International Journal of I.C. Engines and Gas Turbines
Vol. 4: Issue 2
www.journalspub.com

An Overview on Sterling Engine

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ABSTRACT
This paper presented an overview on Stirling engine, working principle and history of sterling engine. Power and efficiency of the engine must be not lower than their averaged values for the same engine working in unsteady conditions. This paper represents different researches on sterling engine and its modification and use from past to present.

Keywords: Sterling engine, cyclic compression, steam engine, solar-powered Stirling engines

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INTRODUCTION TO STERLING ENGINE

A Stirling engine is a heat engine that operates by cyclic compression and expansion of air or other gas (the working fluid) at different temperatures, such that there is a net conversion of heat energy to mechanical work. More specifically, the Stirling engine is a closed-cycle regenerative heat engine with a permanently gaseous working fluid. Closed-cycle, in this context, means a thermodynamic system in which the working fluid is permanently contained within the system, and regenerative describes the use of a specific type of internal heat exchanger and thermal store, known as the regenerator. The inclusion of a regenerator differentiates the Stirling engine from other closed cycle hot air engines.

Working Principle

This is traditionally known as an external combustion engine in contrast to an internal combustion engine where the heat input is by combustion of a fuel within the body of the working fluid. Unlike the steam engine's use of water in both its liquid and gaseous phases as the working fluid, the Stirling engine encloses a fixed quantity of permanently gaseous fluid such as air or helium. As in all heat engines, the general cycle consists of compressing cool gas, heating the gas, expanding the hot gas, and finally cooling the gas before repeating the cycle.

History

The Stirling engine is perhaps the simplest form of engine. The engine, then called the economizer, was first developed and patented by Rev. Robert Stirling in Edinburgh, Scotland in 1816. Robert Stirling not only developed and built heat engines, but was also a reverend in the Church of Scotland. His engine was later explained and further developed by Professor McQuorne Rankine in the mid-1800s.

However, the engine was never developed for common use. It followed earlier attempts at making an air engine but was probably the first to be put to practical use when in 1818 an engine built by Stirling was employed pumping water in quarry. Figure 1 is an illustration to Robert Stirling's 1816 patent as Stirling Engine.

The patent also described in detail the employment of one form of the economizer in his unique closed cycle air engine design in which application it is now generally known as a 'regenerator'.

Subsequent development by Robert Stirling and his brother James, an engineer, resulted in patents for various improved configurations of the original engine including pressurization which had by 1843 sufficiently increased power output to drive all the machinery at a Dundee iron foundry. The need for Stirling engines to run at very high temperatures to maximize power and efficiency exposed limitations in the materials of the day and the few engines that were built in those early years suffered unacceptably frequent failures. The Stirling engine always took a back seat to more popular engine designs such as the steam engine and the internal combustion engine. But today as people have forecasted an eventual end to the fossil fuel source, the Stirling engine concept has regained the interest of many developers. The engine can run on a variety of fuel sources and has a work output far closer to the theoretical ideal efficiency than most engines. The Stirling engines are frequently called by other names, including hot-air or hot-gas engines, or one of a number of designations reserved for particular engine arrangement. In the beginning of 19th century, due to the rapid development of internal combustion engines and electrical machine, further development of Stirling engines was severely hampered.

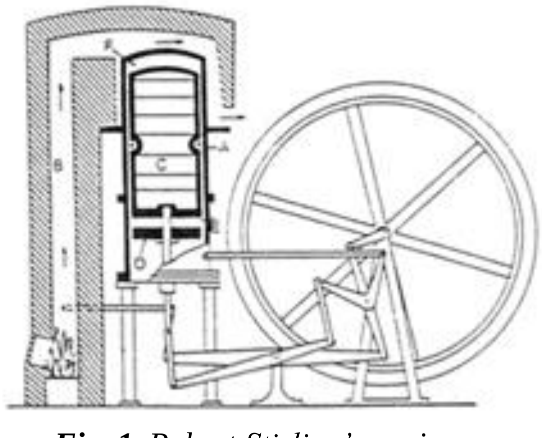

Fig. 1. *Robert Stirling's engine.*

NAME AND CLASSIFICATIONS

Robert Stirling was a Scottish minister who invented the first practical example of a closed cycle air engine in 1816, and it was suggested by Fleeming Jenkin as early as 1884 that all such engines should therefore generically be called Stirling engines. This naming proposal found little favour, and the various types on the market continued to be known by the name of their individual designers or manufacturers, e.g., Rider's, Robinson's, or Heinrici's (hot) air engine. In the 1940s, the Philips company was seeking a suitable name for its own version of the 'air engine', which by that time had been tested with working fluids other than air, and decided upon 'Stirling engine' in April 1945. However, nearly thirty years later, Graham Walker still had cause to bemoan the fact such terms as 'hot air engine' remained interchangeable with 'Stirling engine', which itself was applied widely and indiscriminately; a situation that continues.

Like the steam engine, the Stirling engine is traditionally classified as an external combustion engine, as all heat transfers to and from the working fluid take place through a solid boundary (heat exchanger) thus isolating the combustion process and any contaminants it may produce from the working parts of the engine. This contrasts with an internal combustion engine where heat input is by combustion of a fuel within the body of the working fluid. Most of the many possible implementations of the Stirling engine fall into the category of reciprocating piston engine.

LITERATURE REVIEW

Literature survey is an important part of any project work. A large volume of literature is available in journals and books on this particular explaining Stirling engine working process.

Bancha Kongtragool (2003) provides a literature review on solar-powered Stirling engines and low temperature differential Stirling engines technology. A number of research works on the development of Stirling engines, solar-powered Stirling engines, and low temperature differential Stirling engines is discussed. The aim of this review is to find a feasible solution which may lead to a preliminary conceptual design of a workable solar-powered low temperature differential Stirling engine [1].

Results from the study indicate that Stirling engines working with relatively low temperature air are potentially attractive engines of the future, especially solar-powered low temperature differential Stirling engines with vertical, double-acting, gamma-configuration.

In A.A. El-Ehwany (2011) work, elbow-bend heat exchangers were suggested to be used as a heater and a cooler in an alpha-type Stirling engine. Elbow-bend heat exchanger is a bank of tubes arranged in a quadrant either in line or staggered with different normal and parallel pitches. Eight of such heat exchangers having different dimensions were tested experimentally for steady flow (in a previous work by the same authors). The experimental results were correlated for heat transfer and pressure drop. In the present work, an alpha-Stirling engine with twin parallel cylinders on a common crankcase was suggested to use elbow-bend heat exchangers as a heater and a cooler. In the heater, the flue gases flow inside the tubes and the working gas fluctuates about the heater tubes. In the cooler, the coolant flows inside the cooler tubes and the gas flows about the cooler tubes. A computer program in the form of a spread sheet was prepared to solve numerically the engine cycle in the vision of Schmidt theory. Upon calculations, the most suitable stroke/bore ratio, phase angle and speed were found out for nitrogen as a working gas. In a comparison among the proposed engine and practical ones by the literature, it was found that; the proposed engine delivers about 13% more power per cc per ΔT than those by the literature at high thermal efficiency level [2].

Mohammad H. Ahmadi (2013) demonstrates a detailed review of performance of Stirling engine based thermodynamic methods like Finite Time Thermodynamic analysis, Isothermal model, non-ideal adiabatic method. The aim of paper is summarize overall research work being carried out worldwide on thermodynamic performance evaluation of Stirling engine using different thermodynamic method. In this paper, the conventional thermodynamic methods for GPU3 Stirling engine were compared. The outcome of this comparison revealed that PSVL was better than the other methods [3].

Zbyszko Kazimierski (2014): The crucial role in the externally heated air valve engine is played by its heat exchangers which work in a closed cycle. These are: a heater and a cooler and they are subject to a numerical analysis in the paper. Both of them are equipped with fixed volumes that are separate settling chambers causing that heat exchangers behave as almost stationary recuperates and analysis of the stationary behaviour is the main goal of the paper. Power and efficiency of the engine must be not lower than their averaged values for the same engine working in unsteady conditions. The results of calculations confirm such a statement. The pressure drop in the exchanger is another natural phenomenon presented. It has been overcome by use of additional blowers and the use of them is an additional focus of the presented analysis. A separation of settling chambers and additional blowers is a novelty in the paper. There is also a pre-heater applied in the engine which does not differ from well-known heat exchangers met in energy generation devices. The main objective of the paper is to find the behaviour of the engine model under stationary conditions of the heat exchangers and compare it with the non-stationary ones [4].

Fernando Sala (2015) the aim of improving the performance of Stirling engine applications with relatively low maximum temperature (150°C–300°C), working fluids that have noticeable real gas effect have been considered. The simulation model developed for the preliminary analysis of Stirling takes into account the losses of mechanical power and the efficiency of regenerator with two dimensional coefficients on the bases of experimental data available in literature. The result from this simplified analysis can be taken into consideration when evaluating the potential of these Stirling engine with real gas. Such a result means that the use of fluid mixture as the working fluid now becomes interesting, since the critical point of mixtures can be gradually adapted to meet design requirements [5].

Varun Punnathanam (2016) demonstrate the supremacy of the non-dominated sorting genetic algorithm- with simulated binary cross over and polynomial mutation operators for the multi-objective optimisation of Stirling engine system. The finite times thermodynamics model involves seven decision variables and consist of three objectives: output power, thermal efficiency and rate of entropy generation. The supremacy of the suggested strategy is also demonstrated on the experimentally validated polytrophic finite speed thermodynamics based Stirling engine model for optimisation involving two objectives and ten decision variable [6].

Kai Wang (2016) presented a review for the research development of Stirling cycle engines for recovering low and moderate temperature heat. The Stirling cycle engines are categorized into four types, including kinetic, thermoacoustic, free-piston, and liquid piston types. The working characteristics, features, technological details, and performances of the related Stirling cycle engines are summarized. Upon comparing the available experimental results and the technology potentials, the research directions and the possible applications of different Stirling cycle engines are further discussed and identified. It is concluded that kinetic Stirling engines and thermoacoustic engines have the greatest application prospect in low and moderate temperature heat recoveries in terms of output power scale, conversion efficiency, and costs. In particular, kinetic Stirling engines should be oriented toward two directions for practical applications, including providing low-cost solutions for low temperatures, and moderate efficient solutions with moderate costs for medium temperatures. Thermoacoustic engines for low temperature applications are especially attractive due to their low costs, high efficiencies, superior reliabilities, and simplicities over the other mechanical Stirling engines. This work indicates that a cost effective Stirling cycle engine is practical for recovering small-scale distributed low-grade thermal energy from various sources [7].

CONCLUSION

It is used to produce electricity, heat for home and to produce domestic hot water. This allows great prospects for the Stirling engine. It is possible to use of Stirling engine as an auxiliary source of electricity for submarines and surface vessels, like in the Swedish and Australian navies. An appropriate choice of fuel (for example, liquid oxygen and liquid hydrogen) would reduce the risk of pollution in case of an accident. The use of the Stirling engine as the mean of main propulsion, we can imagine its use as an auxiliary source of electricity and heating. Its vibratory level and its faint noise are great assets for its use. These features of the engine have

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keep Stirling engine in focus for design and development for better system efficiency where there is a large scope.

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