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STIRLING ENGINE AND RENEWABLE ENERGY SOURCES

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Abstract: The paper introduces the image of the functioning of fundamental thermodynamic processes that are required for the gas working action. It systematizes the application forms of renewable energy resources and also their potential for objective topic. The application of the objective technology is developed by various technical devices that demand their further development in order to improve the utilization. The major attention is paid especially to the solar radiation which represents the renewable resource of energy as well as it becomes the supporting element of other forms, for instance biomass, the wind energy, etc. The paper is at the place of biomass potential valuation, as well. There would be possible to start the revolution in the scope of the individual electrical industry in Slovak republic by partial biomass application on the objective technology.

1 Introduction, the principle of Stirling engine operation

"The Stirling engine is an example of an engine with an external fuel burning. Invented and patented in 1816 by Robert Stirling. The principle of the Stirling engine is based on four cyclically-recurring thermodynamic behaviors, which are graphically displayed in Picture nr.2 in the p-v and T-s diagrams.

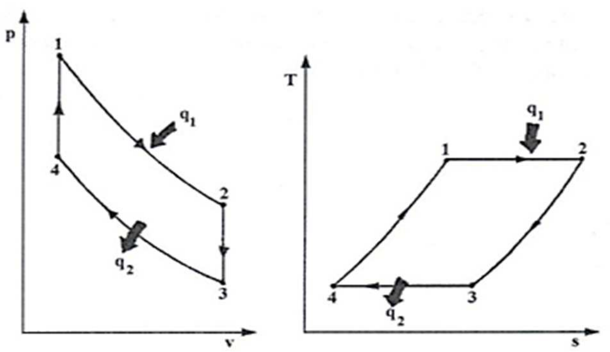

Figure 1 Thermodynamic events occurring during the Stirling cycle in the p-v and T-s diagrams

A first run running from 1 to 2 is an **isothermal expansion**, in which the working gas is heated by the continuously heated walls of the engine's hot chamber.

A second run from point 2 to point 3 is **isochoric regeneration**, which involves the internal transfer of heat from the working gas to the regenerator.

A third run running from point 3 to point 4 is **isothermal compression** in which the heat from the working gas is fed to the heat sink.

The fourth run from point 4 to point 1 is **isochoric regeneration**, in which the working gas is heated by heat from the regenerator "[1-3].

2 Piston movement in the Stirling engine

"The Stirling engine operates with an indeterminate hermetically sealed volume of working gas, which does not change with the surroundings but flows between the engine rollers and the heat exchanger, condenser and regenerator" as shown graphically in Picture nr. 2 [1,4,5].

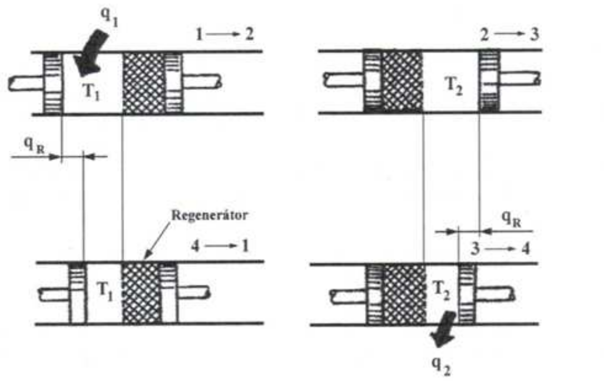

Figure 2 Piston movement in the Stirling engine

"As a regenerator, a wire or ceramic grid can be used which has high heat capacity and low thermal conductivity and serves for the temporary storage of thermal energy.

At the start of the first altimeter, running from point 1 to point 2, all the working gas is at the temperature T1 and the pressure p1 in the left chamber of the piston. With the heat supplied from the temperature source T1, the working gas heats up and thus the left piston is moved outward as a result of isothermal expansion, and a useful work is done when the pressure drops.

During the second one, running from point 2 to point 3, the two pistons in the isochoric regeneration move at the same speed to the right while the working gas is forced through the regenerator into the right cylinder chamber. During extrusion through the regenerator, the gas is cooled from T1 to T2 with T2 <T1.

During the third act, running from point 3 to point 4, the right piston moves inwards and compresses the working gas whose pressure is increased as a result of isothermal compression, while the heat from the working gas is drawn through the cooler to the surroundings.

Eventually, during the fourth act, running from point 4 to point 1, the pistons move at the same speed at the same time to the left while the working gas is forced through the regenerator where it is heated from T2 to T1.

This closes the cycle, whereby the total heat energy (qr) that the working gas passes in the regenerator during the second 2-3 is the same as during the act 4-1 when the gas is heated.

The performance and efficiency of the Stirling engine depends on the ratio of the size and stroke volume of both pistons, expansion and compression over a cycle, as well as the design of heat exchangers and regenerators" [1,6].

"With the development of the Stirling engines, the engine has fallen into oblivion, but a better knowledge of the thermodynamic events taking place in the Stirling cycle, as well as the possibility of using new materials in its design, suggest that Stirling's new engine will be able to compete very well with the classic spark ignition engine. The great advantage of the Stirling engine is its high efficiency, which is stated above 40% in top engines. It is not necessary to use noble fuels for its drive, but less valuable fuels, renewable energy sources or waste heat from different plants can also be used. Stirling's engine is less loud than spark-ignition engines. It is easy to maintain and is characterized by long-term reliability. Its shortcomings are bigger dimensions, bigger weight and a longer start time that moves in a few minutes. Despite these shortcomings, Stirling engines of the new generation can be expected to find wider application, especially in relation to the use of renewable energy sources" [1,7].

3 Means of renewable energy applications for the Stirling engine

Applying heat from renewable energy sources or waste heat that would not be used at all means driving the Stirling engine and producing energy without producing other greenhouse gases.

3.1 Application of solar energy

The application of solar energy requires in the technology in question certain technical equipment which must be ensured for continuity of operation.
The concentration of sunlight is divided into two groups:
1. concentration of sunlight using mirrors,
2. concentration of sunlight using lenses.

1. using mirrors :
   a) parabolic (hollow mirror),
   b) a set of planar mirrors.
2. using lenses:
   a) lenses-coupling.

3.1.1 Parabolic mirrors concentration

The principle of beam concentration in reflection in a parabolic mirror is as follows.

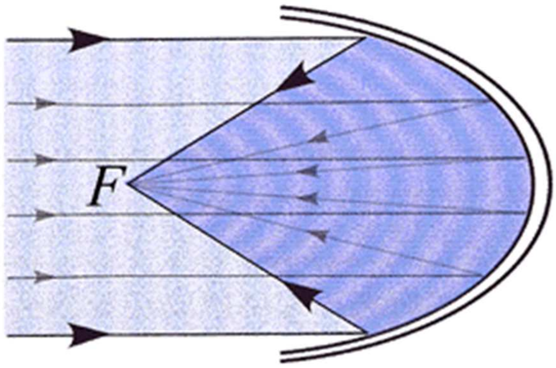

Figure 3 Parabolic mirror reflection

Picture nr. 3 shows how the light rays coming from the left reflect the hollow sphere and concentrate to a single point marked F, the focus of the mirror. In this focus of the mirror, a Stirling engine heater is located, where concentrated sunshine reflected from the mirror has a diameter of up to 17 meters in some types. Radiation is densified to one point [8].

At this point temperatures of 600 to 1200 degrees Celsius are achieved. The efficiency of sunlight conversion to electrical energy when applying the Stirling engine in the parabolic focus is 31.25%. When using photovoltaic panels made of polycrystalline silica, the efficiency is between 12 and 14%.

Figure 4 Grouping of planar mirrors into a parabolic shape

In Picture nr. 4, a group of 82 mirrors is concentrated into 1 focus. Each of these devices can produce up to 60,000 kW of electricity annually. Over the next few years, more than 70,000 Sun Catchers will be exposed in sunny

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California, which can produce electricity for up to 1 million high-energy US households [9].

3.1.2 Concentration using clutch lens

The flow of light rays through the clutch lens is directed from left to right (Fig. 5). On the right, after the lens passage, the beam is grouped in a focal point marked F.

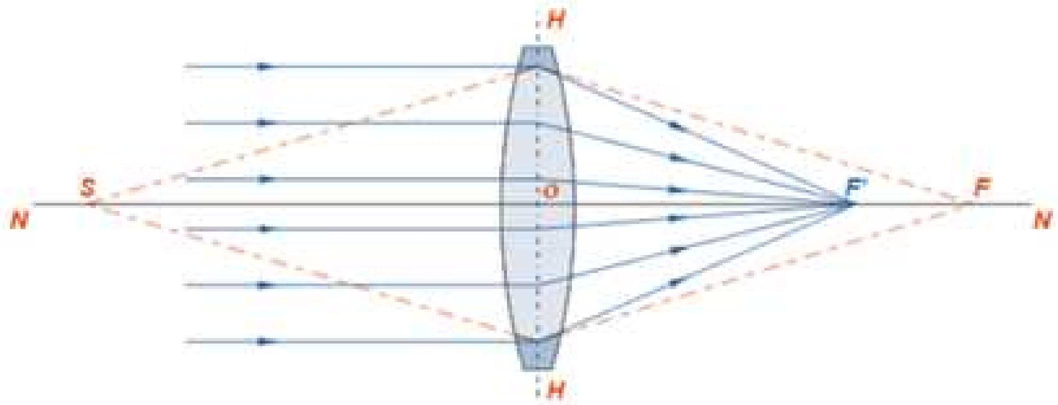

Figure 5 Flow of light rays through clutch lens

Figure 6 Lightening the light flow to 1 point by the lens coupling

In the Fig. 5 and Fig. 6 we can observe the condensation of the heat flux of the solar radiation centered in the focus by the clutch lens. This system is still very little used in the production of electricity by Stirling engines, as a considerable amount of money is needed to produce such a lens [10]. The mirror is the much cheaper form.

3.2 Utilization of thermal energy by combustion of biomass

"Because of the different forms of biomass, the energy contained in it is different. The energy content of dry plants (moisture content 15-20%) is about 14 MJ / kg. Fully dry biomass can be compared to coal with a calorific value of 10 to 20 MJ / kg for brown coal and about 30 MJ / kg for black coal. At the time of collection, however, the biomass contains a considerable amount of water ranging from 8 to 20% for straw, 30 to 60% for wood. The water content of the manure from which biogas is obtained is 75 to 90% and in some aquatic plants, hyacinth up to 95%. On the other hand, the water content of coal is between 2 and 12%. For this reason, the biomass energy at the time of collection is usually lower than that of coal. However, the chemical composition of biomass makes it a substantially more environmentally friendly fuel than coal. This is related to the fact that biomass has a lower sulfur content than coal. The ash incineration content is also lower than coal, and the ash does not contain toxic metals and other contaminants and can be used as a fertilizer for its nutrient content"[11]. From our experience, we can conclude that biomass derivatives have the greatest potential in terms of calorific value and water content of straw, whose water content reaches only 15% and energy gain up to 4 kW / kg. Interesting fuel, but the product of plant production is rape oil, whose energy gain is 10.3 kW / kg.

3.2.1 Stirling's engine powered by biomass fuel

Compared with traditional fuels that heat the Stirling engine heater, they are on the other hand, the more often biomass products. In this context, biomass products can be understood in particular as: wood sawdust, wood chips, straw, wood waste, bio oils.

A unique and successful cluster of scientists and engineers in Stirling engine powered by biomass would find up to 1,600 km towards North in the capital of Denmark, Copenhagen, at Stirling DK, a Danish Technical University. Their interest is mainly in the Stirling engine, which could operate in separate buildings and on the principle of cogeneration would provide energy self-sufficiency in the field of heat and power generation.

4 Conclusion

The engine was designed for low maintenance and long service life. The engine is rated at 100,000 working hours, which means approximately 4166 days, ie over 11 years, with service intervals every 4000 to 8000 hours, i.e. every 166 to 333 days.

The original proposal was based on 15 years of R & D at the Technical University of Denmark, Copenhagen. 9 engines have been designed and tested for over 30,000 hours. Research and development is currently geared towards increasing efficiency and implementing new ideas. In Chapter 3.2 and in Chapter 3.2.1, I present applications that are addressed by scientists and students at the Technical University of Copenhagen, Denmark.

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