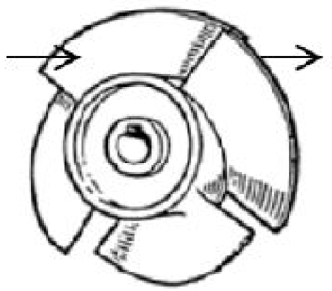
Keywords: *Engines, Pumps*

1. Introduction

Pumps are the most important mechanical devices that play an important role in our daily lives. They have been used in the form of Persian wheels or water wheels since ancient times for irrigation purposes. They cause displacement of the working fluid by adding energy to it.
A common way to classify these pumps is on the basis of method of addition of energy to the working fluid. On the basis of this classification, pumps can be classified as following:
1) Dynamic pumps-in these pumps, energy is added to increase velocity of fluid. They may be further classified as axial flow, Radial flow or mixed flow pumps.
In Radial flow pumps, fluid enters axially and flows out radially. They are more suited for high volume flow rates and high heads, whereas in axial flow pumps, fluid enters and leaves axially. These pumps are suited for low heads and low flow rates.
In mixed flow pumps, fluid enters axially and leaves both radially and axially. They are more suited for medium heads and medium flow rates.



a) Radial pumps



b) Axial pumps

c) Mixed Flow Pumps

Fig. 1. Dynamic pumps

2) Displacement type-energy is added periodically by application of force to the fluid boundary. Piston pumps are common type of such devices.

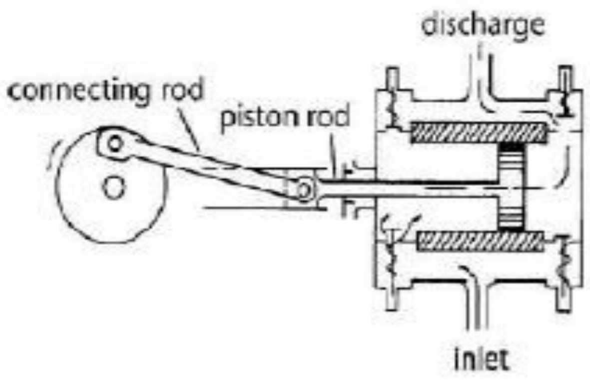


Fig. 2. Piston engine

2. Historic development of Stirling engines

As you enter the past, you will find direction for the future"- Ivo Kolin,[2]

During the industrial revolution of 18th century, steam engine became a primary source of power. But this device has its own drawbacks. Its maximum efficiency is at the most 2% and there were many accidents involving explosions. This prompted engineers to look for alternative sources of power like Stirling engines.
A Stirling engine is a hot air engine operating on the principle that air expands on being heated and contracts on being cooled. These devices have zero exhaust and are external combustion engines, hence wide variety of fuels can be used to run a Stirling engine which include alcohol, bio -products or waste gases etc These engines are suitable for operations which have following needs**:**
A) Constant power output.
B) Noise less operation.
C) Long startup period.
D) Low speeds.
Development of Stirling engine is widely attributed to the Scottish scientist Sir Robert Stirling. The first version of this engine developed in 1815 was heated by fire and air cooled. Figures of some of these early versions are presented in coming sections.

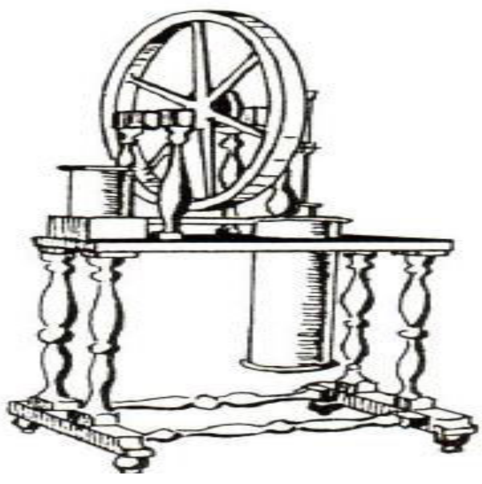


Fig. 3. Earliest version of a Stirling engine developed by Stirling brothers

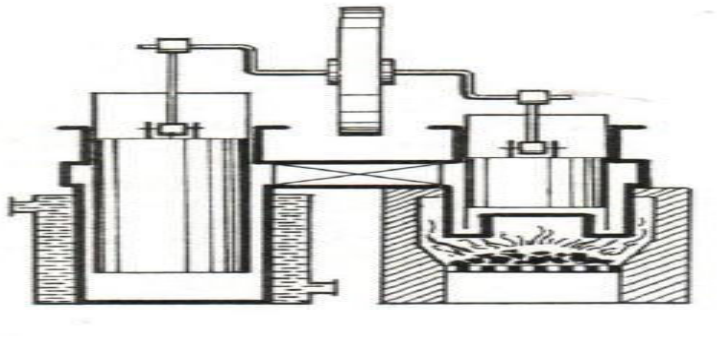


Fig. 4. Alpha type Stirling engine developed in 1875

Later Erickson in the year 1864 invented the solar powered engine to heat the displacer tube at hot side. The heat was obtained by use of solar reflectors. First alpha type engine was built in the year 1875 by Rider. Reader and Hooper proposed the first solar powered heat engine for irrigation purposes in the year 1908. Following this Jordan and Ibele designed a 100W solar powered engine for pumping of water. In year 1983 a low temperature difference Stirling engine was patented by the White having an efficiency of about 30%.Colin later presented a design with a low temperature difference of 15°C & Senft published specifications of a engine with very low temperature difference of 5°C between hot and cold ends [3].
Some of following events can be considered as important milestones in the design and development of a Stirling engine for use as a pump:

1688: Thomas Savery develops a drainage pump which was a liquid piston machine.
1909: Development of Humphrey pump.
1931: Malone designed and developed an engine with regenerative cycle similar to a Stirling engine.
1965: Philips Company patented a Stirling engine.
1977: The metal box company develops Stirling engine for irrigation purposes in Harwell lab.
1985: McDonnell designed an engine with parabolic reflectors to focus solar energy thus achieving a high temperature of 1400°C.

Fig. 5. McDonnell Engine

3. Heat engines [4]

A thermal engine is a device which converts heat energy into mechanical energy. The operation of a heat engine can be described by a simple thermodynamic cycle as follows:

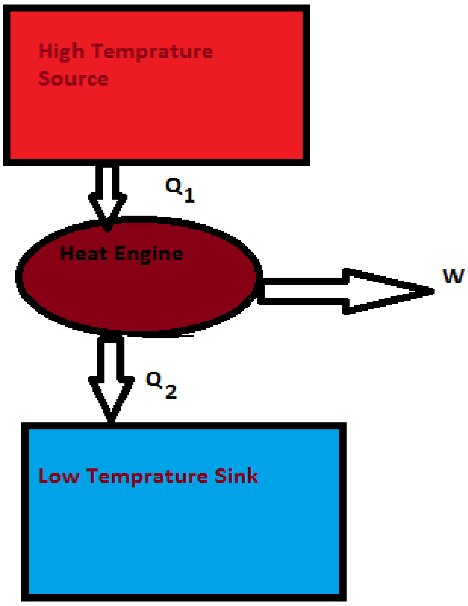


Fig. 6. Heat engine

Efficiency

$$\frac{W}{Q_h} = \frac{Q_h - Q_c}{Q_h}$$

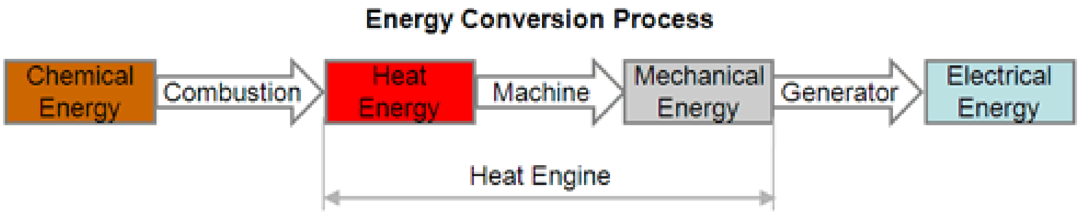


Fig. 7. Energy conversion in a Heat Engine

Heat engines can be further classified as external combustion engine or internal combustion engine. An engine where fuel is burnt outside the engine is an external combustion engine, whereas in the internal combustion engine, the fuel is burnt inside the engine. An engine operating on a Carnot or Stirling cycle is an example of an external combustion engine while one operating on an Otto or Diesel cycle is an internal combustion engine. Comparison of these cycles is presented below:

TABLE 1: Comparison of various engines

Type of combustion	**Cycle**	**Compression**	**Heat addition**	**Expansion**	**Heat Removal**
External	Carnot	Adiabatic	Isothermal	Adiabatic	Isothermal
External	Stirling	Isothermal	Isometric	Isothermal	Isometric
Internal	Otto	Adiabatic	Isometric	Adiabatic	Isometric

4. Conclusion [5, 6, 7]

Parabolic mirrors can be used to focus solar energy for operation of a liquid piston engine; such a device is shown below.

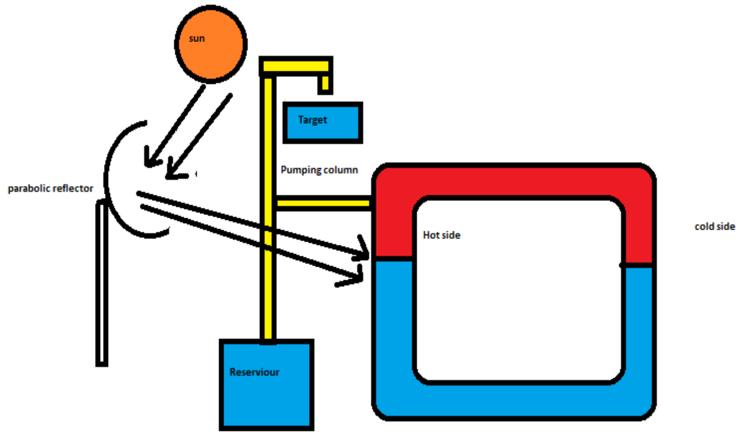


Fig. 8. Commercial set ups for solar liquid piston engine

Many commercial setups have been built, tested and operated by the team of Dr Tom Smith and Dr. Markides at the engineering department of the University of Cambridge. Typical data for cost, efficiency and CO_2 emissions is discussed here assuming a lift head of 10 m.

TABLE 2: Comparison of irrigation costs for various methods

Mode of irrigation	Cost or irrigation per hectare per day
Electric pumps	£0.34-£0.55
Diesel pumps	£0.29-£0.17
Photovoltaic pumps	£1.27-£4.07
Liquid piston pumps	£0.29-£1.07

TABLE 3: Comparison of pumping costs and efficiency of various methods

Mode of irrigation	Efficiency	Pumping cost per unit power output
Photovoltaic pumps	20-40%	£3.35-£10.7
Liquid piston pumps	2-4%	£1.50 -£3

TABLE 4: Comparison of emissions

Mode of irrigation	CO2 emissions per hectare per day(kg)
Diesel pumps	2.3-3.6
Solar P-V pumps	0.8-1.3

Going by the reliable data obtained, future of this technology seems to be bright and to tap the economic potential of there are several organizations currently involved in research in field of Stirling and liquid piston engines. Some of these are listed below:

1) STM co-operation-holders of various Stirling engine patents and developed a 40KW engine for use in GE hybrid vehicle.

2) Sun power-founded by Beale, pioneers in development of cryogenic coolers of capacity 35 W-7.5KW.

3) Infinia-developers of 1KW free piston engines and cryogenic coolers.

4) SES-makers of large parabolic dish operating solar power stations of 850 Mw capacities.

5) Thermo fluidics limited-formed in year 2006 by Dr Tom Smith of the University of Cambridge and supported by carbon trust is developing such pumping devices for use in Brazil, India and Ethiopia.

References

[1] http://www.unesco.org/water/wwap/wwdr/wwdr3/pdf/WWDR3_Water_in_a_Changing_World.pdf;
[2] http://www.engin.swarthmore.edu/academics/courses/e90/2005_6/E90Reports/FK_AO_Final.pdf;
[3] http://www.inference.phy.cam.ac.uk/sustainable/refs/solar/Stirling.PDF;
[4] http://www.mpoweruk.com/heat_engines.html;
[5] C. D. West, "Liquid Piston Stirling Engine", Van Nostrand Reinhold, New York, 1983;
[6] S. Narayan, 2015, "A Review of Design of Stirling Engines", Hidraulica no 3/2015, ISSN 1453 – 7303, pp. 18-26;
[7] S. Narayan, 2015, "Designing of Liquid Piston Fluidyne Engines", Hidraulica no 2/2015, ISSN 1453 – 7303, pp. 18-26.