Building a parabolic solar concentrator prototype

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Abstract. In order to not further degrade the environment, people have been seeking to replace non-renewable natural resources such as fossil fuels by developing technologies that are based on renewable resources. An example of these technologies is solar energy. In this paper, we show the building and test of a solar parabolic concentrator as a prototype for the production of steam that can be coupled to a turbine to generate electricity or a steam engine in any particular industrial process.

1. Introduction

The optical systems based on solar energy have been developed and implemented since the XIX century. The maximum development of these systems was not until 1970 due to the global oil crisis, leading to the search for alternative sources of energy such as wind, bio-fuels, solar energy, etc. There is a whole range of technological options designed to take advantage of the solar energy but only a few are popularly known, for example, the solar systems for hot water or photovoltaic systems to produce electricity. However, there are other technologies that are mature enough to be commercialized on a large scale that are unknown by most people. An example of these is the design featuring the semi-cylindrical parabolic solar concentrator. A semi-cylindrical parabolic solar concentrator is based upon the direct conversion of solar energy to thermal energy by heating a working fluid, reaching temperatures above 300 °C, depending on the efficiency of the concentrator. It is for this reason that parabolic solar concentrators are suitable for use in a wide variety of industrial processes which use thermal energy, such as dairy, processed waste, electricity, etc., replacing in this way the use of fossil fuels. An example of the application of these parabolic solar concentrators are the eight so-called solar thermal power plants SEGS-II, III, …, IX built in California, USA, with more of 2.5 million square meters of parabolic solar concentrators. In the next section, we describe the process of building and testing of our semi-cylindrical parabolic solar concentrator prototype.

2. Building of the parabolic solar concentrator prototype

The main basis of the prototype solar concentrator is a parabolic reflective surface, which takes advantage of every ray of light coming from the infinite is concentrated at the focus. In the focus of the parabolic surface is placed a metal tube, which serves to transform solar energy to thermal energy. By circulating a fluid inside the metal tube is achieved above, in our case we use water, which will be converted in steam by the transformation of energy in this area. For make more efficient the energy
transformation the metal tube is isolated from the environment through a glass tube with vacuum between them, figure 1.

Figure 1. Parabolic solar concentrator prototype.

The reflective surface of the solar parabolic concentrator prototype has the following dimensions: 200 cm of length, 100 cm in width, and 50 cm focal length. To form this surface, we use a aluminum plate that has deposited a highly reflective film called REFLECTECH, which was developed by the company ReflecTech, Inc. and the National Renewable Energy Laboratory (NREL), figure 2. The company guarantees that the reflective film has a reflectance greater than 90%.

Figure 2. Gluing of the reflective film REFLECTECH on the aluminum plate.

A support structure was designed to form the half cylinder parabolic solar concentrator as shown in figure 3a. The completed structure is shown in Figure 3b illustrating the parabolic shape. Figure 4 shows the aluminum plate with reflective film attached to the supporting structure that gives the parabolic shape to the solar concentrator.

The support structure of the parabolic solar concentrator has two arms at the ends to keep the metal and glass tubes on the focus of the parabola as shown in figure 4. These arms are used simultaneously to form an axis of rotation, which helps the parabolic solar concentrator follow the Sun and thereby maintain the concentration of solar radiation onto the metal tube.
Next, two connectors of stainless steel coupler were manufactured to join the metal tube to the glass tube. These are used to maintain a separation between the two tubes, and as shown in figure 5, the joint between the tubes and connectors was sealed with high temperature silicone glue. In one of the connectors, as shown in figure 6b, we placed a valve to remove air between the tubes. The purpose of this valve was to transfer heat to the water inside the metal tube as efficiently as possible. Then, we use a vacuum pump to remove the air between the tubes. A vacuum gauge was used to monitor the pressure between the tubes to achieve a pressure of 420 millimeters of mercury.

Figure 3. Support structure of the parabolic solar concentrator.

Figure 4. Aluminum plate with the reflective film attached to the support structure

Figure 5. Join and sealed of connectors to the metal and glass tubes.
The metal and glass tubes are fastened to the support structure of the parabolic solar concentrator. At the focal length of this concentrator, stopcocks capable of withstanding high pressure are placed to regulate the entry of water into the metal tube at the other end and to regulate the output of water steam in the other side, as shown in figure 7a. We build a base for maintaining a water tank raise, which supplies the solar concentrator of water, and ensure that water flows through the metal tube freely, as shown in figure 7b. On the side of the steam outflow we place a thermometer and a pressure gauge to monitor temperature and pressure of the steam inside the metal tube, as shown in figure 8.

We coupled a motor for solar tracking in one of the arms of parabolic solar concentrator prototype so that direction of the pointing of the solar concentrator is always toward the sun as shown in figure 9.

Figure 6. Valve adapted in a one of the stainless steel connectors to remove the air between the tubes, b) Vacuum gauge.

Figure 7. a) a) Parabolic solar concentrator with the stopcock connected, b) Water tank that supplies to the parabolic solar concentrator.

Figure 8. Thermometer and Pressure gauges.
3. Results
After the construction of the parabolic solar concentrator prototype we proceeded to do performance tests. Figure 10 shows the steam obtained with this solar concentrator, after reaching a temperature of 200 °C and a pressure of 12kg/cm$^2$ on a sunny day and in 25 minutes. Table 1 shows some of the temperatures and pressures achieved with the parabolic solar concentrator prototype in one day with some clouds. These tests were made during the rainy season.

![Figure 10. Steam obtained with the parabolic solar concentrator prototype.](image)

| Time  | Temperatures (°C) | Pressures (kg/cm$^2$) |
|-------|-------------------|-----------------------|
| 12:15 | 42                | 0                     |
| 12:20 | 70                | 0.75                  |
| 12:25 | 90                | 1.5                   |
| 12:30 | 110               | 2                     |
| 12:35 | 125               | 3                     |
| 12:40 | 140               | 4.8                   |
| 12:45 | 155               | 6.6                   |
| 12:50 | 65                | 0                     |
| 12:55 | 70                | 0.5                   |
4. Conclusions
We have built a parabolic solar concentrator prototype with materials that can be found in the market easily and cheaply, with the exception of reflective film, which was imported.

On a clear day we can achieve temperatures above 200 ºC and pressures up to 12 Kg/cm². Our design could have achieved a higher temperature and pressure but this design is constrained by the errors associated with the shape of the parabolic surface of the parabolic solar concentrator prototype. Another source of error that affects the heat transfer to the water inside the metal tube is the vacuum leak between the seals of silicone of the tubes and couplers.

In this work, we have made a qualitative evaluation of the operation of the parabolic solar concentrator prototype. We need still to make a quantitative evaluation of it to have a real evaluation of the prototype.

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