STERLING EXTERNAL COMBUSTION ENGINE SOLAR PARABOLIC COLLECTOR

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Abstract— A Sterling engine operates by cyclic compression and expansion of air or other gas with solar parabolic collector is a heat engine that, the working fluid, at different temperature levels such that there is a net conversion of heat energy to mechanical work. The engine is like a steam engine in that all heat transfer takes place through the engine wall. This is traditionally known as an external combustion engine in contrast to an internal combustion engine where the heat input is by combustion of a fuel within the body of the working fluid. Unlike the steam engine's use of water in both its liquid and gaseous phases as the working fluid, the Sterling engine encloses a fixed quantity of permanently gaseous fluid such as air or helium. As in all heat engines, the general cycle consists of compressing cool gas, heating the gas, expanding the hot gas, and finally cooling the gas before repeating the cycle. There are two major types of Sterling engines that are distinguished by the way they move the air between the hot and cold sides of the cylinder.

Keywords— Solar thermal heating system; Solar collectors;

I. INTRODUCTION

Parabolic trough technology is currently the most proven solar thermal electric technology. This is primarily due to nine large commercial-scale solar power plants, the first of which has been operating in the California Mojave Desert since 1984. Large fields of parabolic trough collectors supply the thermal energy used to produce steam for a Rankine steam turbine/generator cycle. There are two basic types of parabolic trough solar heating collectors that have been commercially developed: cylindrical parabolic troughs and compound parabolic collectors. A standard cylindrical parabolic trough has a fixed receiver/absorber positioned in the middle of the trough at or slightly above the radius across the edges of the reflector. The shape of the trough (rim angle) determines the focal point, and thus the position of the receiver. The reflector surface is usually polished aluminum, aluminized plastic, silvered glass, or stainless steel. The receiver usually has an absorber tube coated with a selective material that has a high absorption for the solar spectrum and low emittance for infrared radiation. The absorber tube may be enclosed in glass with a vacuum to reduce heat loss due to convection and radiation. Receiver temperatures can reach 750°F (400°C).

A.Global Solar Radiation:

The performance of any solar system requires information on the availability of energy in direct beam, diffuse energy from the sky or the reflected energy from the ground and other objects. For empirical estimation, solar radiation of possible sun sine and cloud are used from meteorological exist data, and at location where no measured data a linear interpolation is made by using total horizontal data from the nearest location.

B.Solar Radiation Data:

Many countries through networks under meteorological organizations record and maintain solar radiation data mostly in long leys received on a horizontal surface in different observations centers. Data are available for daily or hourly solar radiation, wind velocity, temperature and duration of sun sine and cloudiness for over three decades. This information are available in different forms and they are to be used carefully because the records may provide bean, diffuse or total radiation, instantaneous values integrated over an hour in a day, measurements in incline or fixed slope or normal, daily measurements averaged by month and hourly average by month. Average solar radiation data provide information about general trends. Based on accurate values of daily means of solar radiation at one location, solar radiations for every month in different parts of the world are complied. The daily average total fluxes for sunlight on a horizontal surface for the month of June, in various parts of the world are given. The greatest amount of solar energy is found around the earth between the 15 degree and 35 degree north and south parallels, where there is a minimum monthly mean radiation of 20MJ/m^2/day. These regions are on the equatorial side of the world's arid deserts. In some of the areas there is usually over 3000 hrs sunshine/

year, over 90% of which come as direct radiation.

The next favorable region for solar energy applications is in the belt between 15 degree north and 15 degree south parallels. The scattered radiation is high with about 1500 hrs sunshine/year. The influx of solar radiation ranges from 12 to 20MJ/m²/day. Between 35 degree and 45 degree parallels, at the edge of deserts the solar radiation averages 16 to 20MJ/m²/day. The regions beyond 45 degree north to 45

degree south are limited in their year-round direct use of solar energy. More than 80% of the world's inhabitants live between 40 degree latitude in about 14MJ/m²/day. In U.K. the average daily total solar radiation is about 16 MJ/m²/day, in summer and about 2 MJ/m²/day in winter. The total on a horizontal surface is about 3500 MJ/m²/year. On the other hand, Australia which is enjoying quite the opposite weather and vegetation receives about 6500MJ/m²/year nearly twice as much.

Because of the inclination of the earth axis to the plane of its orbit, the maximum altitude of the sun and the length of the day vary substantially with latitude and season. This effect can be seen in the measurements of solar radiation over the seasons for various latitudes. In summer they are compensating so that the on a clear day the total energy falling on a horizontal surface is 30MJ/m²/day at all latitudes up to the polar area.

The distribution of the total duration of bright sunshine in India ranges form 2500 to 3600hrs/Year. The global solar radiation of nearly 27 MJ/m²/day is available on a horizontal surface over arid and semi arid regions. During monsoon and winter months the global solar radiation falls to 10 to 20 MJ/m²/day. Nearly 10% of area of the country receives global radiation exceeding 20 MJ/m²/day and about 70% of the area 17 to 20 MJ/m²/day. These are favorable regions for harnessing solar radiation. The desert zones of the earth are having highest insulation. Arid and semi arid regions of the country comprise 10% and 30% respectively of the area of the whole country.

The average solar radiations (MJ/m²/day) in some cities in India are given.

STATION	WINTER DEC-FEB	SUMMER MAR-MAY	MONSOON JUN-SEP	POST MONSOON OCT-NOV
PUNE	19.2	25.2	18.2	18.3
CHENNAI	18.9	24.3	19.9	16.6
KOLCUTTA	15.7	21.6	16.4	16.1
NEW DELHI	15.2	24.1	20	17.6

II. INDIAN SCENARIO IN THE SOLAR FIELD

India lies between 7 N and 37 N latitudes, and the prospects of using solar energy here is very bright. The average intensity of solar radiation in India is 500-600 cal/cm² per day, and the solar energy annually received by it is 5 x 10^{15} KWH. If India can tap one percent of the incident solar radiation, it can generate many times the energy of its actual requirement at present. A study of the average solar radiation falling on major Indian cities in different months of the year shows how easily Indian cities receive a huge quantity of solar energy at practically no cost. This free and easy availability of solar energy has forced India to develop its use. As a result, in the fifties, Indian government laid stress on the development of devices which used solar energy to meet specific needs. Scientists at the national physical laboratory in New Delhi

devised solar cookers, water heaters and water pumps among other things, for the use in the country. In the seventies, a committee headed by the energy and petroleum ministry recommended that basic research on solar energy by carrying out in all universities and frontal research organization. Several universities and institutes such as central building research institute, Tata energy research institute and IITs subsequently took up research work on the development of solar energy technologies. The main thrust was application of solar energy in rural sector and supplementing commercial energy in urban areas. In the eighties the department of non conventional energy sources was assigned the main responsibility for advancement of solar energy utilization. A 1991-1992 report published by the ministry of non conventional energy sources revealed that despite head way made in India in the utilization of solar energy, the ratio of energy used to energy available, was extremely low. India annually received 5 x 10 / 15 KW hr. of solar Energy, but utilizes only 13 x 10/7 KW hr., or 0.0000026% of it.

How ever there has been a significant growth in the use of solar heating systems in India, in the form of solar water heaters, domestic and industrial solar cookers, solar crop diverse, kilns, desalination, systems etc. India is now in touch with many developing countries for the development of renewable energy. It coordinates the applications of solar energy among G-15 countries, and provides fellow ships to scientists from those countries. Solar shops that sell solar energy appliances are coming up fast. One example is Aditya, owned by the Delhi energy development agencies. It has branches in Kolkata, Trivandrum, Bhuvaneshwar, Bhopal, Jaipur, Patna, Baroda and Chandigarh. In Kerala, ANERT is doing well in solar energy products.

We get both light and heat from the sun, these can be converted into other forms of energy.(a) light from the sun can be directly converted in to electricity with the help of solar cells, by photo voltaic (PV) effect which was first discovered by Beckured in 1839. The cells are usually made of crystalline silicon, a substance found abundantly in earth's crust. Solar cells have many potential uses. They can run machines ranging from pocket calculators to water pumps of 230 V/60W. The cost and efficiency depend on the material used.

In India the PV program started in 1976, while the commercial production of solar cells started in 1984. India ranks high among the world's producers of PV systems. Indian companies produce 40% of the world's supplies. According to the MNES sources, until 1995, 1 lakh PV systems were I operation in India. MNES had setup a target of operating 1, 50,000 lanterns, 5000 house hold lights and 3000 solar water pumps. Solar PV has been projected as the energy source of the future. The progress of the PV program has been hindered by the high cost of these systems. Amoco-Envon solar power development (A joint venture by 2 American multinationals) proposed to MNES to setup a 2400MW solar PV power plant in the Thar Desert in Rajasthan, which enjoys India's highest solar radiation of 2173 KWH/M²/year, and the highest sunshine hours at 3285 a year.

The plant would start with a production of 10 MW and increase it to 100MW annually. In west Bengal, a 50MW solar plant went in to operation on Mausuni Island in sundarban area on March 4, '01. The plant which cost RS.1.5

crore to setup, could supply power to 400 houses on the island, and is reported to be the largest of its kind in India by WBREDA. It has plans to augment this plant and supply power to all 4000 houses there. WBREDA established a 26 KW solar power plant at Mrityujpur in 1998, and has supplied power generated from solar energy to 2 villages-kamalpur and South Haradanpur. In October last year, a 2.2 KW solar power plant was inagurated at a height of 14,000 feet in the Himalayas, near the Sikkim border.

The plant was designed by WBREDA and executed by exide at a cost of RS.15 lakhs, provided by MNES. The power generated here utilized by the trainees of the Himalayan mountaineering institute at their base camp. This plant is the first in the world to be at such a high altitude. In UP, there were plans to setup 2 large solar power plants of 100MW capacity each, at Kaluanpur and Surat village, to supply power to 400-600 houses in the locality. At Borodia, on the UP-MP border, a solar power plant of 4KW power capacity has been established by UPENDA for domestic supply and street lighting.

From the above mentioned details, it is clear that India has tremendous potential to lap the solar energy.

There are many scattered villages without electricity. These villages need water pumping and electrification. Due to the location of the villages remote from the cities, a conventional power plant may be too costly because of the length of transmission lines. Diesel generators also need transports of fuel and maintenance. In such circumstances photo voltaic generation of electricity for pumping water will be a most economical method.

A. Types Of Solar Collector

Not only are there many different ways that solar energy can be applied, but there are also many different methods for collecting the solar energy from incident radiation. Below is a listing of some of the more popular types of solar collectors.

- Glazed flat-plate solar collectors
- Unglazed flat-plate solar collectors
- Unglazed perforated plate collectors
- Back-pass solar collectors
- Concentrating solar collectors
- Air based solar collectors
- Batch solar collectors
- Solar cookers
- Liquid-based solar collectors
- Parabolic dish systems
- Parabolic trough systems
- Power tower systems
- Stationary concentrating solar collectors
- Vacuum tube solar collectors

B. Components And Description

The main components of this paper are,

- Solar Parabolic Collector
- Reflector
- Tilting Mechanism
- Cooker
- Frame stand

(a) Solar Parabolic Collecto

The most common types of concentrating solar thermal heating collectors are based on the parabolic trough. Parabolic troughs are U-shaped, concentrators that focus sunlight onto a linear receiver tube located along the focal line of the trough. The receiver may be enclosed in a transparent glass tube to reduce heat loss from the absorber and maximize absorption of solar energy. They generally have single-axis tracking.

Other types of concentrating systems have an array of reflectors that individually track the sun and focus sunlight onto a central receiver located on a tower. Development of these systems has focused on electric power generation. There are two basic types of parabolic trough solar heating collectors that have been commercially developed: cylindrical parabolic troughs and compound parabolic collectors.

In this paper, the type of concentrating system that is possible to use in a heating application is the parabolic dish. This has a bowl shaped reflector that focuses the sun onto a relatively small receiver. For optimum performance they require dual axis tracking and the receiver moves with the reflector. This complicates their practical application for water and space heating. Most parabolic dish systems are very sophisticated systems used for electricity generation or very simple systems for cooking food on a small-scale. The dish can be oriented east to west or north to south. They are typically single-axis tracking. In our project, the type of tracking is single axis (east to west). Most applications of tracking parabolic troughs are relatively large systems to supply heat for domestic water and space heating in commercial and institutional buildings.

(b) Reflector

One side coated glass mirror is used as a Reflector. The reflector is used to reflecting the sun rays to the collecting chamber. The Glass thickness is 2.4 mm. The Glass is one side coated by the mercury.

(c) Tilting Mechanism

There are two types of tilting mechanism are used for solar thermal heating system. They are,

- Single axis Tracking (From east to west)
- Double Axis tracking (East to west or north to south)

The tilting mechanism is having central pipe, guide bush and nut. The parabolic disk is tilted in one direction from ease to west.

(d) Cooker

The cooker is fixed to the center of the parabolic dish collector. This is made upof aluminium materials. The reflected sun rays are concentrated on this center of the

cooker, so that the substance is heating efficiently. The clamp is used to hold the cooker.

(e) Frame Stand

Frame stand is made up of mild steel round pipe. The diameter of the pipe is 50 mm. The total height of the stand is 900 mm.

III. BASIC PRINCIPLE OF SOLAR PARABOLIC DISH

A. Focussing Type Solar Collectors

These collectors are not generally used in domestic application. However, to achieve high temperatures and to meet thermal energy requirements these systems can also find place in near future for domestic application. Based on the present trend in research taking place, a brief description may help readers to absorb the basis for better understanding. A focusing collector is a special device where the surface of the collector is so modified to reflect or refract the falling radiation on to the absorber which is situated either along the focus line or at the focal point. But in case of flat plate collectors of water or air heating systems, the absorber is just below the glass panel (collector) all along, where collector (panel) and absorber are flat.

These focusing collectors can increase radiation effect on absorber from as low as 2 times to 10,000 times of the incident radiation. At this absorber point, a suitable device to hold a pot can be fitted to receive the concentrated radiation cook or to boil water. However, the same radiation can be carried away by heat transfer in a tube containing water/ liquids on circulation basis.

The structure of the reflector can be divided into two parts as the shell- the supportive structure & the living area exposed to sun. The shell must be strong to withstand various environmental factors like wind, seasons, etc., to maintain its required shape. This shape decides efficiency of the whole system supported by selective lining.

The lining of the parabolic surface plays major role on overall efficiency of the system. In fact, achieving near 100% smooth and uniform surface is advised to avoid spreading of beam due to micro-roughness/undulations. For doing so, coating with aluminium foil with minimum 80-85% reflectivity is recommended. Even silver coating of the source reflectivity will do the job. However, aluminium having lighter thermal conductivity may constitute to the heat losses due to conduction. To avoid this very thin foil is recommended to minimize the losses.

Selective coating of reflector surface with black crome (Cr Ox) is more attractive and cost effective. This can be electroplated on various metallic surfaces like steel, alluminium & copper. This black crome can also withstand above 100%C operating temperatures.

B. Basic Principle of Solar Concentrators

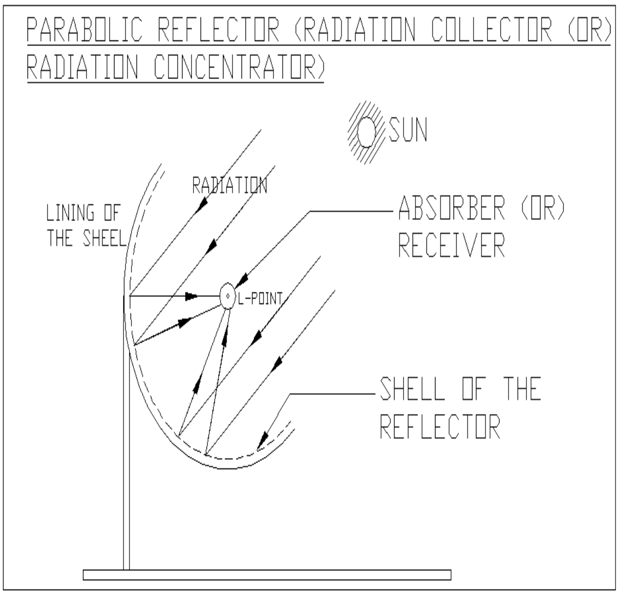
In a layman's language, when the surface of a reflector has curvature indicates that, reflector surface is optical in nature, depending on the degree of curvature. Solar rays reach and fall on earth at an angle ½ on any given point. As shown in the picture, the sun rays falling on a point (A)of the parabolic

concentrator form an image of the sun at the focal point of the. This means, the receiver or absorber which is at the point / center of such image will have maximum intensity as in the case of sun. The concentrating nature of the reflector thus increases the temperature at its focal point. This basis principle is employed in designing various types of solar concentrator to suit end- use requirements.
As seen in the picture, the radius is the focal point and the diameter of the rim of the reflector is the area exposed to sun. This is referred as aperture (a) or opening. In the case of parabolic structure the extent of diameter is the opening for sun and in case of cylindrical concentrators, the extent of width is the opening for the sun. The aperture (a) determines the total radiation received by the reflector per unit area, whereas the focal length determines the size and sharpness of the images of sun. As a result the ratio of a/f is the index of energy flux concentrated at the focal point /on receiver. To increase the intensity of energy flux on receiver, one should know the other physical relationship exists between aperture and receiver. This is known as Concentration Ratio
(CR) = (AA) / (AR)
Where,
Aa - Area of the concentrator aparature
Ar - Area of the receiver absorbing the energy

This relationship determines the effectiveness of the concentration.

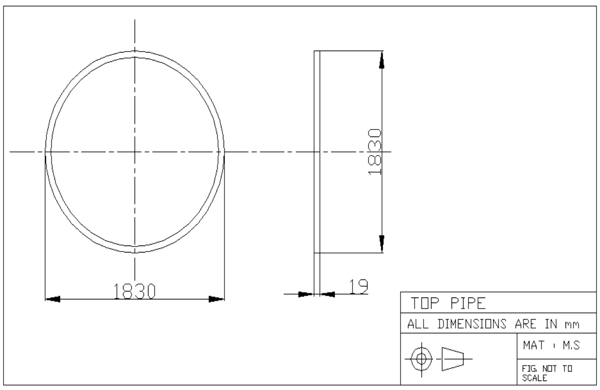
C. Design Aspects

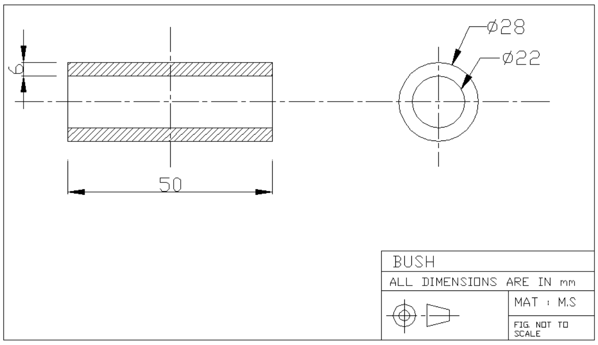
Sun rises from east and sets on west. During this travel intensity of sun on earth also varies. Under these circumstances, the design of the focussing concentrators must suit these phenomena. If the field view of the concentrator is much larger than the angular size of the sun, then there is no need to follow the travel path (tracking) of sun. Designs based on this are known as non-tracking concentrators.
In non-tracking concentrators ratio Aa/Ar is less when compared with tracking systems. Based on these facts, a wide range of solar focussing concentrators are being designed to provide heat energy ranging from 100 C to 500 C.

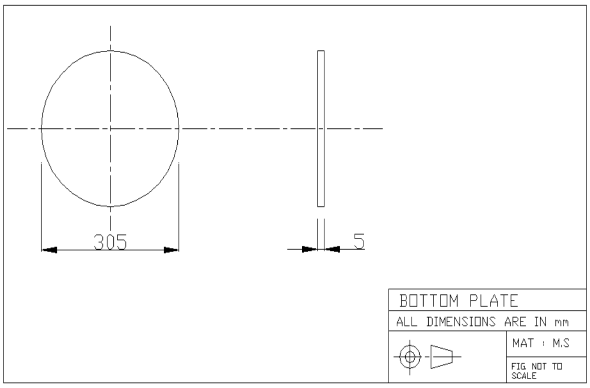


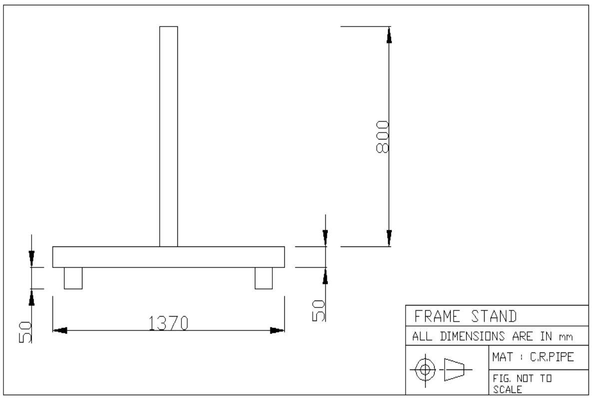
D. Working Principle

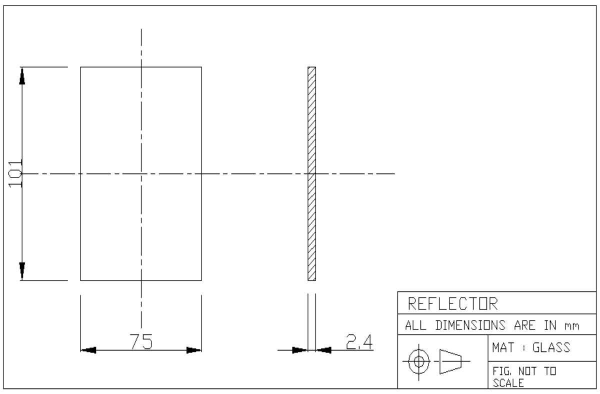
In this paper, the type of concentrating system that is possible to use in a heating application is the parabolic dish. This has a bowl shaped reflector that focuses the sun onto a relatively small receiver. The glazing is chosen so that a maximum amount of sunlight will pass though it and reach the absorber.
For optimum performance they require dual axis tracking and the receiver moves with the reflector. This complicates their practical application for water and space heating. Most parabolic dish systems are very sophisticated systems used for electricity generation or very simple systems for cooking food on a small-scale. Other types of concentrating systems have an array of reflectors that individually track the sun and focus sunlight onto a central receiver located on a tower. Development of these systems has focused on electric power generation.

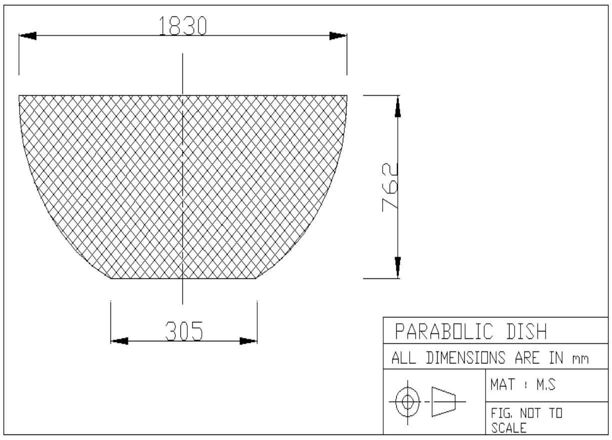


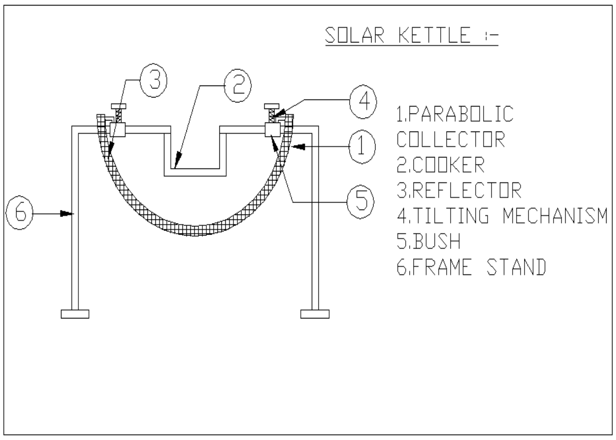












E. Advantages

Economical aspect:

- Least maintenance cost.
- No transportation from long distance
- No rent for electricity utilized
- No fuel required for operation

Technical aspect:

- No moving parts, thus long life
- Noiseless operation
- No person required to operate the system

Manufacturing aspect:

- Simple in construction, so easy to fabricate
- No heavy materials are used

Safety aspect:

- Pollution free
- Less chance of accidents

F. Limitations And Applications

Limitations:

- High initial installation cost
- Care should be taken for Cooking
- Need large size of solar panel area for high power output.

Applications:

- Domestic Applications
- Industrial thermal heating Applications

CONCLUSION

In this paper, solar thermal heating system was developed with purposes to get a compact and low cost heater. The prototype engine was experimented using air in atmospheric condition and with no load. Also, mechanical loss under pressurized condition was measured. It was discussed how to get higher performance based on the experimental and calculated results. As the results, it was confirmed that the development of higher performance heat exchangers and decreasing of mechanical loss were required. On the other hand, it was considered that a compact Stirling engine was optimized by detailed measurements for a heat balance. The investigate the detail of heat balance. This research aimed at the development of a compact Stirling engine with low production cost. When the compact, low cost and high performance Stirling engine is developed, it will contribute to solution of environmental pollution and energy utilization.

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