SOLAR POWERED STIRLING ENGINE GENERATOR

Sherwin C. Pangan, Vien Mauris M. Macapagal, Gilson V. Mempin, and *Genesis T. Samonte*
Adviser*: Cyrus Sagana, ME*

Abstract

The Solar Powered Stirling Engine Generator is designed to convert heat energy from the sun into mechanical energy using a stirling engine. The stirling engine drives the generator to produce useful electrical energy and it then stores the electrical energy on batteries. The stirling engine is a heat engine that operates in a cyclic expansion and compression of a working substance like air or other gas indifferent temperature producing a mechanical work from conversion of heat. The engine is an external combustion engine which means the engine uses heat from the outside source. This is a very good characteristic of the engine because the concentrated solar heat can be used in producing useful work. The heat from the sun is focused in small area using a parabolic dish concentrator with reflective material. The study focused on the design and development of solar powered stirling engine generator. The cost to benefit ratio is one of the major concern as well as the impact of the engine in the environment. The prototype developed demonstrated the feasibility for a large scale design that can equal if not surpass solar panel due to its efficiency and cost of fabrication which is 2/3 lower than solar panels.

Keywords: stirling engine, parabolic dish concentrator, external combustion, solar energy, battery.

Demand for energy to sustain human's daily living is increasing dramatically for the past years. As a result, the supply of fossil fuel is depleting. According to CIA World Factbook, "it was clear that fossil fuel reserves are finite- it's only a matter of time to consume it up." Every year, global consumption is currently equivalent to over 11 billion tons of oil in fossil fuels. Crude oil reserves are vanishing at the rate of 4 billion tons a year. If this rate will be carried on without any increase of supply for our growing population, our known oil deposits will be gone by 2052.

Another reason why we need to work immediately in converting energy from renewable resources is because of the harmful effect of burning fossil fuels in the environment. According to Flavin and Dawn, the burning of fossil fuels in the conversion to energy creates waste of H2O and CO2. Since CO2 is a natural greenhouse gas, too much of it in the atmosphere has been proven to cause global warming. Last year, emission of CO2 from fossil fuels was 6.2 billion tons, increasing fourfold from 1950.

There is a lot of alternative way of producing energy like solar panels, hydroelectric generator and wind mills but most of them requires large amount of money to install and operate with high maintenance .However there are some alternative source of energy that requires low cost installation and maintenance, like stirling engines.

Stirling engine is a heat engine that operates in a cyclic expansion and compression of a working substance e.g. air or other gas in different temperatures producing a mechanical work from conversion of heat. It was invented by a Scottish inventor named Robert Stirling in 1816. It was first used to pump water in a quarry. The use of stirling engines in 1900 was replaced by steam engines because of the number of failures. These failures are due to the need for stirling engines to run at very high temperatures to maximize power and efficiency exposing the engines to its limitations because of the available materials during that time. But because of the availability of the materials in the modern day that can withstand these limitations, the development and study about stirling engines is increasing.

In the study made by Wongwises et. al. (2002), solar energy is one of the best renewable energy sources that can be used as an input energy source for heat engines. As a matter of

fact, any heat energy source can be used with the Stirling engine. The solar heat can be focused onto the displacer hot-end of the Stirling engine, creating a solar-powered prime mover. The direct conversion of solar power into mechanical power reduces both the cost and complexity of the prime mover. In theory, the principal advantages of Stirling engines are their use of an external heat source and their high efficiency.

The decreasing amount of fossil fuels and its harmful effect in the environment triggers the experts to find cheap, efficient and eco-friendly alternative way of producing energy.

Problem Statement

This study seeks to answer the following:

1. What is the appropriate design in making a solar powered stirling engine generator?
2. What are the equipment and materials needed to generate energy from solar heat using solar powered stirling engine generator?
3. What are the advantages of using solar powered stirling engine compared to using solar panel?
4. What test is needed to ensure the efficiency of the engine?
5. What is the development cost of solar powered stirling engine generator?

Conceptual Framework

Shown in Figure 1 is the IPO model that served as the basis of the development of the study.

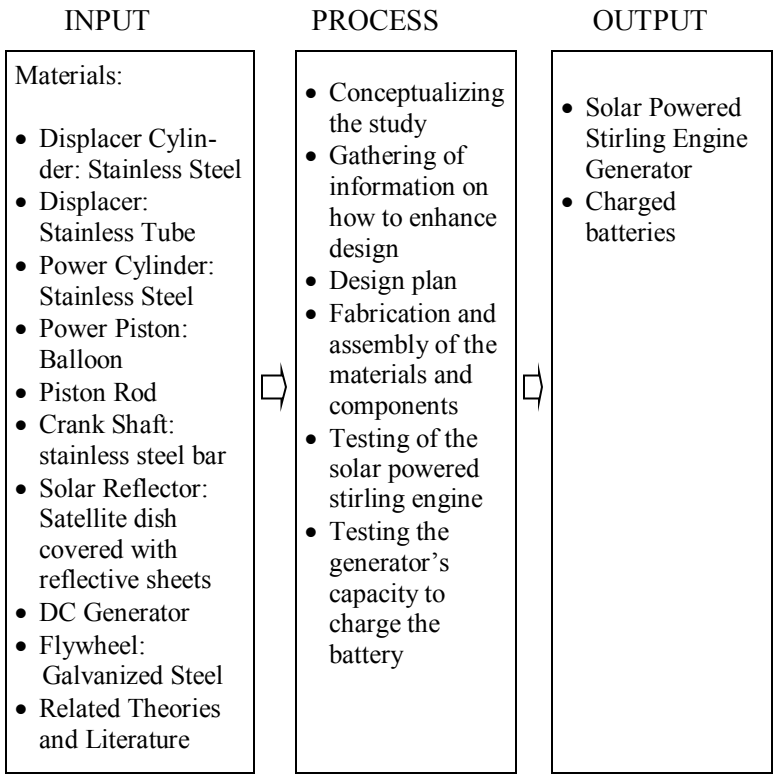

Figure 1. Conceptual Framework

The creation of the system requires two sub-system fabrication. The first one is the fabrication of the stirling engine and the second one is the fabrication of the base with the solar dish collector. It is important to finish first the engine before starting on the base, as there might be some adjustment in the design during the fabrication of the engine. The stirling engine is divided into five major components, the flywheel, displacer, crankshaft, power and displacer cylinders where some components that must be made simultaneously like the power

and displacer cylinder. The solar dish collector can be made simultaneously with the engine. To make the fabrication process faster, preparing and cutting the desired dimensions for the materials are the first things that need to be done. The researchers outsourced the works involve in preparation of the materials including the fabrication of component parts. During the fabrication of the engine, the fabrication for the solar dish and base was done simultaneously. After completion of the parts, the researchers assembled all component parts to develop the system, and after the completion of the system, testing the solar powered stirling engine was done.

For a typical power producing Stirling engine, the ratio of swept volume of displacer cylinder to power cylinder is 1.5 to 2 and for a LTD type Stirling engine, this ratio is 10 to 20. So that, the researchers have to first assume the dimensions of power cylinder before finding the displacer side dimensions. It is desirable to keep the clearance between the displacer and inside diameter of the displacer cylinder as small as possible but the two must not touch because the friction may slow or stop the engine. The reasons for the small clearance are: 1. to minimize dead volume in the engine, 2. the increased gas velocity provides better heat transfer from increased turbulence when the gas impinges on the hot or cold plates. During the testing of the system it was observed that I.D. of displacer cylinder = O.D. of displacer piston + Clearance. Also, Length of the cylinder = 2/3 x length of displacer. Length of power cylinder = stroke + power piston length. The selected material for displacer cylinder should have high thermal conductivity and the material for displacer should be thermally insulating and light in weight. But, for power cylinder material should have low thermal conductivity. (http://www.ijesrt.com© International Journal of Engineering Sciences & Research Technology)

Therefore, selected component of the system should be of the following materials:

1. Displacer cylinder :Stainless Steel
2. Displacer : Stainless Tube
3. Power cylinder : Stainless Steel
4. Power piston : Balloon

5. Flywheel: Steel
6. Piston rod: Steel
7. DC generator
8. Solar Concentrator: Satellite dish covered by Reflective sheets

Methods

This section presents the research design in pursuing the study and includes how the development of the project was done in accordance to the systematic procedure and processes. This section also includes the design, selection, identification of materials, methods, and techniques used in creating the system.

1. *Data Gathering*. Applied research is a design to solve or to investigate practical problem of the modern world, rather than to acquire knowledge for knowledge's sake. It focuses on analysis and solving social and real life problems. The researchers gathered data based on the design of a solar powered stirling engine. The goal of the research is to create a generator that can produce direct current to charge batteries.

2. *Design*. The design of solar powered stirling engine generator was based on the solar powered stirling project featured in International Journal of Engineering Sciences and Research Technology and the availability of materials in the market. It was especially designed for easy operation.

3. *Selection and identification of materials*. The Solar Powered Stirling Engine Generator consisted of several components designed to meet the specifications of the study.

4. *Fabrication*. The researchers worked as a group in every aspect of the study including civil works, electrical, electromechanical and process.

5. *Testing process*. Testing of the Generator was conducted to determine the workability of the engine.

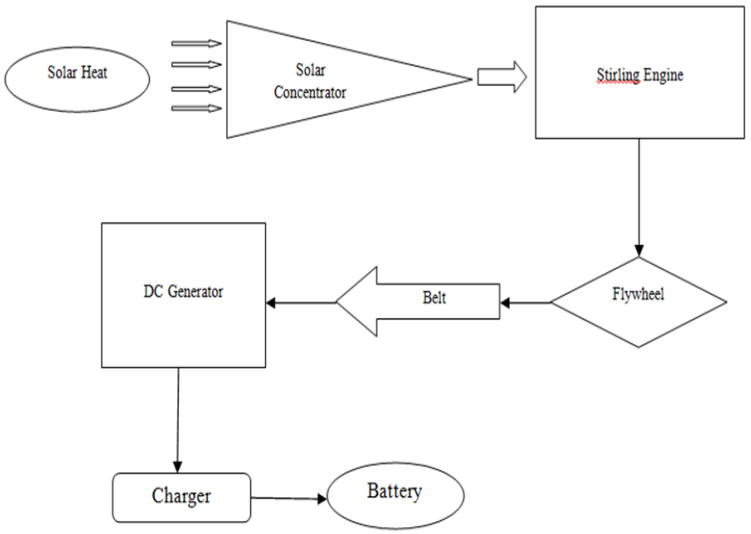

Figure 2. Block diagram of the Solar Powered Stirling Engine

Identification of components needed in constructing the system.

The researchers looked for materials and components that best suit the specifications and requirements in constructing the system. The availability of the materials was also considered.

Table 1. Material Specifications

Materials	Dimensions	No. of Pieces
Stainless Tube	2 " dia. (Length :140 cm)	1 pc.
	1" dia. (Length :40 cm)	1 pc.
Stainless Cap	2 " dia.	2 pcs.
	1" dia.	1 pc.
Bike wheel Spokes	2 mm dia.	2 pcs.
	3 mm dia.	2 pcs.
Generator	5 – 9 volts output	1 pc.
Balloon		1 pc.
Bolt	7mm	4 pcs.
Nut	7mm	8 pcs.

Table 1. Continuation

Materials	Dimensions	No. of Pieces
Cooling Fins	4" dia.	5 pcs.
Power Bank	8000 mAh	1 pc.
Wires no.16	4 m.	2 pcs.
Stainless Bolt	6mm	3 pcs.
Stainless Nut	6mm	2 pcs.
Base	Height: 3 ft.	1 pc.
Satellite Dish	Typical Size	1 pc.
Mounting	2.5" dia.	1 pc.
Flywheel	5" diameter	1 pc.
Displacer	Length : 80 cm Diameter :1.7"	1 pc.
Hose Clamps	(Small)	1 pc.
Hose Clamps	(Big)	1 pc.
Shrinkable tube	Length: 12"	1 pc.

- **Completed Project**

Figure 3. Completed Project

Data and Results

The following are the average data collected from a series of testing done on a one week basis.

Table 2. Testing Result

	10 am	11 am	12 noon	1 pm	2 pm	3pm
Engine Speed (RPM)	150rpm	150rpm	220rpm	210rpm	160rpm	135rpm
Power Output of the Generator	5.2 watts	5.2 watts	6 watts	5.8 watts	5.15 watts	4.7 watts
Temperature of Hot Side	150 °C	170 °C	215 °C	220 °C	215 °C	180 °C
Temperature of Cold Side	30 °C	34 °C	38 °C	42 °C	45 °C	48 °C
Thermal efficiency	80%	80%	82.33%	81%	79%	73.33%

Multiple tests were conducted to determine the efficiency of the engine on different time of the day starting from 10 am up to 3 pm. The researchers found it hard to test the engine during cloudy day when the solar heat is not enough to operate the engine.

Safety and Control Measures

To ensure safety in operating the Solar Powered Stirling Engine, the following must be observed.

- Do not play with the System. It deals with high temperature that may cause burn to the skin.
- Wear protective equipment like Sunglasses.
- Make sure the Focal Point is pointing at the Displacer Cylinder. If not, Adjust the Solar Reflector. Adjusting from left to right can be done by rotating the Solar Reflector from the base. And for up and down, can be done by loosening and tightening the two (2) nuts located at the back of the Solar Reflector.

- For more detailed information: Please read the Operation and Maintenance Manual (OMM).

Maintenance

In maintaining the effectiveness, maximum benefits, usability and functionality of the Solar Powered Stirling Engine, the following directives must be observed.

- Check for leaks. Before placing the engine at the mounting, check for leaks especially at the Power Cylinder.
- Lessen the Friction. Put grease at the crankshaft to lessen the friction.
- Reflectivity. Always check for dust particles in the Solar Reflector before using.
- Connectivity. Check the wiring of the system if it got burned or not connected.

Conclusion

Based on Table 2 above the engine's speed and efficiency as well as the power output of the generator was based on the temperature difference between the cold side and the hot side of the engine. The temperature on the hot side continued to rise until 1 pm and the engine experienced temperature drop at 2pm and 3pm. Since the engine was in continuous operation the cold side temperature was increasing from the start, up to the end of testing thus affecting the efficiency of the engine.

Based on the gathered data, the researcher therefore concluded that using solar powered stirling is more efficient compared to using solar panels based on the efficiency that the researchers gathered versus the existing standard efficiency of solar panels of 15-25 percent. The cost in fabricating the solar powered stirling engine is almost 1/3 of that in buying a 10 watts solar panel.

Recommendation

The following are the recommendations for researchers interested to study Solar Powered Stirling Engine:

1. Since the researcher used low quality Reflective Film, the researchers recommend the use of higher quality material to increase the reflectivity. Also, increase the diameter of the solar dish.
2. Increase the capacity of the generator.
3. Increase the speed of the engine. By using higher quality materials and improved design for the crankshaft and flywheel, this objective can be attained.
4. Lessen the friction present in the engine.
5. Use a solar tracker to provide automatic adjustment of the focal point.

References

Chen, C., Ho C., Yau H., (2012) *Performance Analysis and optimization of a Solar Powered Stirling Engine with Heat Transfer Considerations*, Retrieved from www.mdpi.com/journal/energies

Kongtragool B., Wongwises., S., (2003) *"A review of solar-powered Stirling engine and low temperature differential Stirling engines,"* Renewable and Sustainable Energy Reviews, vol. 7. Retrieved from http://research/omicsgroup.org/index.php/Stirling_engine

Martini, W.R. (1979) "*Stirling engine design manual*" NASA CR -135382, 1979, In: M.J. Collie, editor. Stirling engine design and feasibility for automotive use. Retrieved from https://www.hindawi.com/journals/isrn/2012/321923

Patel, R., Pandya B. (2014) *Solar Powered Striling Engine – A New Hope*. Retrieved from https:// www.worldwidejournals.com/global-journal-for-research -analysis_GJRA/file.php? val=October_2014_1413376898_21.pdf.

Prajapati, H., Vadher R., (2015) *Gamma type Solar Stirling Engine*. Retrieved from http://www.ijesrt.com International Journal of Engineering Sciences & Research Technology.

Thombare, D.G., Verma, S.K., (2008) "*Technological development in the Stirling cycle engines,*" Renewable and Sustainable Energy Reviews, vol. 12., Retrieved from http://research.omicsgroup.org/index.php/ Stirling_engine

Saini, A., Khhli, S., Pillai, A., (2013) Solar Powered Stirling Engine Driving Water Pump. Retrieved from https:// www.slideshare.net/mobile/esatjournals/solar-powered-engine-driven-water-pump-34753039