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Design and Optimisation of Solar Thermal Organic Rankine Power Cycle using Parabolic Collector

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Abstract - **In the present investigation, The design and optimisation of solar thermal organic Rankine power cycle using parabolic collector has been done. Parabolic trough collector to be used such as absorber tube, glass cover and reflector surface has been designed for direct normal solar radiation. Concentration collecting device is selection for dilute form of solar energy. The studies are mainly focussed keeping in view the objective like design of parabolic trough collector for Patna city (Bihar), selection of the working fluid to be used the organic Rankine cycle (ORC) and the design and optimisation of organic Rankine power cycle. Working fluid n-Pentane which has suitable thermodynamic properties and Eco-friendly has been selected here and used. From the studies carried out it has been formed that n-pentane ORC have batter performance in the temperature ranging from 60^{0}C to 90^{0}C. The ORC is optimised at a constant condenser temperature of 35^{0}C and the evaporator temperature was varied from 65^{0}C to 95^{0}C. The maximum efficiency of the cycle was formed to be 4.10% at saturation and 4.76% when evaporator temperature is superheated.**

1. INTRODUCTION

The parabolic collector device is large amount of thermal energy source, the optimization power of the organic rankine cycle at the heat source parabolic trough collector. Cylindrical parabolic trough collector has been designed for the Patna city. Parabolic trough power plants use parabolic trough collectors to concentrate the direct normal solar radiation on a tubular receiver. Large collector fields supply the thermal energy, which is used to organic rankine cycle via the counter flow heat exchanger. The working fluid used is n-pentane. The selection of working fluid suitable for the ORC has been done[1]

2. DESIGN OF PARABOLIC TROUGH COLLECTOR.

2.1-Solar Radiation Geometry;-

The latitude φ of a location is the made of angle by the radial line joining the location to the centre of the earth. The slope angle β made by the plane surface with the horizontal axis. The declination angle δ is the made by the line joining the centre of the sun. The declination angle varies from the maximum value and minimum value depend the time condition, the maximum value of +23.45^{0}on 21 June and minimum value of – 23.45^0 on 21 December.

δ (in degrees) =23.45sin[$\frac{360}{365}$(284+n)]……….(2.1.1)

Where n is the number of day in the year.

The hour angle ω is an angular measurement of time and is the equivalent to 15^0 per hour. The hour angle also varies to +180^0 to -180^0 the time measuring it from noon based on local apparent time (LAT).the positive value at morning time and negative value at evening time.

It can be shown that the equation,

$\cos\theta = \sin\phi\,(\sin\delta\cos\beta + \cos\delta\cos\gamma\cos\omega\sin\beta) + \cos\phi\,(\cos\delta\cos\omega\cos\beta - \sin\delta\cos\gamma\sin\beta) + \cos\delta\sin\gamma\sin\omega\sin\beta$……………………………….….. (2.1.2)

Therefore the tilted factor

$r_b = \frac{\cos\theta}{\cos\theta_z}$ ……………………………….. (2.1.3)[2]

2.2-Thermal Analysis of Cylindrical Parabolic Collector

Thermal analysis may be discuss of a cylindrical parabolic collector, the thermal analysis same types of the flat plate collector an energy balance on the absorber yield following equation.

$q_u = A_s S - q_l$……………………………………. (2.2.1)

Where,

q_u= rate of useful heat gain,

A_a= effective area of the aperture of the cylindrical parabolic collector

S = Solar beam radiation per unit effective aperture area absorber

q_l=rate of heat loss from the absorber.

The similar equation of a rate of heat loss and that equation can be written in items of an overall loss coefficient.

$q_l = U_l A_p (T_{pm} - T_a)$…………………… (2.2.2)

Where U_l= overall loss coefficient

A_p= area of the absorber surface,

T_{pm}= average temperature of the absorber surface,

T_a= temperature of the surrounding air,

We combine equation,

$q_u = A_A[s - \frac{U_l}{c}(T_{pm} - T_a)]$……..... (2.2.3) [2]

2.3-Design Equation of the Collector Efficiency.

Concentration Ratio,

$$C = \frac{\text{Effective aperture area}}{\text{Absorber tube area}}$$

$$C=\frac{(W-D_o)}{\pi D_o} \text{……………………………..…..} (2.3.1)$$

Where,

C = Concentration ratio
W = the aperture width
D_0= Outer diameter of the absorber
L = length of the aperture

Parabolic Collector Efficiency Factor, (F'),

$$F' = \frac{1}{U_l\left[\frac{1}{U_l}+\frac{D_o}{D_i h_f}\right]} \text{………...………………..} (2.3.2)$$

Where F'= parabolic collector efficiency factor,
U_1 = Overall heat loss coefficient.
D_0= Outer diameter of the absorber,
h_f= heat transfer coefficient.

Collector Heat Removal Factor,(F_R),

$$F_R = \frac{m\ C_p}{\pi\ D_o\ L\ U_l}[1\text{-}\exp(-\ \frac{F'\ \pi\ D_o\ L\ U_l}{m\ C_p}\}] \text{……......} (2.3.3)$$

Thus, the useful heat gain rate

$$q_u = F_R(W - D_o)\,L\ [S - \frac{U_l}{C}(T_{fi} - T_a)\ ] \text{………....} (\ 2.3.4)$$

The collector efficiency

$$\eta = \frac{q_u}{(I_b\ r_b + I_d\ r_d\ )\,WL} \text{………………………} (2.3.5)$$

In this case of the parabolic collection only direct normal beam radiation condition following,
If the parabolic collector efficiency, than the diffuse radiation is zero

$$\eta = \frac{q_u}{(I_b\ r_b\ )\,WL} \text{………………….. } (2.3.6)\ [2]$$

Table. 2.3.1- Relationship between full day efficiency of beam irradiation & Time

Time (LAT)	Beam irradiation w/m^2	Efficiency %
07-08	641.2	29.24
08-09	707.8	31.90
09-10	752.8	33.90
10-11	828.3	35.62
11-12	760.3	35.90
12-13	817.6	35.37
13-14	800.8	34.65
14-15	738.1	33.03
15-16	668.2	30.38

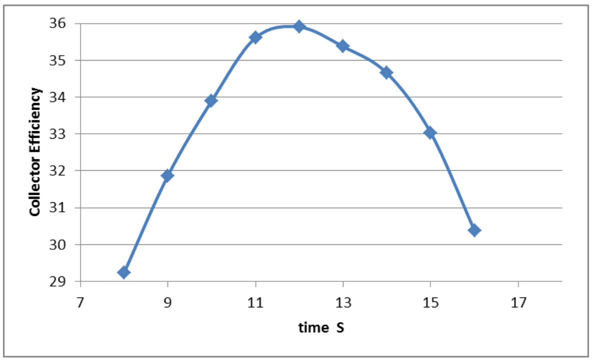

Figure.2.3.1- Collector Efficiency vs Time

3-DESIGN & OPTIMIZATION OF ORGANIC RANKINE CYCLE

1) Feed pump are working condition following the working fluid inter the feed pump to increase fluid pressure. If feed pump work produce

$$W_p = v_3\,(p_4 - p_3) \text{…………………………….....} (3.1)$$

2) The condenser are working condition following to rejected heat to the environment, it is normally to working fluid.

$$Q_{out} = m\,(h_2 - h_3) \text{…………………………….. } (3.2)$$

3) Heat exchanger to transfer heat from heat source to the following working fluid. The heat source heat is collect to the solar thermal energy collected by the parabolic trough collector. Heat received the collector,

$$Q_{in} = m\,(h_1 - h_4) \text{ ……………………………. } (3.3)$$

4) Turbine are working condition following the work conversion. Turbine work is

$$W_t = m\,(h_1 - h_2) \text{……………………………. } (3.4)$$

5) the organic rankine cycle efficiency is define as the ratio of the total work done of a system to heat supplied in the heat exchanger is called the organic rankine power cycle. It is denoted by η.

The Total work done of a system = turbine work – pump work

$$= m\,(h_1 - h_2) - v_3\,(p_4 - p_3) \text{……………… } (3.5)$$

$$\eta = \frac{\text{Work done}}{\text{heat received}} \text{………………………..…… } (3.6)$$

$$\eta_R = \frac{m\ (h_1 - h_2) - v_3\,(p_4 - p_3)}{m\ (h_1 - h_4)} \text{……………… } (3.7)$$

The pump work is very small

$$\eta_R = \frac{m\ (h_1 - h_2)}{m\ (h_1 - h_4)} = \frac{(h_1 - h_2)}{(h_1 - h_4)} \text{…………. } (3.8)\ [3]$$

The Carnot cycle Efficiency,

$$\eta_R = 1\text{--}\frac{T_1}{T_2} \text{... } (3.9)\ [4]$$

Where. T_1 = Maximum Temperature C
T_2 = Minimum Temperature C

And Overall Efficiency,

$$\eta_O = \eta_R \times \eta_{Collector} \text{……….......... } (3.10)\ [4]$$

4 - RESULT & DISCUSSION

1-Optimize organic rankine cycle the system has been optimized and following figure no.6.4 shows the depended overall ORC efficiency with respect to evaporator temperature at saturation condition, the optimize efficiency is 4.10% and 85°C

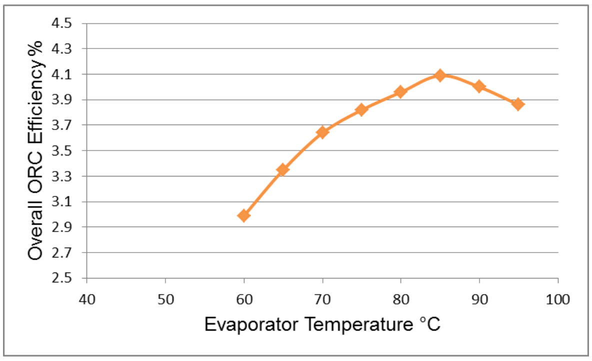

Figure.4.1 Overall ORC efficiency vs Evaporator temperature at saturation condition

2- Optimize organic rankine cycle the system has been optimized and following figure no.6.8 shows the depended overall ORC efficiency with respect to evaporator temperature at superheated condition, the optimize ORC efficiency is 4.76% and 85°C

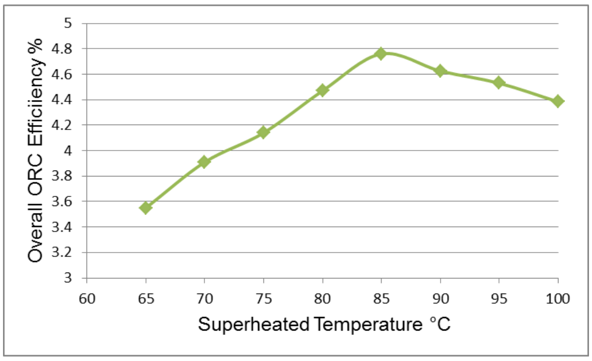

Figure.4.2.Overall ORC efficiency vs Evaporator temperature at superheated condition

5-CONCLUSION

It is observed that from design & optimization analysis of solar thermal organic rankine power cycle using parabolic trough collector. .

1. Solar energy conversation to power through ORC is feasible and commercially used also.
2. From the literature it is inferred that the challenges still exist required proper Selection of working fluid.
3. Cylindrical parabolic collector concentrating solar and storage thermal energy at a high temperature.

4 The Cylindrical parabolic collector efficiency is 46.66% at inlet fluid temperature (60°C) ORC system.

5. ORC system is optimized for a maximum efficiency of 4.10% saturation condition and for 4.76% superheated condition at a condenser temperature of 35°C and evaporator & superheated temperature of 85°C

REFERENCE

[1] Sotirios Karellas, & Andreas Schuster*(2008) Supercritical Fluid Parameters in Organic Rankine Cycle Applications. Vol. 11 (No. 3), pp. 101-108, Germany

[2] S P sukhame & J N Nayak 3rd edition (2008) Solar Energy “Principle of thermal collection and storage” Tata Megraw Hill

[3] Cheng Eng Cong, Sanjayan Velautham &Amer Nordin Darus (2005) Solar Thermal Organic Rankine Cycle as a Renewable Energy Option vol No.20,68-77

[4] P K NAG fourth edition (2008) Engineering Thermodynamic, Tata Megraw Hill

[5] http://www.mtholyoke.edu/~wang30y/csp/PTPP. Html

[6] Matthew Roesle, Volkan Coskun & Aldo Steinfeld (2011) Numerical Analysis of Heat Loss from a Parabolic Trough Absorber Tube with Active Vacuum System. Vol. 133 / 031015-1

[7] Angad Singh Panesar (2012) A study of organic Rankine cycle systems with the expansion process performed by twin screw machines, Ph.D. Thesis. City University London