Analysis of concentrated solar powered conical reactor with coal ash as catalyst

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Abstract. Nowadays there is an increase in the usage of non-renewable products to produce the energy required to sustain in day to day life, which results in the generation of harmful emissions such as greenhouse gases, in turn, leads to an increase in earth's surface temperature and depletion of the ozone layer. On the other hand, the generation of usable energy requires fossil fuels to satisfy the thermal input. So switching to renewable energy for the thermal input for fossil fuels saves the environment for further damage, mainly solar energy which is abundantly available and free of cost. Hence creating much more interest in researchers to establish and enhance the performance of solar energy coupled reactor. By implementing solar energy as the input for the reactor there will be a decrease in the consumption of fossil fuels to produce heat energy. In this present study solar concentrated power is used as an input fuel supply to the reactor process where the dish type concentrator used of diameter 1.4m and has a focal length of 0.28m which is focused towards the preferred conical shape reactor because of the effective flux distribution inside the reactor than the other shapes. The reactor volume of 13.9m³ is fixed at the focal distance where the receiver absorbs more amount of radiation from the concentrator, leads to an increase in the temperature inside the reactor and the specimen inside the reactor will generate gases. by using the coal ash as a catalyst there is a temperature increase of 10%. That is without any catalyst the reactor inside temperature is 100°C and with coal ash as catalyst 110°C.

1. Introduction
The serious issue around the world is pollution due to which the temperature of the earth is increasing year by year. The main pollution causing is by using fossil fuels for every requirement to satisfy our daily needs which in turn increases pollution. To decrease pollution lot more research is going on renewable energy and solar energy is the best use for any thermal input in our day to day life. We already were using solar technology products like solar water heaters, solar cookers, solar heaters, etc. The pyrolysis process gives an alternative fuel which helps for replacing the traditional fuels like diesel, petrol, etc. A lot of fuel is required as a thermal input for this process if it is replaced with the concentrated solar power the temperature which is required for the process can be achieved. There are several types of solar concentrators among them point focus concentrators should be used. There are several shapes of reactors available but there is a lot more difference in the temperature distribution inside the reactor. With the help of literature, a conical shape reactor is a more helpful ineffective distribution of temperature as compared with the other shapes.
2. Literature review

There is a lot more need of energy in our day to day life and lot more energy is wasted in the process of doing work on the other hand solar energy is not used properly to satisfy the needs. Moreover, convectonal reactors use lot more fossil fuel to produce biofuel for this reason we can use concentrated solar power as an input for the reactor. Many researches have been done to optimize the using of fossil fuel among them some are following below.

Antony O Onokwaia et al.[1] had constructed a solar cooker with the help of a parabolic dish type concentrator. They achieved an efficiency of around 44%. He also investigated different conditions and climatic changes and there also be more optical losses in the experiment analysis. Imhamed M. Saleh et al.[2] had used glass plates as a reflector which helps in concentrating more amount of energy at the focus point. They achieved a maximum temperature of 635°C at the focal point. These glasses play an important role in reflecting the incident radiation towards the copper tubes which carry liquid. M.Uzair et al.[3] A parametric study was conducted on a parabolic dish type receiver which shows that airflow near the receiver will also show an impact on the temperature distribution. This is due to the wind flow and these will be considered under the optical and transfer losses of the receiver. The receiver should be placed where the wind speed should be low so the losses will be minimized.

Hiba Cherif et al.[4] this study concentrates on the receiver system that should be placed on the perfect height which helps to receiver high energy which is known as a focal point of the parabolic dish. A different temperature can be achieved by varying the height at which the receiver is placed. Ahmed M. Daabo et al.[5] The study concentrates on the optical efficiency as well as the flux distribution of the three different geometries: cylindrical, conical and spherical, of a cavity receiver, to analyze their behaviour using an advanced ray-tracing method. The results of this study have shown that there is a connection between the flux distribution on the internal surfaces of the cavities and their optical efficiency.

Vanita Thakkar et al. [6] This study gives us a complete understanding of using the solar concentrating technology to use as a heat input for the industries and some companies which help for the less use of fossil fuels which cause pollution and using of renewable energy will be increased. R.H.Bogaard et al [7] had analyzed different materials that are conducting the heat more rapidly than the other materials. Among the stainless steel is conducting more heat through it than the other materials. There are several different they of ss present in the market according to its chromium composition. We need to select according to our application process.

Yong Shuai et al.[8] had done a performance analysis on the ray tracing on the parabolic dish type concentrator. Tracking plays an important role in the solar concentrators which helps in keeps the focal point stable. Thirunavukkarasu Venkatachalam et al. [9] Had done an experimental study on the conical cavity receiver with different aspect ratios. Energy efficiency and overall heat loss factor of the receiver is evaluated and compared. Y.P.Chauhan et al [10] In this study they used plastic waste as the feed for the pyrolysis process to get oil from it. This is mainly focused on recycling plastic and to decrease pollution. Here they used coal fly ash as a catalyst that is used to increases the temperature inside the reactor. This is a low-cost catalyst and very effective in increasing the temperature.

3. Experimental setup and methodology

The main parts of this setup are the parabolic dish and the reactor.

3.1 Parabolic dish

The parabolic dish is a movable and manual tracking (two-axis tracking) is to be done. The schematic layout of the dish is exposed in figure 1 below. The diameter of the collector is 1.4m (118cm) with a depth of 0.28m (28cm). Aluminium tin foil sheet are the reflector material which is placed on a reflected surface. The focal length of the collector in the system is 0.58m (58cm). The area of the dish is 1.5m², with a rim angle of 81°and is defined as the ratio of focal length to aperture diameter and focal length of 0.58m .the parabolic dish has a holder to hold to Receiver. The stand is used to hold on a dish with a height of 0.75m (75cm).
Figure 1. Schematic layout of parabolic dish.

| Diameter       | 1.4m |
|----------------|------|
| Depth          | 0.28m|
| Area           | 1.5m²|
| Rim angle      | 81°  |
| Focal length   | 0.58m|

Table 1. Dimensions of the parabolic dish.

The dish is consisting of six individual leaf's which can be combined with nuts and bolts to form a parabolic dish type structure the single leaf is as shown below. By arranging this, the parabolic dish will be formed and rigidly fixed. For reflecting purpose aluminium foil tape is used which has a good reflecting index. That reflects the amount of energy that falls on the surface.

Figure 2. Leaf of the parabolic dish.
Figure 3. Parabolic dish after foil is attached.
3.2 Reactor
Stainless steel material sheet is cut into required dimensions and with the help of a welding conical shape reactor is made. The reactor with a base diameter 260mm, the upper diameter 130mm and a height of 450mm. The total volume of the cone is 13.9 cm³. Inside the reactor we should place some spaceman by which we are extracting the gas. So we should try to make a compact shape. One holding stand should be done for the reactor in such a way that it should perfectly sit in the stand and grab the incoming radiation from the concentrator. The type of welding used is TIG welding is also known as tungsten inert gas welding this is a high electric arc welding which holds the material very tightly. This is also known as gas tungsten arc welding.

![Final appearance of the reactor](image)

**Fig 4** Final appearance of the reactor.

3.3 Methodology and layout

![Schematic representation of experimental setup layout](image)

**Figure 5.** Schematic representation of experimental setup layout.
The layout of the experimental setup will be arranged as shown in above figure, where the conical reactor \(a\) fabricated for analysis is placed at the focal point of the parabolic dish concentrator \(b\) to get the maximum radiation concentrated to convert as heat energy in order to satisfy the thermal input for reactor application which is aligning towards the best possible direction of grasping sun’s radiation facing in south as experiment is carrying in Northern hemisphere. And the whole assembled apparatus is placed on the dish stand \(f\) which has a provision of wheels for better mobility. On the other hand, the duct \(e\) is connected to the reactor output which help is carrying the hot gas after the processing in reactor using solar concentrator’s radiation input towards the collector\(d\) which uses to collect the final output of oil after the condensing at condenser\(c\) provided in between as shown in the above figure.

**Figure 6.** Final setup under sunlight.

### 3.4 specimen

In this experiment leaves are taken as feed for the reactor and waste plastic is also used for the pyrolysis process comparing both the specimens’ plastic is the burns in low temperature compared with the leaves. These leaves are dried in the sunlight then the moisture present in it will evaporate. So it is easy to make the pyrolysis process. And coal fly ash is used as a catalyst inside the reactor which will help to increases the temperature distribution inside the reactor.

**Figure 7.** leafs dried in sunlight.
4. Results and discussion

![Radiation data graph when catalyst is not used.](image1)

**Figure 8.** Radiation data graph when catalyst is not used.

![Radiation data graph when catalyst is used.](image2)

**Figure 9.** Radiation data graph when catalyst is used.

The above data of radiation is recorded with the help of a pyranometer. These readings show that the different radiation readings which are global radiation and diffused radiation. The more the radiation the temperature will also increase with it and on an average of 600 w/m$^2$ to 700 w/m$^2$ is receiving on a clear sunny day and there is also change to increase in radiation during the summer season.
The temperature that reached is 100°C without catalyst and 110°C with catalyst there is a 10% increase in the temperature distribution inside the reactor. Which is also not suitable for the pyrolysis process. So the temperature can be increased by increasing the area of the concentrator which helps to grab more amount of sun's radiation.
To reach the required temperature the experiment is conducted with the help of Scheffler dish and temperature readings are taken and it reached up to 250°C and which is useful for the pyrolysis process. And the temperature will also vary according to the radiation.

As shown in the above figure the output comes at temperature above 200°C and by using good catalyst in the reactor. And the temperature distribution inside the reactor should be in a linear manner.

5. Conclusion
Based on the above experimental analysis the following can be concluded:
Conical shape reactor helps for effective distribution inside the reactor as compared with the other shapes of the reactor which may differ from 20% to 30% according to the literature.

The heat in the form of radiation from the concentrator will reach the reactor bottom and through the conduction process the temperature will pass through the walls of the reactor and the temperature inside the reactor is increased.

There is a variation of 10% of the increase in temperature with and without a catalyst. The temperature without catalyst reaches around 100°C. And on the other hand the temperature with catalyst reaches around 110°C.

Low-temperature grade biowaste such as food, plastic, etc can be used with the parabolic dish type concentrator.

Leaves required more temperature as compared with the other type of specimens.

Tracking is also important parameter to reach the temperature that required for the pyrolysis process.

Solar radiation is not constant throughout the day so we need to use the radiation when it is available.

This study has high scope in the usage of solar energy in the future. For the pyrolysis process if some part is used with the solar and the remaining part can be supplied with the traditional fuel then it has more efficiency and low usage of fuel. Further analysis is continued by varying the orientation and specimen.

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