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The Stirling engine: Operation principle, classification, and applicability

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Abstract: Stirling external heat generators use external heat such as coal, kerosene, alcohol, natural gas, firewood, straw, methane gas. There are many designs like alpha, beta, gamma, free piston and many others. The Stirling engine is very popular because of its high fuel efficiency (no excess fuel, utilizing any heat source including solar energy) and relatively quiet during operation. . The motors are widely used in practice, such as for pumping irrigation water, acoustic thermostats, for use in nuclear or geothermal power plants. NASA also experimented with placing a Stirling engine in a truck in the 1990s. In addition, the Stirling engines were also armed by some navies for their submarines.

Keywords: heat engine, external combustion engine, Stirling engine

1. Introduction

At present, the energy sources on earth such as oil, coal ... gradually exhausted is no longer available to exploit anymore. In addition, these sources of energy are the main cause of air pollution that affects human life. Meanwhile, solar energy is plentiful and pollution is reduced. Therefore, focusing on the use of solar energy is a new direction in industrial energy, especially in today's rainy season, energy saving issues are on the forefront. In order to make the most out of solar energy, we need to find new technological solutions for electric and thermal motors, which are widely used in everyday life applications. It is committed to addressing both energy and environmental issues, while also ensuring sustainable development goals. In conventional terms, renewable energy is understood to be energy sources or methods of harnessing energy that, if measured by human norms, are infinite. Infinite has two meanings: Either energy exists so much that it cannot become exhausted because of human use (such as solar energy) or renewable energy in a short time and Continuously (for example, biomass energy) in processes that have been going on for a long time on Earth.

In the sense of physics, energy is not renewable, firstly by the sun, and transformed into different forms of energy or energy carriers. Depending on the circumstances, this energy is used immediately or temporarily reserved. The use of the term "reproduction" is commonly used to refer to reproductive cycles that are much shorter for humans (such as biogas versus fossil fuels). In the sense of human time, the Sun will be a source of energy for an almost endless time. The sun is also a constant source of energy for many processes in the Earth's biosphere. These processes can provide human energy and also bring about the so-called renewable materials. The flow of wind, the flow of water and the heat of the sun has been used by humans in the past. The most important in the industrial age is water power in terms of technology use and in terms of ecological costs. In contrast to the use of these processes, the extraction of energy sources such as coal or oil, the sources of energy that are consumed today much faster than they are generated. In terms of the definition of "endless" existence, nuclear fusion (fusion reactions), when technically feasible, and nuclear fission (fission) With breeder reactors, when the uranium or thorium extraction energy can be kept low, they are renewable sources, although they are usually not included in the category.

The Stirling engine is an external combustion engine using pistons. It was invented and developed by Dr Robert Stirling in 1816. It is a high performance thermal engine that can achieve up to 50% to 80% of the ideal reversible thermodynamic efficiency (such as Carnot cycle) in converting heat energy into energy only due to friction and material limitations. This engine also works on many heat sources, from solar energy, chemical reactions to nuclear reactions.

Stirling engines can cost more than internal combustion engines of the same capacity, but have adaptive properties for many applications. It is more efficient, does not produce much noise, is stable and durable, does not require much maintenance, and can operate at the different temperature between hot and cold sources in wide ranges from tens of ^{o}C to thousands of ^{o}C.

With energy costs rising in the early years of the 21st century, and with concerns about global warming, Stirling engines are gaining interest in putting into power plants with renewable and renewable energy, aerospace sector.

Different designs of Stirling engines usually have a block of gas enclosed in a closed chamber in which the gas can be air, hydrogen or helium. The gas chamber contains two parts, one exposed to a high temperature heat source and the other exposed to a low temperature.

During operation, the volume of air in the chamber is pushed back from the heater to the cooler or vice versa, thanks to the movement of the piston or the gas volume swing between the two parts. . The air gap between the heater and the cold air will be applied to a bearing piston. Pistons will operate flywheels and external machinery, and can control the movement of pistons or rams to move air between the two hot and cold parts.

In most designs, it is not necessary to have valves to close the flow of air, so the mechanical system is simple and highly reliable. An important part of the Stirling engine is the heat trap, located on the passage of the air mass from the hot to the cold, usually made of metal wire blocks. It has the effect of absorbing the heat of the air mass from the hot passage, preserving the heat, and warming the air from the cold. This part significantly increases the efficiency of the engine, and is an important detail in Robert Stirling's invention of 1816. In some designs, the runner plays the role of pushing gas back and forth between the heater And the cold side, which has the role of keeping heat.

2. Operating principle and properties

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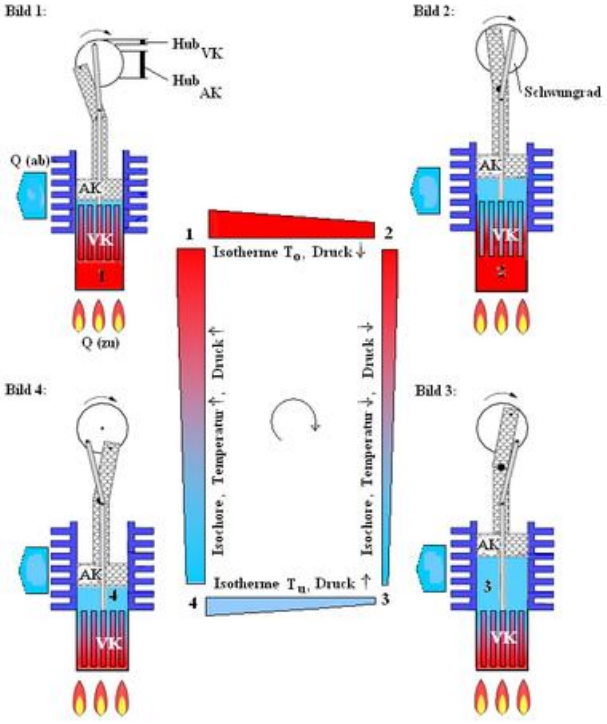

Figure 1. Operating principle of Stirling engine

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the role of keeping heat. Stirling engines operate on a four-stage Stirling cycle: cooling, compression, heating and expansion.

The ideal Stirling cycle is a reversible thermodynamic cycle and therefore has the same performance with the Carnot cycle (when operating between the same heat sources). Actual performance is lower, but higher than other external combustion engines such as steam engines and higher than most modern diesel engines (diesel or gasoline engines).

The four processes of the ideal Stirling cycle are:

Cooling factor

Isothermal compression

Reheat warmth

Isothermal expansion

This ideal cycle has dramatic volume and pressure variations between periods. The Stirling Cycle actually has a gradual transition. Actually, the cooling or heating process can be effective between 100% (isothermal), 0% (thermal), actual compression or expansion can be described by the polytropic process [1]:

$$PV^n = k.$$

Where P is pressure, V is volume, k is constant, and n is within the range $1 \leq n \leq 2$

C_v is the specific heat at constant volume (J/kgK), C_p is the specific heat at constant pressure (J/kgK).

Friction and heat loss (due to direct heat transfer to cold) is the main reason why the efficiency of the Stirling cycle is about half the efficiency of the Carnot cycle between the same heat sources [2]. There are many designs for Stirling engines.

Alpha type

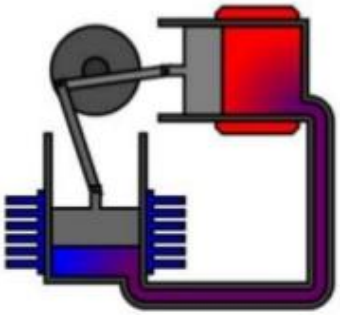
The alpha-type Stirling engine has two bearing pistons located in a hot cylinder (contact with a high temperature source) and a cold cylinder (in contact with a cooler). This design produces high power with a compact motor size. However, cylinders and pistons working at high temperatures will suffer from technical limitations, such as their lifespan.

Beta type

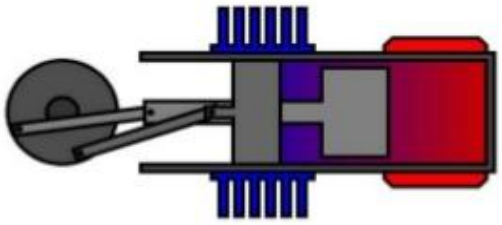
Stirling engine type beta has only one piston bearing coaxial with the runner. Only pistons fit closely with the cylinder, while the engine does not fit in the cylinder and does not perform mechanical work on the air, which only moves the gas from the hot side to the cold side and vice versa. When the gas is pushed to the hot side, it will expand and work on the piston bearing. In this design, the pistons are always on the cold side and therefore not subject to technical restrictions due to high temperatures.

Gamma type

The gamma-powered Stirling engine is essentially a beta engine but the pistons are in a separate cylinder by the cylinder. The gas block can move between the two cylinders but remains in a common volume. This design has a low compression ratio but is simple.



(a)



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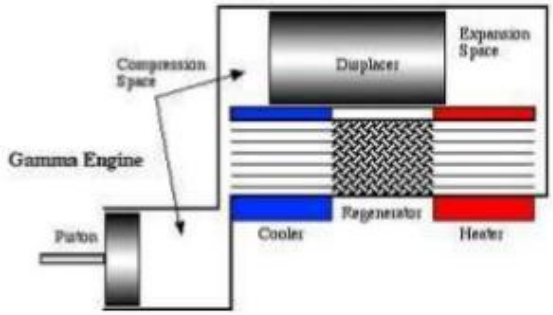

(c)

Figure 2. Stirling engine, alpha type (a), beta type (b), gamma type (c)

Piston free

Stirling free-piston engine is linked to translucent generator, designed by NASA. There are many designs in which the pistons (and runners) are free to move without interconnection or with external mechanical systems. The reciprocating vibration of the bearing pistons can operate on a reciprocating generator; At the same time the translator generators can operate in reverse mode, in which the current is supplied to regulate the movement of the piston and the crane. Pistons that can be made of liquid or diaphragm are elastoplastics to simplify the lubrication problem.

Other types

Some inventors also pursue the design of a rotating Stirling engine, in which the gas directly creates the torque for turning the machine. There is also a design for the Stirling engine to function as a water pump, where water acts as a heat sink for the cold.

2.1. Properties

Advantages

External combustion chamber, continuous combustion, can control not to excess fuel, thus limiting toxic emissions compared to cycle burning in the chamber inside. Take advantage of any heat source. Many designs have pistons located on the cold side, reducing lubrication problems, increasing lifespan, reliability. Without valves, simple mechanical systems, simple and optional fuel supply systems are also factors that increase the reliability of the engine. Operates at low pressure, therefore safer and more compact than steam engines. No need for an air supply (if the source of heat is not obtained from the burning of fuel), it can operate under submarine or in space. Operate more easily in cold weather than internal combustion engines.

Disadvantages

It is necessary to have a heat exchanger in the hot and cold parts of high efficiency. Cooling (cooling) units in the cold room can be complex and take up more space. Power and speed are hard to change quickly. Stirling engines are not as efficient as Stirling engines containing hydrogen or helium. However, hydrogen causes many technical difficulties such as high losses.

3. Applicability

Power and heat supply system

WhisperGen, a New Zealand-based company based in Christchurch, has built Stirling engine generators and heaters called microCHP. They use natural gas to both produce electricity for sale to the public grid, and to heat the water. In 2004, they announced that it had sold 80,000 such machines to households in the UK. Another 20 machines were tested in Germany in 2006.

Utilizing the solar energy

The generator uses sun-shaded mirrors to heat the Stirling engine head at the center of the mirror.

Solar-powered generators incorporate Stirling engines to outperform solar cells. On August 11, 2005, Southern California Edison announced the purchase of Stirling's Stirling Energy Systems' 20-year stirling solar power generators (20,000 units) enough to generate 500 megawatts of power. These systems are installed on an area of 19 km² to capture the sun.

Stirling engines can utilize solar energy to pump water, instead of generating electricity, for irrigation. The inlet water flow is a function of heat dissipation for the cool part of the engine.

Stirling air conditioner

When applied to the piston bearing, the temperature difference will appear at the hot and cold head of the Stirling engine. This mechanism can be used to create low temperatures at the cold ends, which are the refrigerant chillers of the refrigerator or the chiller of the air conditioner. Hot heads will be heat dissipated into the environment. As with the Stirling engine, the performance of the Stirling air conditioning unit also increased as heat was stored between the hot head and the cold head.

Philips produced refrigerators to produce liquid nitrogen in the 1950s, and this unit was still active in the field of air conditioning manufacturing in Stirling.

Air-cooled heaters also work with the Stirling cycle on large amplitude sound waves. Public supplies for Stirling refrigerators can be obtained from other Stirling engines. Such a system can capture the sun to cool the interior of the house (the heat of a Stirling engine, which drives a Stirling engine, and Stirling air-conditioning cools the house). And the advantage is that the hotter it gets the cooler.

4. Conclusion

Stirling engines are rapidly gaining ground in modern inventors as they seek to mechanize the heat to create low-emission engines and zero emissions. This is a high-performance heat engine that converts heat energy into energy. The stirling motors work on many heat sources: from solar energy, chemical reactions to nuclear reactions. It is more efficient than internal combustion engines of the same capacity. It works stable, no maintenance, no noise. With rising energy costs, Stirling engines are being considered for inclusion in renewable energy generators.

References

[1] Van Wylan, Gordon J. and Sontag, Richard F. (1976). Fundamentals of Classical Thermodynamics SI Version 2nd Ed. New York: John Wiley and Sons. ISBN 0-471-04188-2.
[2] Walker, G. (1985). Free Piston Stirling Cycle Engines. Springer-Verlag. ISBN 0-387-15495-7.
[3] Hargreaves, C. M. (1991). The Philips Stirling Engine. Elsevier Publishers. ISBN 0-444-88463-7.
[4] https://vi.wikipedia.org/wiki/%C4%90%E1%BB%99ng_c%C6%A1_Stirling
[5] http://cadcamcae.edu.vn/hoc-catia-day-catia-dong-co-dot-ngoai-dong-co-stirling/
[6] Sopogy, (2011).'Solar Power Technology. http://www.sopogy.com.
[7] SunPower, (2012). Sun Power High Performance Free-Piston Stirling Engines http://www.sunpower.com.
[8] Therminol, (2012).Heat Transfer Fluids, http://www.therminol.com.
[9] Thimsen, D. (2002). 'Stirling Engine Assessment,' Energy International, Inc., Bellevue, Technical Report 2002.