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A Study of Pyrolysis On Biomass Using Solar Energy

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Abstract

Bio-fuel production by pyrolysis process is now an established process. Many of the projects are being run all over the world. Normally, for regular pyrolysis external biomass heater which uses coal is used as heating source to enable the gasification of the biomass in the reactor. The By- products of the pyrolysis process viz. 'Bio char, Bio-oil and Syngas can be used for various applications in regarding sectors. The potential alternative for conventional pyrolysis is SOLAR PYROLYSIS OF BIOMASS'. The aforesaid topic comprises of the combination and concentration of energy possessed by biomass and solar radiations to generate the bio-fuel which is direct substitute for fossil fuels and natural gases.

Keywords: Bio-fuel, solar radiation flux, solar collector.

1. Introduction

In 21st century, energy crisis has made many renewable energy alternatives to contribute in total energy consumption per capita. All renewable sources possess energy which is available in decentralized form. The need of the century is to develop combined and concentrated form of renewable energy which can be utilized as direct substitute for conventional fuels. The aforesaid topic comprises of the concentration of energy possessed by biomass and solar radiations to generate the bio-fuel which is direct substitute for fossil fuel and natural gases.

There are several methods available for energy production from biomass which stretches from direct burning to more complex processes including gasification or pyrolysis. Among the thermo-chemical conversion processes, pyrolysis has become increasingly popular due to the fact it gives products of better quality compared to any other thermo- chemical processes for biomass conversion.

2. Solar Alternative: The Concept

Solar energy is a very large, inexhaustible source of energy. The power from the sun intercepted by the earth is approximately 1.8 x 1011 MW which is many thousands of times larger than the present consumption rate on the earth of all commercial energy sources. Thus, in principle, solar energy could supply all the present and future energy needs of the world on continuing basis. This makes it one of the most promising candidates of unconventional energy sources. In addition to its size, solar energy has two more factors in its favors. First unlike fossil fuels and nuclear power, it is an environmentally clean source of energy. Second it is free and available in adequate quantities in almost all parts of the world where people live.

Solar radiation flux is sometimes reported in Langleys per hour or per day (1 Langley = 1 Cal/cm2 = 1.163 x 10-2 kWh/m2).The unit 'Langley' has been adopted in honor of Samuel Langley who made the first measurement of the spectral distribution of the sun. It is observed that the annual average daily diffused radiation received over the whole country is around 175 Langley per day. The maximum values measured over the whole country are about 300 Langleys per day in Gujarat in July, while minimum values, between 75 and

100 Langley per day, are measured over many parts of the country during November and December as winter sets in.

This observation clears that solar energy can be utilized for pyrolysis process all around the country efficiently. Appropriate arrangement and design can utilize this solar energy for the process of pyrolysis. Even the solar energy has the potential to fulfil the requisites for Fast Pyrolysis.

Utilizing both the renewable energy sources in combination is a win-win situation and reducing the pollution caused by external biomass heater.

3. Solar Collector

In order to achieve higher concentration ratios and

temperatures, it becomes necessary to have point focusing rather than having line focusing or just a flat plate collector. Paraboloid dish collectors are the point focusing collectors. Such collectors can have concentration ratios ranging from100 to a few thousand and have yielded temperatures up to

2000ºC.However ,from the point of view of the mechanical design, there are limitations to the size of the concentrator and hence, the amount of energy which can be collected by one dish. Commercial versions have been built with dish diameters up to 17m. SK14 is the available Paraboloid dish collector in the market having aperture diameter of 1.4 m.

4. Experimental Set Up

In order to carry out solar pyrolysis on pine wood dust set up is designed. It consists following components.

i) SK14 collector

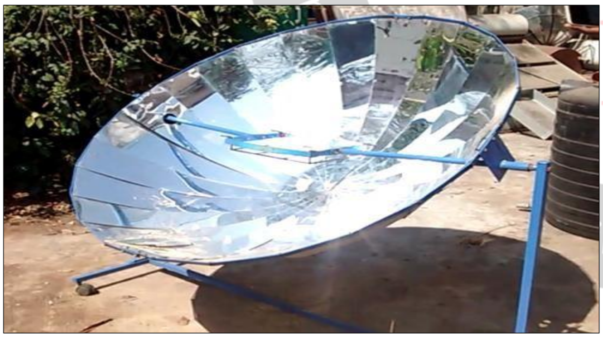
ii) Reactor

iii) Temprature sensors

iv) Biomass

i) Sk-14 Paraboloid Dish Collector

SK-14 parabolic concentrator SK 14 is a solar concentrator developed by Dr. Ing Dieter Siefert. Itis a concentrating type parabolic dish useful for households and small establishments. A typical dish has an aperture diameter of 1.4 meter and focal length 0.28 meter. The reflecting material used for fabrication is anodized aluminum sheet which has a reflectivity of over 80%. The tracking is manual and thus has to be adjusted in 15 to 20 minutes time. It has a delivering power of about 0.4 kW which can boil 2 to 3 liters of water in half an hour. The temperature achieved at the bottom of the vessel could be around 2000C to 3000 C which is sufficient for roasting, frying and boiling. The cost of the one may vary from Rs. 3,000 to Rs. 5,000 depending on the type of reflectors used and the salient features provided by the manufacturers.



Solar SK14 Collector

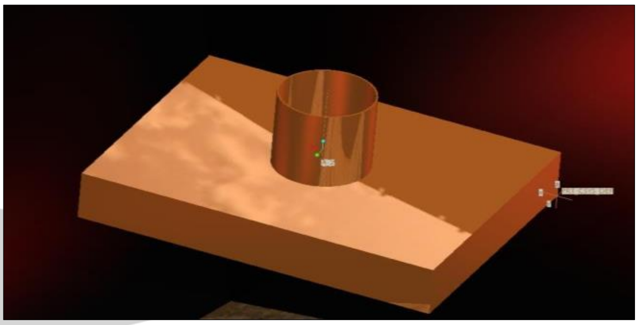
ii) Reactor

The Reactor is the portion of the solar pyrolysis unit that stores the biomass, absorbs the concentrated light, and heats the biomass.

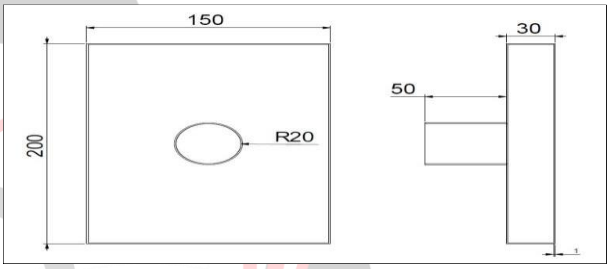
On the focal point of the SK14 collector, cubiodal reactor is manufactured and the rectangular area of 150 x 200 mm2 is always kept in contact with solar radiations .The increase in thickness of reactor causes insulating to layer of bio-char to form and thus further reducing the heat transfer. Hence the thickness of the cuboidal box is optimized on the ANSYS by thermal analysis. It is checked that all the heat received is totally distributed to biomass at every single point in reactor. The optimized thickness comes out to be 30 mm.

a)Reactor design

Design part for reactor includes deciding the shape and size of reactor .Initially, the cylindrical reactor was chosen for analysis but results were not as expected. So, the cuboidal shape (150*200*30) was selected and was analyzed using ANSYS WORKBENCH.

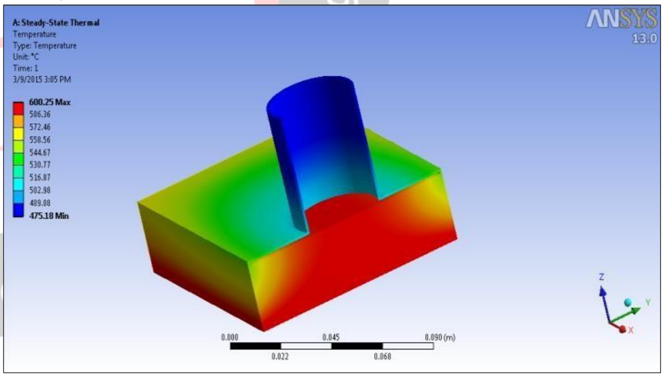


3D Model of Copper reactor

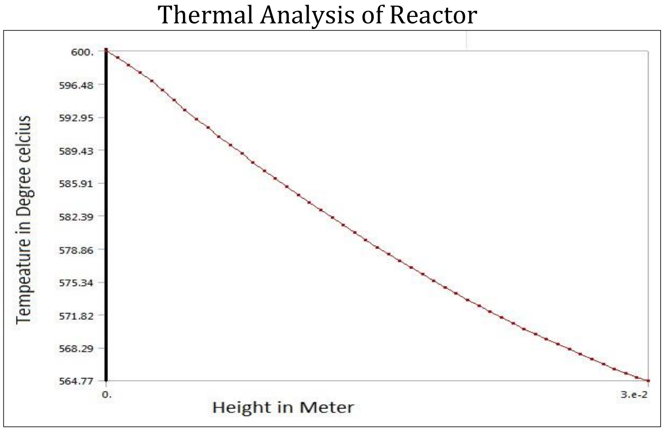


2D Drafting of reactor

Figure shows Pro-e Model of reactor and 2D drafting of reactor.



Thermal Analysis of Reactor



Graph of Height Vs. Temprature

Figure shows thermal analysis result of reactor in Ansys. The temperature of reactor and biomass varies from600ºC to 564.77ºC from bottom to Top which clears that this reactor is good enough to carry out pyrolysis. Graph shows the temperature distribution along the height of reactor at cross-section at mid plane.

b) Material selection

Material properties are extremely important as a parameter in design. In particular, thermal conductivity and heat capacity are important properties directly affecting the process of pyrolysis.

Material used for reactor is copper. It is used in many heating applications because it doesn't corrode and has a high melting point.(1085ºC)

Considering the cost factor copper is more preferable than silver. The only other material that has similar resistance to corrosion is stainless steel. However, its thermal conductivity is 30 times worse than copper's.

Table no.1 Material Properties

Metal	Thermal conductivity	
	(Btu/(hr-ft-F))	(W/(m•K))
Silver	247.87	429
Copper	231	399
Gold	183	316
Aluminium	136	235
Yellow brass	69.33	120
Cast iron	46.33	80.1
Stainless steel	8.1	14

Table No.1 shows thermal conductivity of varies materials.

c) Thickness

The thickness of the reactor is taken as 1 mm for copper sheet. Design for manufacturability (DFM) is used for thickness selection. The standard thickness available in the market for copper sheets is 0.4mm, 0.5mm, 0.8mm , 1mm, 2mm and so on. The Brazing ability reduces with reducing thickness. Also cost goes on increasing as thickness increases. Taking the above considerations, 0.8 mm cannot be used for brazing thus 1 mm thickness is chosen as it minimum possible thickness which can be brazed.

iii) Temperature Sensor

Temperature sensor used is thermocouple (K-type).Type K (chromel–alumel) is the most common general purpose thermocouple with a sensitivity of approximately 41 µV/°. It is inexpensive, and a wide variety of probes are available in its −200 °C to +1350 °C range. The maximum temperature using Solar Paraboloid dish collector SK14 is 700°C .Thus K type is chosen.

iv)Biomass Used

Biomass used for trial is pine wood dust. It has highest volatile matter in it which is suitable for trial with limitation of size on SK14 collector. The following table shows the contents of biomass available:

Table no.2Biomass Properties

Sample	Air Dried Moisture (%)	Ash (%)	Volatile Matter (%)	Fixed Carbon (%)	Gross Calorific Value (%)
Shredded Green waste	6.1	1.0	77.6	15.3	18.12
Pine Chips	4.4	13.8	16.0	65.80	26.59
Wood	20	0.4	82	17	-
Birch	18.9	0.004	-	20	-

5. Experiment Procedure

The system works by using sunlight available during 60% of the year, to heat the biomass in a closed container, at near 500°C. This turns the biomass into charcoal, which can be used in a number of stoves, particularly the newly popular Toyola stove which reduces charcoal required and smoke released.

The proposed system for solar pyrolysis should be used as per the following procedure:

1) Biomass is chopped and crushed into fine piece of size 2mm to 4 mm.

2) It is dried in open atmosphere under sunlight for couple of hours on previous day.

3) Then it is filled in the reactor made up of copper with outer surface painted black .Reactor is completely dry from inside.

4) Measured quantity of biomass is rammed in the reactor and air tight cork is placed at the top.

5) Thermocouples are placed in their position.

6) Reflecting surfaces of SK14 are inspected whether they are clean.

7) Around 9 am to 9.15 am reactor is placed at the focus point of SK14.

8) Proper tracking of the dish is done manually.

9) Initial temperature is measured and thereafter for each 15 temperature readings are noted.

10) Solar radiations are measured by sun meter during the trial.

11) Provision is made for collection of gas outlet, which is connected to gas analyzer.

12)After the sunset or 5 pm biomass is removed and analyzed.

6.Conclusion

Solar Pyrolysis of biomass is novel solution for clean energy generation. Pyrolysis of biomass can be carried out solely on concentrated solar energy. With the help of recent technologies even the fast pyrolysis is possible.

Thermal analysis is done on the designed reactor to study the temperature distribution inside reactor. The temperature variation in the reactor is within the range564.77°C to 600°C. The optimized cuboidal reactor with 30 mm thickness can be used with solar energy rather than conventional fossil fuels which will generate yields in the form of Bio-Char, Bio-Oil and Syngas.

7. Future Scope

The above topic can be further expanded by optimizing reactor design in order to have less time for the process to get better product yields. Also simulating the process by standard software can give exact outcomes obtained from the process and finally to improve the efficiency of the process.

8.Acknowledgement

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