Development of Solar Heating System by Use of Fresnel Lens for Stirling Engine

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Abstract— Due technological advancement, consumption of fuel is increased and because of that world is facing problems like global warming, Greenhouse gas emission and air and water pollution also all the fossil fuels are in limited stocks and most of them need to be imported. So there is a need of energy source that is non-polluting, freely available and renewable. Solar energy is best suited in specified categories. So use of solar energy need to be increased. In solar panel, solar energy is initially converted in electrical energy and then it is converted in mechanical energy but in Stirling engine solar energy is directly converted in mechanical energy. Stirling engine works on the principle of expansion and contraction of air with respect to increase and decrease of temperatures in this work one stirling engine is operated by solar energy and its performance is measured.

Keywords: Stirling Engine, Solar Heating System, Fresnel Lens

I. Introduction

Stirling Engines are a quiet, non-polluting, and reliable method to generate power. Originally invented in 1816 by Robert Stirling, these engines use an external heat source to vary the temperature of a gas. The gas expands when heated and compresses when cooled, thus generating motion through the changing temperature of the piston. Furthermore, Stirling engines are capable of using a wide variety of heat sources. This creates an opportunity for renewable energy sources to be used. There are three main configurations of a Stirling engine: Alpha, Beta, and Gamma.

In this work Gamma type stirling engine is used. As shown in figure in Gamma type stirling engine, there are two plates attached.Upper plate is cold plate and bottom plate is hot plate. Temperature of hot plate is continously maintained high by suppling heat and temperature of cold plate is maintained low by rejecting heat to the surrounding.When displacer will be at top position, air will come in contact with hot plate so air will be heated.Temperature and pressure of air will increase so it will apply force on piston so piston will move towards upper side and displacer is connected with same crank shaft so it will come down.So air will be displaced and will come in contact with cold plate so again pressure and temperature of air will decrease and piston will come down so displacer will travel towards upper side.This process continues.This is how power can be generated by use of temperature difference.

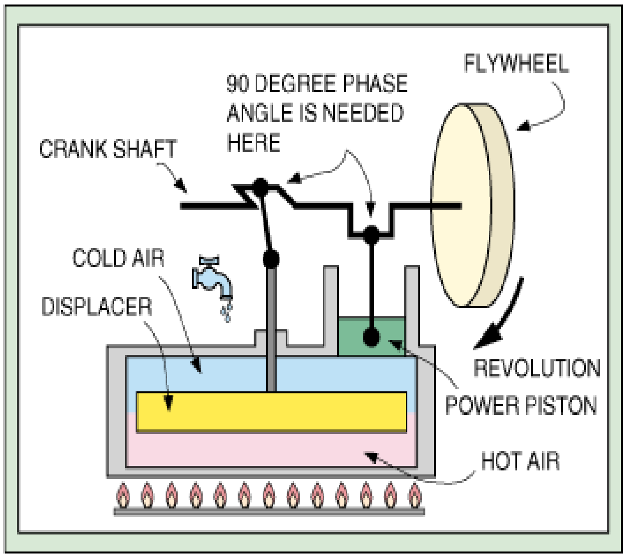

Fig. 1: Gamma type Stirling engine

Fresnel lens: A fresnel lens is an optical component which can be used as a cost-effective, lightweight alternative to conventional continuous surface optics. The principle of operation is straightforward enough: given that the refractive power of a lens is contained only at the optical interfaces (i.e. the lens surfaces), remove as much of the optical material as possible while still maintaining the surface curvature. Another way to consider it is that the continuous surface of the lens is “collapsed” onto a plane. An example of this concept is shown in Fig.2

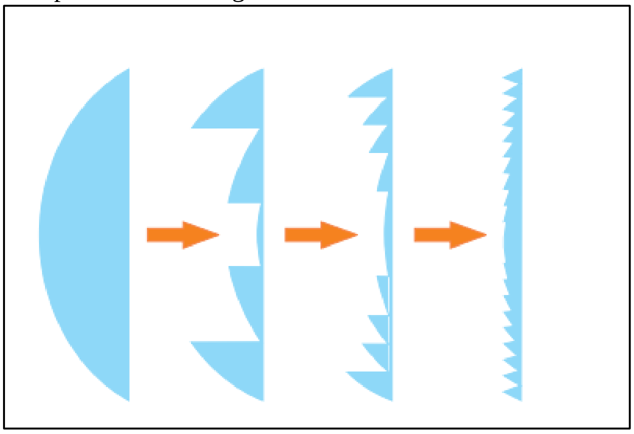

Fig. 2: Collapsing a continuous surface aspheric lens into an equivalent power fresnel lens.

II. Literature Review

Bancha Kongtragool et al. in 2006 , Designed and developed two single-acting, twin power piston and four power pistons, gamma-configuration, low temperature differential Stirling engine. The engine performance was tested with air at atmospheric pressure by using a gas burner as a heat source.

The engine was tested with various heat inputs. Variations of engine torque, shaft power and brake thermal efficiency at various heat inputs with engine speed and engine performance were presented.

Yoshitaka Kato in 2017, proved that The low temperature differential Stirling engine with channel-shaped heat exchangers and regenerators achieved approximately 5 times the indicated power per a stroke volume of displacer of the cases using flat-shaped heat exchangers

Shahrir Abdullah et al. in 2005 presented design considerations to be taken in designing of a low temperature differential double-acting Stirling engine for solar application Fabrizio Alberti et al. in 2014 presented and discussed the design and first prototype realization for a brand new generation of Stirling engines. The unit was realized within the DiGeSPo Project, in which it is coupled with a smallsize parabolic trough concentration solar field. The engine was conceived for working with low-temperature heat sources (200-300°C), in order to match the typical temperatures for the solar field itself.

III. Objective and Scope

In stirling engine, heat is given as a input energy. Now if that heat is captured by solar energy then there will not be any operating cost for operation of stirling engine. So in this experiment stirling engine is operated by solar energy. Stirling engine can be used for different application depending on its rpm and torque produced. It can be used for prime mover of machine and also can be used as prime movers for fan. For that its rpm has to be measured at different temperature difference, So here rpm of stirling engine at different temperature difference is measured.

IV. Parameter Selection

For operation of stirling engine, minimum 20 ^{0}C temperature difference is required between hot plate and cold plate.
Here cold plate is directly exposed to atmosphere so its temperature would be around 40^{o}C.
Hot plate temperature should be more than 60^{0}C.
Here one Mild steel rod is selected as heat storage device.
Mass of M.s rod is 3 kg.
And one mild steel plate is also welded with rod for heat transfer purpose .which is of 1 kg.
So total heat required = m C_p ΔT = 4*502.416*20 = 40,193.28 J
So if we want to heat M.S assembly in 5 minutes then around 140 W heat need to be supplied from power source.
Here Fresnel lens is selected as heat source concentrator.
Size of Fresnel lens is 1.4 width and 1.6 m length.

V. Development

Initially Stirling engine is procured which is shown in figure.

Fig. 3: Stirling Engine

For support of Fresnel lens, wooden frame is prepared as shown in figure. Frame is developed in such a way that lens can be adjusted in any of direction and any angle manually.

Fig. 4: Fresnel lens with support

For measurement of temperature one PT 100 temperature sensor which powered by solar panel is procured. Which is shown in figure.

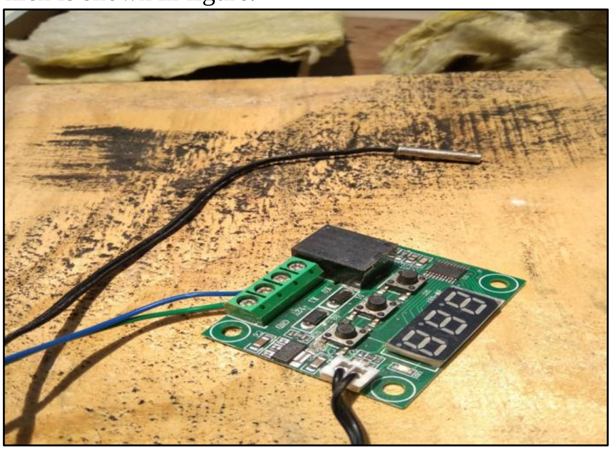

Fig. 5: Temperature sensor with digital indicator

And finally one mild steed heat storage device is selected and welded with mild steel plate which is shown in figure. Mild steel heat storage device is selected in such a way that stirling engine can be directly kept on it.

Fig. 6: Heat storage device

VI. Experimental Set Up

Fig. 7: Experimental set up

From figure it can be seen that by use of Fresnel lens solar rays can be concentrated on specified area and temperature of that area can be increased. In this experiment solar energy is concentrated on heat storage device. After achieving required temperature stirling engine can be kept on heat storage device. To measure temperature, sensor is attached with heat storage device. Temperature sensor and indicator is powered by solar panel as shown in figure. RPM of stirling engine is measured manually.

VII. Result and Discussion

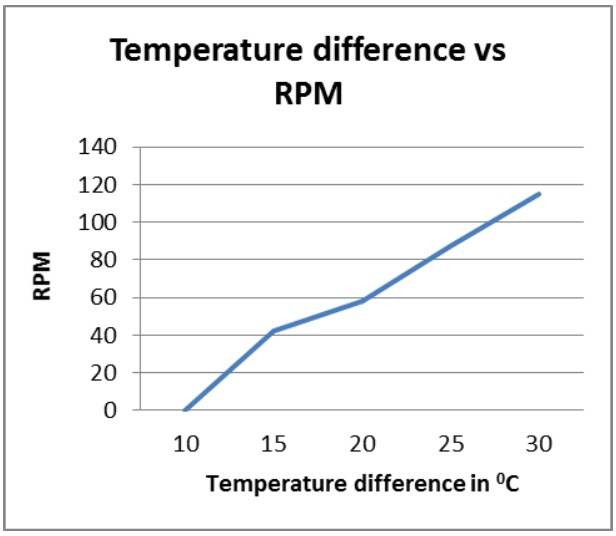

Fig. 8: Graph: RPM vs Temperature difference

From graph it can be observed that for initial starting of stirling engine at least 15^{0}C temperature difference is required. RPM increases with increase in temperature and at 30 ^{0}C temperature difference RPM of stirling engine is around 115.

VIII. Conclusion

From experiment and reading it can be concluded that RPM achieved is in the range of 40 to 120. That is very low compared to the RPM of fan. So to achieve more RPM, gears can be used with bigger size stirling engine. In future, torque developed by stirling engine can be measured and its potential to run heavy machinery can be checked.

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