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Design and Development of Concentrated Solar Collector with Thermal Storage

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***Abstract*--- In present world as we notice increasing demand of Fossil Fuel and its adverse effect on increasing Global Warming, has caused many risks to Mankind. For Sustainable Development and to reduce risks to Human Being an alternative is important. Natural resources are one of those Alternatives. As we Know Solar energy is abundant in nature and can be used for Industrial needs like Thermal energy creation. So, It has been proposed with the idea of Concentrated Solar Collector with Thermal Storage. One such Concept for using solar energy is Concentrated Solar Power. Solar energy is concentrated with the help of reflectors at a point where maximum energy can be extracted. In this project a Parabolic dish is used a reflector. At the Focal point where maximum energy is concentrated, a collector is placed. Here the collector is a vessel with a inlet and outlet for continuous flow of fluid used. The Fluid in vessel is Molten Salt which is used for thermal storage. Thermal Storage helps the use of Thermal energy in non-sunny days. A motorized setup helps this setup to follow sun and have more efficiency. As this setup uses Natural resource for Creation of Thermal Energy, it can be an alternative and used for many other Industrial purposes.**

***Index Terms*— Concentrated Solar Power, Thermal Storage, Solar Collector, Thermal Energy, Parabolic Dish**

I. INTRODUCTION

In present world of industrialization more and more use Fossil fuels have it necessary to find an alternate to preserve this mankind from adverse effects. Natural resources are one such alternative, among which is solar energy which is abundant in nature. *Concentrated solar power* is a technique through which solar energy can be used to make thermal energy for industrial and domestic use. CSP plants were predicted to produce a global electricity contribution of 7% by the year 2030 and 25% by the year 2050, and could meet up to 6% of the world's power demand by 2030 and 12% by 2050, according to the prediction of the European Solar Thermal Power Association. The project of Concentrated Solar Collector with Thermal Storage uses this concept to create thermal energy using solar power. To have more efficiency parabolic dish with a *motorised stand setup* is used. Solar thermal power plants can produce 24 h/day very stable power levels to the grid such as all kinds of other thermal power plants. This is the case of Gemasolar (Spain 2011) or Crescent dune (USA 2015) solar power plants implemented recently which are able, thanks to 15 h of TES capacity, to produce 20 and 110 MW of constant power to the grid, respectively. But one such drawback which comes while using solar power is its availability in non-sunny seasons. To eliminate this Molten salt as fluid is used for the purpose of *Thermal Storage* which can store the thermal energy for future use. This ability to store solar energy makes CSP a flexible and dispatch able source of renewable energy. Additionally, for instance, one megawatt of installed CSP avoids the emission of 688 tons per year of CO2 compared to a combined cycle system, and 1360 tons per year of CO2 compared to a coal/steam cycle power plant. One square mirror in the solar field produces 400 kWh of electricity per year, avoids 12 tons of CO2 emission, and contributes to 2.5 tons savings of fossil fuels during 25-year operation lifetime. Overall, the whole setup can be used to fulfil many industrial and domestic needs.

II. ADVANTAGES AND APPLICATIONS

- Advantages
  1. Use of natural resource (Solar energy)
  2. Thermal energy without use of fossil fuels
  3. Less maintenance
  4. Thermal Energy Storage for non-sunny seasons
  5. More efficiency with help of motorized setup (Sun follower)
- Applications
  1. In Industries where Thermal Energy is required.
  2. In Domestic purpose like heating water.
  3. Can be used to generate electricity as well.

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III. SCHEMATIC DIAGRAM OF SETUP

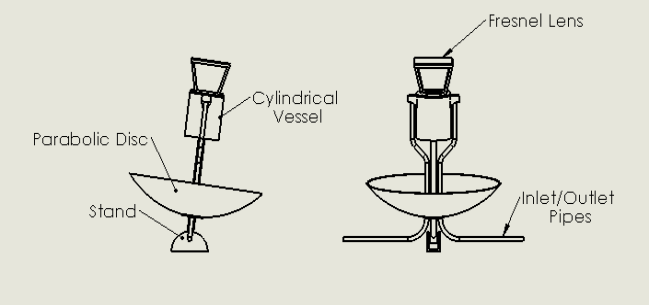

Figure 1: Setup with labelled components

Fig.1 shows the whole Setup of the project. The setup mainly uses the concept of Concentrated Solar Power (CSP). It consists of a Parabolic dish as a reflector which ensures concentration of sun rays to concentrated at a point. A vessel is held at the focal height of the dish with help of a static rod. Inlet and outlet pipes connected at inlet and outlet ports of vessel accompany the flow to fluid i.e., Molten salt. At the top of vessel, a Fresnel lens is held which concentrates sun energy at the led of vessel which ensures maximum energy is concentrated at the vessel. This whole setup rests on a stand which is motorized with a build in light sensor which gives the setup freedom to move at different angles according to the suns path.

IV. COMPONENTS/MATERIAL USED

1. Parabolic Dish

A parabolic dish as a reflector is used in the setup. The spherical diameter of dish is 0.8m with thickness of 0.5 X 10^{-2} m. The material used is Aluminium as it is light in weight and highly reflective. The Focal Point of dish is the point where all the rays are concentrated. Use of parabolic Dish ensures more efficiency as compared to circular Fresnel arrangement setups. This Also ensures no escape of sun rays.

2. Cylindrical Vessel

A cylindrical vessel with both Inlet and Outlet ports for Fluid is used a collector. Its outer Diameter is 0.15m with thickness of 0.4 X 10^{-2} m and height 0.18m. Material Used for this is Cast Iron which is good conductor of heat and a good absorption coefficient. It is covered by a Cap of same material for proper enclosure. A rod of length 0.18m holds it at the centre. This rod keeps it at the focal height of the dish to ensure maximum energy is absorbed it is anodised which makes it black in appearance.

3. Fresnel lens

Fresnel Lens has a good magnification which can concentrate solar rays at a point. It is measured as 0.17m X 0.17m (square in shape). It is held above the vessel cap to Concentrate energy at the top portion. This ensures maximum energy is concentrated which in return will decrease the time of heating.

4. Pipe

For the continuous flow of fluid, Hollow Pipes of outer diameter as 0.017m and thickness of 0.2 X 10^{-2} m pipes are used for Inlet and Outlet >These are connected to the inlet and outlet ports of vessel. These are made of copper alloy with good conductive properties.

5. Molten Salt

Molten Salt which can retain thermal energy for sufficient time period, is used for the purpose of Thermal Storage. This will be further stored in an insulated enclosure for future use. Molten salt being fluid in nature can be circulated through the setup. A DC pump of 0.04 HP is used to circulate the fluid.

6. Stand

A stand with inbuild light sensor and motorised setup allows the whole setup to follow the sun during the day period. This will give the setup a feasible movement as per the sun path.

7. Pump

A small DC pump of 0.04HP will be used near the inlet to pump the fluid through the setup. It has the flow rate of 2.4L/min.

V. WORKING

Using the concept of *concentrated solar power*, the sun rays are made to incident on the Parabolic Dish Reflector. The reflector reflects and concentrates the solar energy at a point. At this point a vessel is held which absorbs the energy. This energy is then conducted by the vessel inside it. A fluid which is molten salt here is pumped in through inlet port in the vessel at regular intervals by a small pump. The fluid absorbs the thermal energy conducted by vessel and after attaining a certain temperature it is made to escape through the output port. This fluid is then further stored for future use in an insulated closure. This process goes on throughout the day with this setup. The stand with motorized setup and light sensor helps the whole setup to follow the sun throughout the day with 180 degree moment. In this way the solar energy is used to generate Thermal energy and store it for future use.

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VI. DESIGN AND ANALYSIS

1. 3D Design of components and setup:

With the help of Solid works 2019 Components of setup were designed and assembled. The 3d Model was then rendered which include whole Setup (Fig.2) and the components of setup (Fig. 2(a), Fig. 2(b) and Fig. 2(c)).

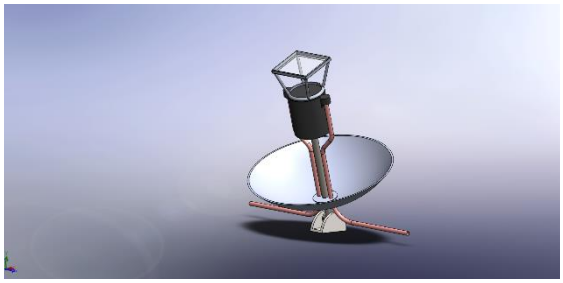

Figure 2: Setup Assembly

Figure 2(a): Cylindrical Vessel

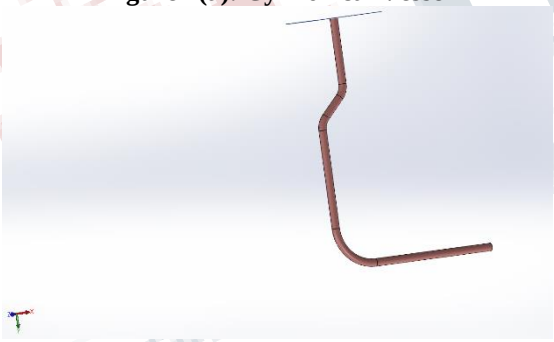

Figure 2(b): Pipe

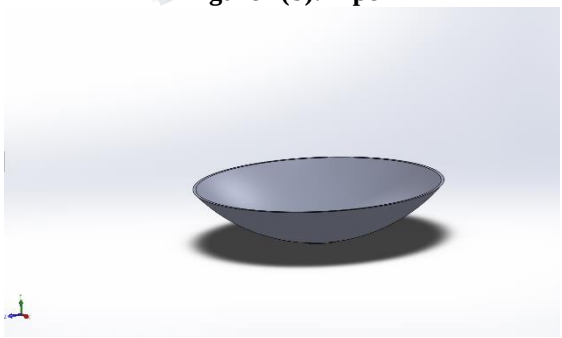

Figure 2(c): Parabolic Dish

2. Thermal Analysis:

To analyze the temperature distribution of the components, Thermal analysis of has been done with the help of Solid works 2019 simulation add-in. It was then rendered which include temperature distribution of Parabolic dish (Fig3(a)) and Vessel (Fig(b)).

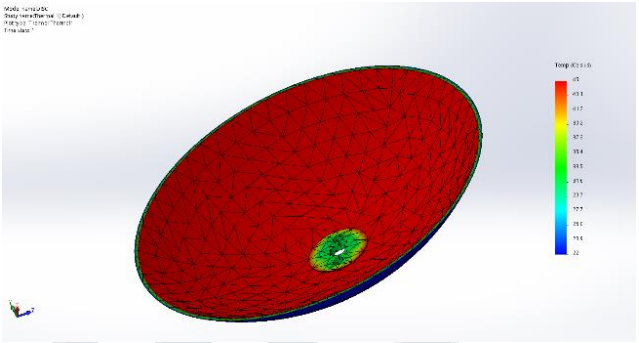

Figure 3(a): Thermal analysis of parabolic dish

Fig 3(a) shows the temperature distribution at parabolic dish in the scale from lowest at 22°C to highest at 45°C.The temperature of the energy incident on the parabolic dish was considered as high as 45°C considering the summer sun rays temp and the initial temperature of dish was considered as 22°C as the room temperature.

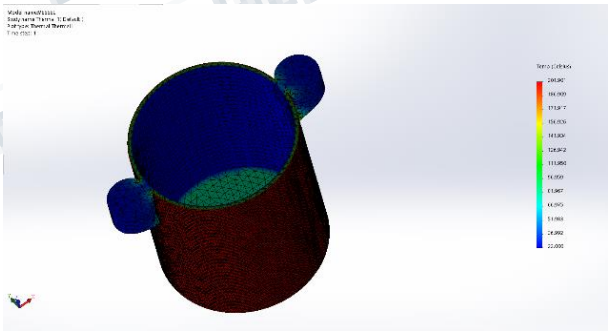

Figure 3(b): Thermal analysis of Vessel

Fig 3(b) shows the temperature distribution at the vessel in the scale from lowest at 22°C to highest at 201°C. The temperature at the outer surface vessel is considered to reach 201°C after a time interval and the inner wall is considered to have the room temperature of 22°C. The maximum temperature considered is after the absorption of heat energy reflected by the disc after a time interval for standard calculation.

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VII. CALCULATIONS

1. Heat energy reflected by Aluminium Disc

Formula: -

[Energy incident - Energy absorbed – Energy transmitted = Energy reflected]

Known Data: -

$E_{incident}$ =1050W/m^2,

Coeff.$_{absorption}$=0.27,

Coeff.$_{transmission}$=0.06, S.A. =0.8 m^2

Solution: -

As we know;

Energy incident by sun = 1050W/m^2

Coefficient of absorption of Aluminium = 0.27

Coefficient of transmission of Aluminium = 0.06

∴ By Formula;

Energy Reflected = 1050-(0.27*1050) -(0.06*1050)

Energy Reflected = **703.5W/m^2**

2. Heat required for water to reach 200°C

Formula: -

[Q=mcΔT] = [Q=mc (T_{final}-$T_{initial}$)]

Known Data: -

m=3 L, c=4184, T_{final} =200°C, T_{intial} =22°C

Solution: -

∴ Q=3*4184(200°-22°)

∴ Q =**2234.25 KJ**

3. Heat Conduction by vessel (Cast Iron)

Formula: -

$[Q = \frac{KA(T_{hot} - T_{cold})}{d}]$

Known Data: -

K=237, A=0.08m^2, T_{hot} =200°C, Tcold ==22°C

Solution: -

∴ Q = $\frac{237*0.08(200°-22°)}{0.004}$

∴ Q = **843.72KJ**

4. Time required to heat water

Formula: -

$[t = \frac{Q}{P} = \frac{heat\ required\ by\ water}{energy\ reflected\ by\ disc}\ ]$

Known Data: -

Q=2234.25KJ, P=211.05

Solution: -

∴ t = $\frac{2234.25*10^3}{703.5*0.3}$ {Area of disc = 0.3m^2}

∴ t = **2.94 hours**

VIII. RESULT

Sr. No.	Experiment Calculation	Formula	Output
1	Heat energy reflected by aluminum dish	P= ($E_{incident}$ – $E_{absorbed}$ – $E_{transmitted}$)*S.A.	**211.05 W**
2	Heat required for water to reach 200°C	Q = mc (T_{final} - T_{intial})	**2234.25 KJ**
3	Heat conducted by Vessel	$Q = \frac{KA(T_{hot} - T_{cold})}{d}$	**843.72 KJ**
4	Time Required to heat fluid (water)	t=Q/P	**2.95 hrs.**

IX. CONCLUSION

A Concentrated Solar Collector with Thermal Storage is a setup to use solar energy to make thermal energy. Also, for other non-sunny seasons Thermal Storage is done in this setup with help of molten salt. This setup can be used for both Industrial as well as domestic purposes. This way of thermal energy creation and storage can save lots of Fossil fuels and preserve the Adverse effect on environment.

X. FUTURE SCOPE

One of our future scope is that we are using the heat absorbed and stored for pasteurization of milk. Pasteurization makes sure milk is safe to drink (by killing any bacteria) and also helps to prolong its shelf life. The process of pasteurization involves heating milk to 71.7°C for at least 15 seconds (and no more than 25 seconds). There are many ancient techniques where fuel like coal, Diesel etc are used for pasteurization (For Steam generation). But if we substitute this ancient technique with our process then amount of fuel saved will approx. for (1000 L of milk) as Coal required for Pasteurization of 1000L of milk is 3.05 Kg and Diesel required is 2.23 kg. All this amount of fuel will be saved as we are using natural resources for pasteurization of milk.

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