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Fabrication of Stirling Engine and study its characteristics

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Abstract

Gama Stirling engine was designed and manufactured using low cost materials, which operates on Stirling cycle. Air was used as a working fluid, the engine can be heated by any fuel. This Study showed the properties of the engine, the efficiency dependent on temperature and pressure , the maximum rpm of engine is 900 . These engines can be used to generate power in rural areas that have not completed the required energy that is powered by conventional fuels.

1. Introduction

Because of depleting the sources of natural fuel quickly and increasing the proportion of pollution, researchers started to invent new sources of continuous energy and non-contaminated environment, so they choose the renewable energies as an alternative fossil fuels. Researchers resorted for manufacturing equipment to take advantage of renewable energy, solar energy is the most used in water purification and heating as partial replacement in the field of heating and cooling as well as in power generation such as the use of solar panels and concentrates to benefit from solar radiation [1,2]. Most countries use wind power such as united states which has the largest wind power plant in order to get 20 percent of wind power in the future [3-5]. Stirling cycle is one that operates on a closed thermodynamic cycle where gas is subjected to expansion and compression at different temperatures [6]. The efficiency is high and uses different types of heat sources such as solar radiation, fuel and combustible materials [7-8] . Stirling engines are unique thermal motors because their maximum efficiency known as the Carnot cycle efficiency [9]. Stirling engine based on a closed cycle which uses working fluid (air or other gas) where are kept the gas-work within the cylinders adding the heat and removed it from workspaces through the wall of the cylinder . engine has a piston work (displacer) [10] .

2. Theoretical part

A - Ideal stirling cycle

Stirling cycle is different from Carnot cycle because there is no adiabatic process in the Stirling cycle. The principle of work of Stirling engine is within volume changes of the working fluid. It is sufficient to clarify thermodynamic phases that create the volumetric expansions and compressions. The thermodynamic processes are four: two isochoric and two isothermal. Fig.1 shows The diagram of P-V and T-S. symbolizes a schematic of Stirling engine configuration, for the Stirling cycle. It has a cylinder that contains two opposing pistons, that separated in space by regenerator. First volume is indicated as a compression space, remain at lower driving temperature, T_C, and other as expansion space, remain at higher driving temperature, T_H. The ideal case is leakage losses exist or no friction.

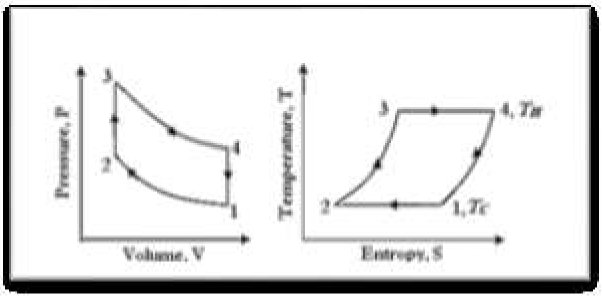

Fig .1: *P-V* and *T-S* diagrams for the stirling engine[11].

(1-2) on the P-V and T-S diagrams show the starting point of the cycle. The Piston within expansion space its inner most dead point and the compressed space is in the outer dead point. Here, volume of compression space is large, temperature and pressure are decreases. In the process (2-3) pressure at the compression space is amplest to work piston (displacer) the expansion space piston toward its outer the more dead point [12]. Two piston have volume remains constant between them during this process while the two pistons move "simultaneously". The regenerator come to play. The storing heat from the regenerator that transferring to the working fluid as it moves towards expansion space volume, increasing the temperature from "T_C to T_H". The working fluid temperature increases to the highest value and is maintained during the process , the pressure is also increased within the expansion volume space. The increase in pressure drives the piston outward to the dead point. While the temperature stays constant in T_H and the compression space piston stays stationary at its inner more dead point. (3-4) . The final process (4-1) expansion space piston move towards compression space piston and the regenerator away from it, simultaneously that is second isochoric process. The volume stay constant while whilst the working fluid flows during transfers its heat to regenerator. It appears in the compression space into T_C. Know the regenerator retains that heat until process starting again where is released into the passing working fluid [13] .

Theoretical Efficiency η of Stirling engine is given by Carnot's law : [14]

$$\eta = \left(1 - \frac{T_C}{T_H}\right) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

B- Stirling engine

A gama and beta types Stirling engines are similar except the power piston in the gama arrangement is upward in separate cylinder on displacer piston cylinder as show in the fig.2. But it is still related to the same flywheel. the gas within the two cylinders can flow freely between them and stays a single body [15]. The gamma engine configuration is one of the simplest types of motor type beta.

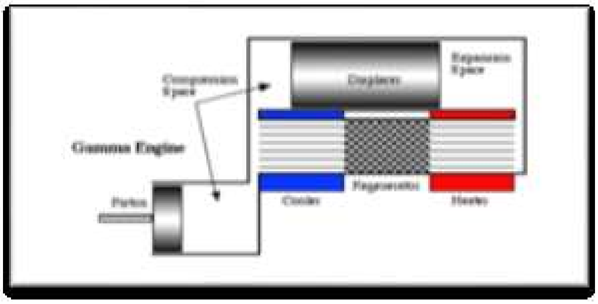

Fig .2 show Gamma Stirling engine type [14].

The gama Stirling engine consists of a displacer piston and a power piston. The difference between them is the difference of their cylinders. The gamma configuration allows for a complete and comfortable separation between the heat exchanger and also between the expansion and the compression of the work space. The heat exchanger is connected with displacer cylinder but expansion and compression work space is connected with piston [16] .

3. Expermental Part

The fabricated engine model works on gas source as show in fig.3, the heating create the temperature differential between the two sides of displacer cylinder, this makes the later to reciprocate in the regenerator, as this reciprocating motion first stroke of the cycle will complete attained by diaphragm, that transfer the motion by connect the piston rod into the flywheel . Heat input on the Stirling engine is given by [14] :

$$Q = mC_p(T_H - T_C) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

m = mass flow rate (kg /sec)

C_P = specific heat constant of the gas or air (KJ /kg.K)

All parts of the engine were manufactured from low cost materials and assembled to form the engine type Gama Stirling .

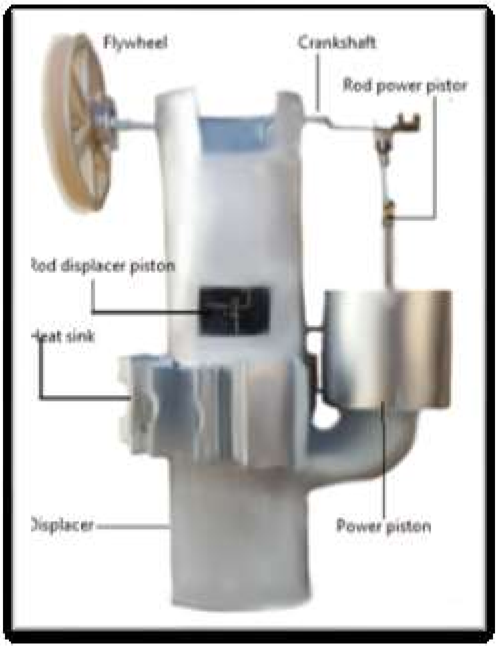

Fig. 3 shows the fabricated of stirling engine

A- Displacer cylinder :

The displacer cylinder material must be thermally insulated and low thermal conductivity, light in weight, it is (10cm) high , (7 cm) diameter, closed on both sides, Fig. 4 shows the displacer [17] .

Fig. 4 shows cylinder displacer

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B- Flywheel: Flywheel composed of circular disc that is joined onto a shaft . It rotates as storage energy. The flywheel stored kinetic Energy is given by:-

$$kinetic\ Energy = \frac{1}{2}\ I\omega^2 \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots (3)$$

ω: angular velocity

I= moment of inertia of the flywheel, which is given by :

$$I = mR^2 \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.. (4)$$

m: mass of the flywheel.

R: radius of the flywheel.

The flywheel have torque known as turning force. the turning dependent on distance of force to axis of rotation add to force exerted torque which is given by [18]:

$$T = mgR \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.. (5)$$

$$T = \frac{2\pi NI}{60} \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.. (6)$$

g: accelerate

N: number of turn

The power is given by [19]:

$$P = T\omega \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots. (7)$$

C- **Piston displacer**

D- The selected material for displacer piston should have tolerate higher temperature.

E- Power piston

Power piston use to further reduce leakage. piston should be able to fall freelly during power cylinder. It these should be NO frication when the ends open and drop slowly under its own weight when ones end is sealed [17] .

4. Calculations

We find Power, Torque and carnot efficiency by using equations (1,6 and 7) table (1) shows characterization stirling engine assemble.

Table 1: show characterization stirling engine assemble.

T_H(°C)	T_C(°C)	η %	RPM	ΔT(°C)	P (w)	Torque (N.m)	t(min)
147	20	86	200	127	8.78	0.42	1
157	29	81	270	128	16	0.565	2
186	43	77	495	143	53.4	1.03	3
218	55	75	600	163	78.9	1.256	4
230	61	73	758	169	126.9	1.6	5
238	63	73	795	175	141.5	1.7	6
242	70	71	850	172	158.4	1.78	7
232	78	66	900	154	178.98	1.9	8
247	80	67	900	167	216.2	2.08	9
267	84	68	900	183	218.7	2.09	10

5. Results and Discussion

The engine was working with air fluid at normal pressure and heated using a cooker. The top end of a displacer piston cylinder Will be used to heat, air cooled the end of power piston cylinder. Atmospheric air is used to the working gas for primary operation of the engine. To know the engine performance, experiments were carried out. The flame's temperature use as the heat source. The results revealed that the engine started to operate at less than three minutes. The factors that influence a constant state temperature conditions were cold end, hot end temperatures and speed of engine. The speed began increasing with time. Because the difference between two temperature (hot and cold) of 183 °C that give maximum RPM (900). as show in Fig. (5) the result are compatible with [19].

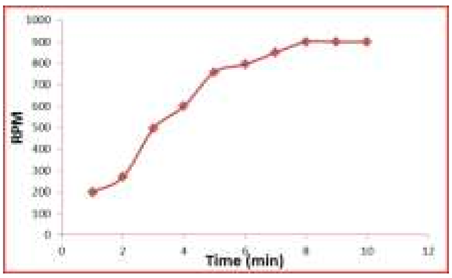

Fig. 5 show relation between speed (rpm) and time

By measure the temperature down displacer this represents the highest temperature T_H and was also measured below displacer this represents low temperature T_C. To confirm that the temperature differential necessary to run the engine. Fig. 6 show the temperature differential increased with time and the result are compatible with [20] .

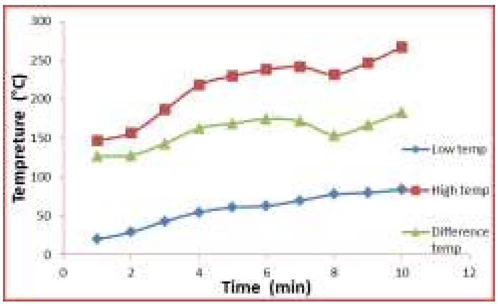

Fig. 6 show relation between temperature and time.

Also by measure Carnot cycle over time we found a decrease in efficiency because of the loss due to high temperature as shown fig.7 and the result are compatible with [21] .

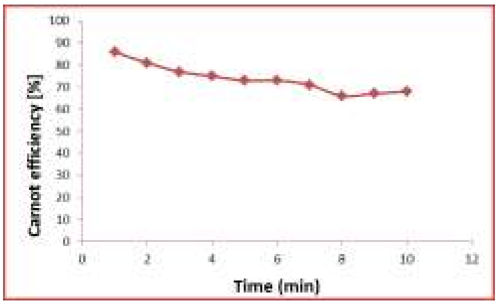

Fig. 7: show relation between carNOt efficiency and time

4- Conclusions

A model of gamma Stirling engine was designed. Air was used as a working fluid. The engine starts to operate approximately 3 minutes at different temperatures among (127-183)°C with rpm (200 – 900). we noticed that temperature increases with time. Engine rpm was increasing with the increasing temperature .

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تصنيع محرك ستيرلينغ ودراسة خصائصه

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قسم الفيزياء ، كلية العلوم ، جامعة تكريت ، تكريت ، العراق

الملخص

صمم وصنع محرك ستيرلينغ نوع كاما باستخدام مواد محلية رخيصة، والذي يعمل على دورة ستيرلينغ. ويستخدم الهواء الطبيعي كوقود عمل، المحرك يسخن باستخدام أي مصدر للوقود. هذه الدراسة بينت ان الكفاءة لعمل المحرك تعتمد على الحرارة والضغط، اقصى قيمة للسرعة 900 . ممكن استخدام هذه المحركات لتوليد الطاقة في المناطق الريفية التي لم تنجز الطاقة المطلوبة التي تعمل بالوقود التقليدية.