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The Temperature-Pressure-Frequency Relationship Between Electrical Power Generating in Stirling Engines

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Abstract

In this research, the variation of electrical power according to temperature, pressure, frequency, and cooler temperature, in Stirling engines was analyzed. The performance characteristics of the low power beta type Stirling engine were determined by gas exchange in this research, and the results were compared and presented by graphics. The performance tests of the Stirling engine heated by using the thermal specification of the sun were realized as 673 K, 773 K, and 873 K for the heater temperatures. The charge pressure was increased from 100 kPa up to 400 kPa with the ranges of 100 kPa. The maximum power was calculated by taking the frequency of crankshaft 10, 30, 50, and 60. Also, the electrical power increase was provided by raising the temperature difference between the hot edge of the displacer and the cooler temperature.

Key Words

"Stirling engines, renewable energy, solar systems, heat engines"

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1. INTRODUCTION

Nowadays, fossil based energy sources are diminishing rapidly and are continually causing a global energy crisis. The necessity for an increase in energy has directed scientists to conduct research into renewable energy sources and more efficient machines which can transform these sources into energy.

The sunlight energy applications of Stirling engines are thought to be used for the climatization of homes and synchronized power generation. Mills (2004), through their research revealed that the most productive transformation unit is the system that consists of a Stirling engine, dish, and a mirror (Mills, 2004). In spite of the productivity of these systems being higher, their common usage was never provided due to a variety of problems. In order to be used easily in rural areas, its design should be small, strong, and suitable for individual usage. The idea for using Stirling engines in housing was suggested 20 years ago, but it was not put into practice at that time. Thus, it is important to develop a Stirling engine which is capable of operating at various temperatures at the present time.

Nowadays, power is generated by traditional sources such as (coal etc.), natural gas, and fuel oil. This usage of traditional sources causes global warming by releasing sera gas into the atmosphere which in turn gives rise to climate changes. A 2ºC temperature increase was realized related to global warming as of 2015. The average global temperature increased from 15ºC to 17ºC. Global warming temperature increases were expected to happen between the years 2040-2050. However, an increase in population and the rapid release of sera gases speeded up the predicted date to 2015. For this reason, the number of studies on how to generate power from sunlight and the machines related to this work should be increased in order to prevent this world from warming further.

2. STIRLING ENGINES

Working with the externally heated principle, Stirling engines consist of a moving mechanism, a heater, a regenerator, a cooler, a power piston, a piston, and a cylinder block. All Stirling engines consist of a regenerator, heater, and cooler parts, regardless of their types. The function of the movement mechanism is to realize the thermodynamic cycle by driving the piston and displacer through timing it.

Today, Stirling engines exist in various types, with the most well-known ones being the Alfa, the Beta, and the Gamma types (Thombare and Verma, 2008). The Beta type Stirling engines are the most commonly used and are well-known due to their high thermal productivity in the engines, which use sunlight as the heat source (Akyol and Kılıç, 2012; Karabulut et al., 2009). The disadvantage of this type of Stirling engine is the decrease in power generation due to the heat difference between the displacer edges as a result of the heat transmitting being too high in the displacer. The Beta type Stirling engine is shown in Figure 1.

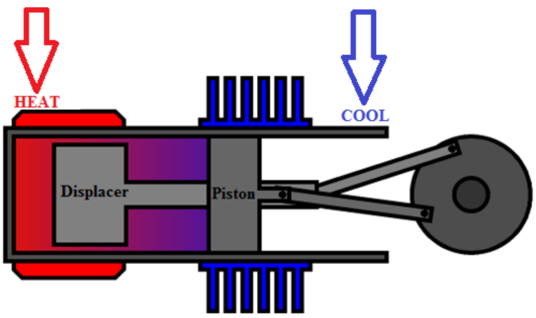

Figure 1. The Beta type Stirling Engine

3. POWER GENERATING SIMULATION OF THE STIRLING ENGINE

Usage of energy which was generated from renewable energy sources such as sun and energy which was generated by using local sources is needed for sustainable development (Cengiz and Mamiş, 2015). Simulation of Stirling engine which has beta type crankshaft movement mechanism taking energy from sunlight was realized in this research. By this means it would be possible to have opinion about parameters such as electrical productivity, pressure, temperature values, working frequency and power for Stirling engines. It could be possible to see the parameters such as variation of temperature and pressure according to the working gas which was used.

3.1. The Effects of the Stirling Engine Parameter for Power Generating

The usage of energy which is generated from renewable energy sources such as the sun, and energy which is generated by using local resources is needed for sustainable development (Cengiz et. al., 2015). The simulation of the Stirling engine, which has a beta-type crankshaft movement mechanism, taking energy from sunlight, was realized in this research. By this means, it would be possible to have an opinion about the parameters such as electrical productivity, pressure, temperature values, working frequency, and the power for the Stirling engines (Cengiz, 2016). It could be possible to see the parameters such as the variation of the temperature and pressure according to the working gas which was used [10].

Table 1. The Entry Data for Which Simulation Was Used [7].

Stirling Engine Data		
Working gas		Air
Average pressure	*pave*	100 / 200 / 300 / 400 kPa
Heater temperature	T_h	673 K / 773 K / 873 K
Cooler temperature	T_k	300 K / 400 K / 500 K
Clearance volume, compression	V_{clc}	8 cm³
Swept volume, compression	V_{swc}	61.045 cm³
Cooler volume	V_k	31.2101 cm³
Regenerator volume	V_r	34.8885 cm³
Heater volume	V_h	28.5093 cm³

3.2. The Variation in Electrical Power Against Pressure and Temperature

The analysis of the generated power was performed under 673 K, 773 K, and 873 K temperatures, and 100, 200, 300 and 400 kPa pressure conditions. It was seen that the electrical power increased depending on the heater temperature and the charge pressure. The maximum power value 352.49 W was reached at 873 K temperature and at 400 kPa pressure. The power pressure relationship in the Stirling engines is shown in Figure 2.

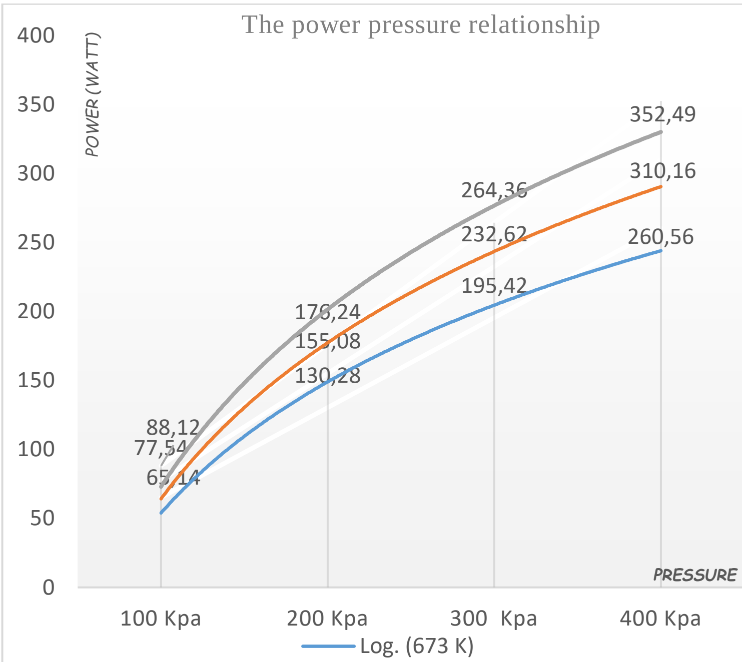

Figure 2. The power pressure relationship in Stirling engines

In the tests performed under 673 K, 773 K, and 873 K heater temperatures, and the 100, 200, 300, and 400 kPa pressure conditions of the Stirling engine operation, the maximum values were reached at 873 K and 400 kPa as 352.49 W energy generating. The pressure and temperature values increased linearly up to a determined value, and then the productivity increase speed was decreased due to the limited heat transmission, friction capacity at the higher temperature, and pressure conditions. The power temperature, and pressure relationship in the Stirling engines is shown in Figure 3.

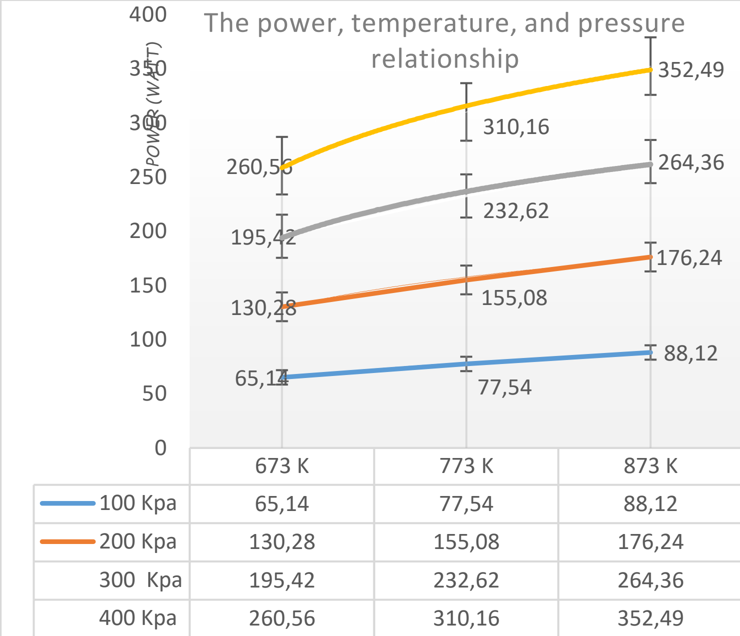

Figure 3. The power, temperature, and pressure relationship in the Stirling engines.

3.3. The Variation in Electrical Power Against Crankshaft Frequency

In the performance tests carried out under 673 K, 773 K and 873 K heater temperatures, and 10, 30, 50, and 60 kPa pressure conditions in the Stirling engine operation, the maximum values were reached at 873 K and 60 kPa as 108.41 W energy generating. The pressure and temperature values were increased linearly up to a 50 Hz value, and then the electrical power increasing speed was seen to decrease in higher frequency values such as 60 Hz due to friction. The power frequency relationship in the Stirling engines is shown in Figure 4.

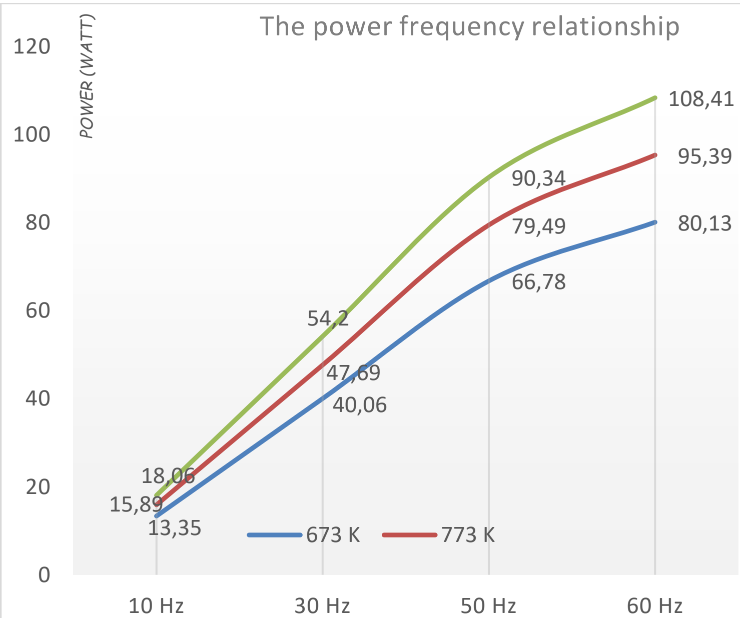

Figure 4. The power frequency relationship in the Stirling engines

3.4. The Variation in Electrical Power Against Cooler Temperature

The power frequency relationship in the Stirling engines is shown in Figure 4. The power and cooler temperature relationship in the Stirling engines is shown in Figure 5. Accordingly, while the temperature difference between the cooler temperature and the heated edge (heat source edge) was 300 K, the minimum electrical power was generated, while the temperature difference was 500 K, the maximum electrical power values were reached. This process was performed twice, so it was seen that the electrical productivity was increased by raising the temperature difference between the edges 673 K input temperature and the 873 K input temperature.

While the source temperature was 673 K;

i. The cooler temperature 300 K (while the temperature difference between the edges 373 K) 66.78 W,
ii. The cooler temperature 400 K (while the temperature difference between the edges 273 K) 39.36 W,
iii. The cooler temperature 500 K (while the temperature difference between the edges 173 K) 17.42 W

energy generated.

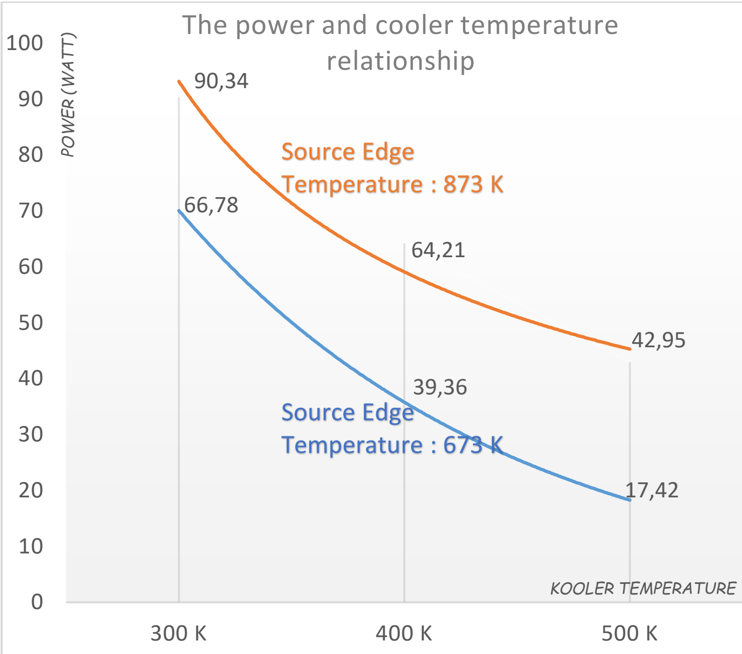

Figure 1. The power and cooler temperature relationship in the Stirling engines

While the cooler temperature was 300 K, 400 K, and 500 K, on the performance test, which was carried out by operating the Stirling engine, the maximum power value 90.34 W energy was generated, while the source edge temperature was 873 K, and the cooler temperature was 300 K. Meanwhile, while the temperature difference between the edges was 573 K, the maximum performance was reached, and 90.34 W of energy was generated.

4. CONCLUSION

The increase in power increases to a maximum at a determined value re: revolutions, temperature, and pressure, and then the electrical power increasing speed is reduced. The reason for the fall in electrical power is insufficient heat transmission which was transferred to the working gas with the increasing engine revolution and the increasing pressure.

Beta type Stirling engines have high productivity in terms of thermal productivity. However, the temperature of the heated edge cools in a short time due to the displacer transmits the heat. For that reason, electrical productivity decreases by fall of temperature between the edges. If the cooler is produced from another composite material which provides late heating of cooler, electrical productivity increases several times. As assessed in this research, while the input temperature was 873 K and the cooler temperature was 300 K, so the temperature difference was 573 K, and the generated electrical power was 90.34, which is the first one of two difference scenarios. In the second scenario, while the input temperature was 873 K and the cooler temperature was 500 K, so the temperature difference was 373 K, which generated electrical power of 42.95. Similar results were obtained in cases where the input source temperature was 673 K.

The displacement became deformed at high temperatures depending on the material used. If the transmission of temperature is prevented by this method, a deformation possibility occurs.

5. ACKNOWLEDGMENT

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