Experimental Investigation of Scheffler Solar Concentrator at different Beam Radiation, Pressure and Wind Velocity in Open Environment

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Abstract: In this paper, thermal performance analysis of 16 m^2 scheffler solar concentrator having diameter 0.5 m of plane receiver has been carried out in actual open environment. This study examines experimentally the receiver heat, receiver temperature, convective heat loss, radiative heat loss, total heat loss and system efficiency at different normal beam radiation over the day of different months from a plain receiver. This study also examines experimentally The super heated temperature, rate of heat generated, and efficiency with different operating pressure. In this experimentation, the effect of different wind velocity on convective heat loss is prepared (with collar and without collar). Heat losses directly affect performance of the system. So its minimization is very important with providing proper insulation to the system and also avoiding the effect wind variation at the surface of receiver. By provide proper insulation with glass wool and avoid wind variation with providing taper collar (30^0 angle) at the periphery of receiver. With collar, it minimizes convective heat loss with variation of wind velocity and insulation reduce the total heat losses. Thermal efficiency of scheffler reflector is very less during initial heating and improve with increasing temperature. Due to this arrangement the efficiency of this system is obtain upto 47.20%. The receiver is painted black.

Keywords- Solar energy, Scheffler reflector, plain receiver, heat losses (cond, conv, rad.), thermal efficiency.

I. INTRODUCTION

The utilization of concentrated solar energy have been the subject of research and development for a number of decades. In last few years have seen success of solar concentrators worldwide, especially for cooking applications and so other applications. These include gasification, increasing the rate of evaporation of waste water, in food processing for processes like chips making, making of jiggery or sugar etc., producing drinking water from hard water and sea water, producing water above 80 degree centigrade, hot water generating systems, and steam generation in process applications in textile, chemical, food, pharmaceutical, paper, dairy and other industries. Now work is also in progress in vapor Absorption Machines (VAM).

Scheffler concentrators were initially designed and developed for the sole purpose of cooking, recently they have found their use in thermal applications with temperatures up-to 180^{o}C. The well knowledge of heat transfer in solar receivers is very important to allow better receiver design and to increase the thermal efficiencies and cost effectiveness of systems. Determination conduction, radiation and convection losses from solar receivers is the most complex, this is due to the various numerous parameters that affect heat loss, which include the large size, varying incident flux and complex geometries of the various receivers. Environmental operating conditions such as wind velocity and direction also affects on various heat losses because the receivers are open to the surrounding. Therefore the systematic analysis of experimental data the resulting observations, insights and quantitative findings are important in better understanding various heat loss from solar concentration system The experimental data in this study are also important for predictions of a number of correlations proposed in the literature and suggestions are made for development of improved correlations by examining aspects of heat loss not yet considered.

The various researchers have reported results with their laboratory studies. Paitoonsurikarn et al [9] reported a correlation based on numerical modelling of four different cavity geometries. Dasin Dahiru Yahya[3] foud out the heat losses from parabolic concentrator solar cooker. R.D.Jiltea[7], Investigate the Convective Heat Losses from Solar Cavities under Wind Conditions and inclination. *Ajay Chandak*[1] *develope* multistage evaporators for integrating with Scheffler Solar concentrators for food processing applications., Indu R. Pillai([]1),Anita A. Nene Foud out thermal efficiency scheffler concentration system.

II. SITE SELECTION

Chandwad is a town located in the Nashik district (Maharashtra), (INDIA). CHANDWAD is a hilly region area. Chandwad is situated at 20.33° North latitude, 74.25° East longitude and 858 meters elevation above the sea level. Time Zone – IST (UTC +5:30)

III. EXPERIMENTAL SETUP (DETAILS)

Fig. 3.1 Test setup

3.1 The specifications of test setup:

1) Scheffler solar concentrator disc: 16 m^2. with A_{ap} = 11.5m^2 and reflectivity=93%

2) Tracking system (PLC based): rotate 15^0/hr clock wise

3) Test Rig Arrangement
   i. Water storage tank : capacity- 35lit.
   ii. Heat receiver : d= 0.5m, €=0.91 (black painted)
   iii. Electrical calorimeter
   iv. Condenser (cross flow)

3.2 The testing equipments:

1) Anemometer: 0.4-30 m/s capacity

2) Infrared Thermometer: 0-650 ^{0}c, €=0.95

3) Solar meter (w/m^2)

4) RTD's (Temperature sensor) : 0-650 ^{0}c (platinum)

5) Electrical energy meter

6) Pressure gauge : 0-25 bar

IV. RESULTS AND DISCUSSION

4.1 Normal beam radiation over a day for different months

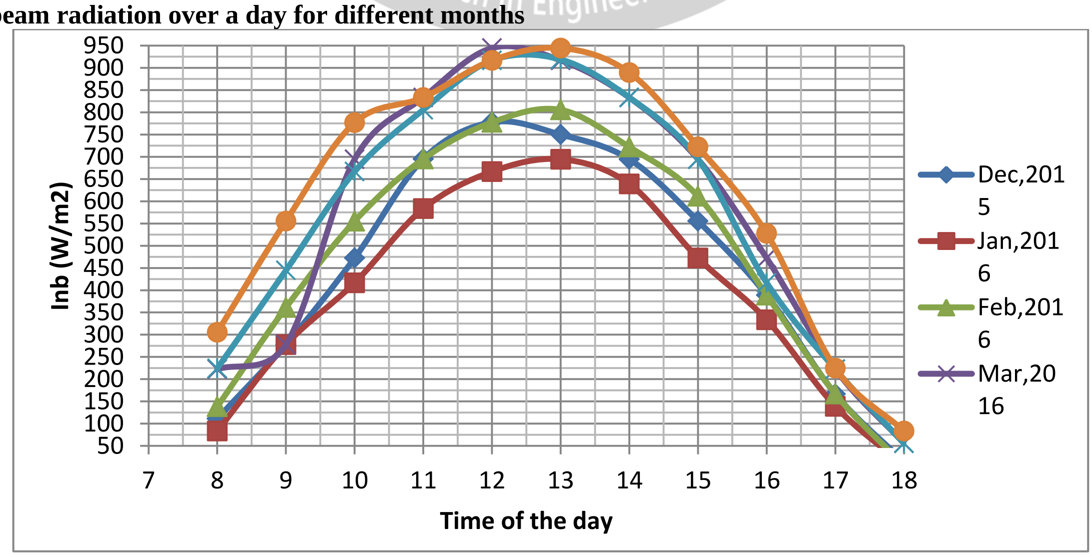


Fig.4.1 Variation of normal beam radiation with time

The various normal beam radiations over a day for different months and it is conclude that, it is vary with time of the day. It also concludes that, it is vary for different months.

4.2 Analysis for different normal beam radiation

4.2.1Receiver heat and Receiver temperature

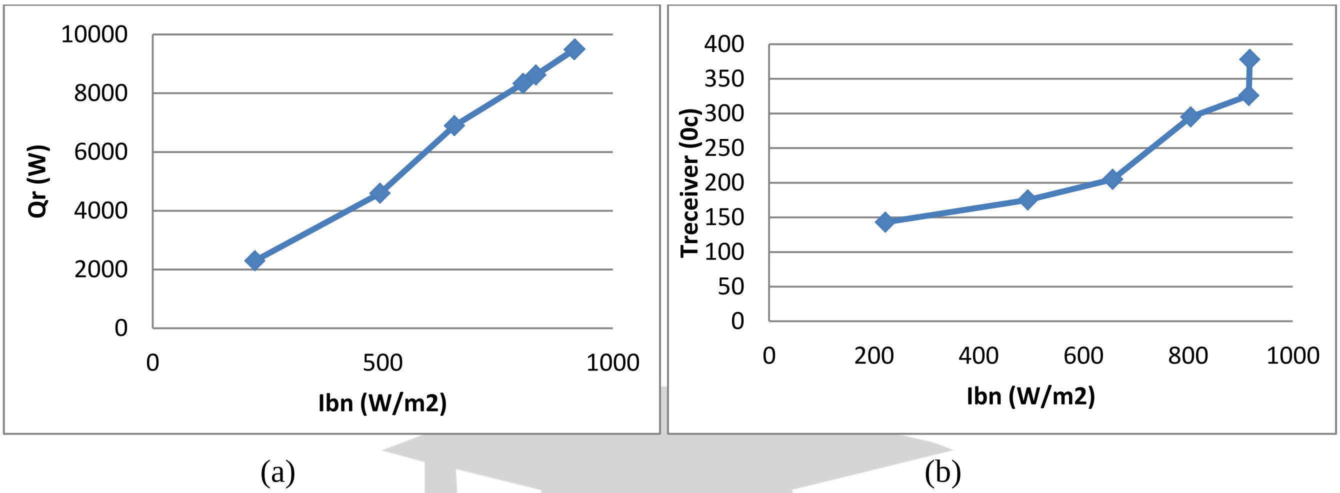


Fig. 4.2 Variation of heat incident on receiver (a) and receiver temperature (b) with normal beam radiation

Heat incident on receiver is totally depends on normal beam radiation, aperture area and reflectivity of Scheffler concentrator. It increases with increasing normal beam radiation. The receiver temperature depends on heat incidents on receiver and time followed by the test. For over a day normal beam radiation increases, it increases the temperature of receiver surface.

4. 2.2 Convective heat loss and Radiative heat loss

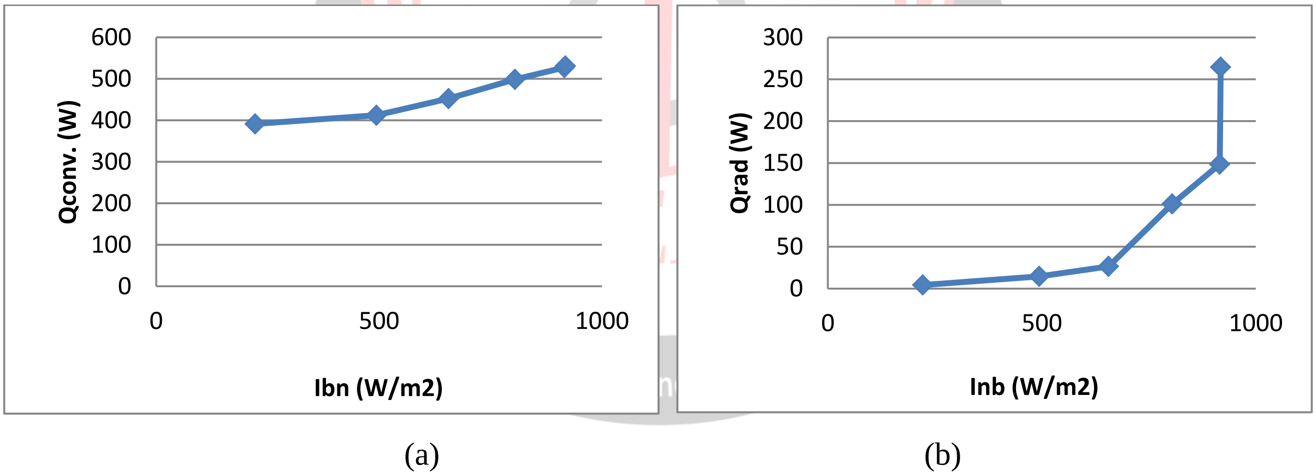
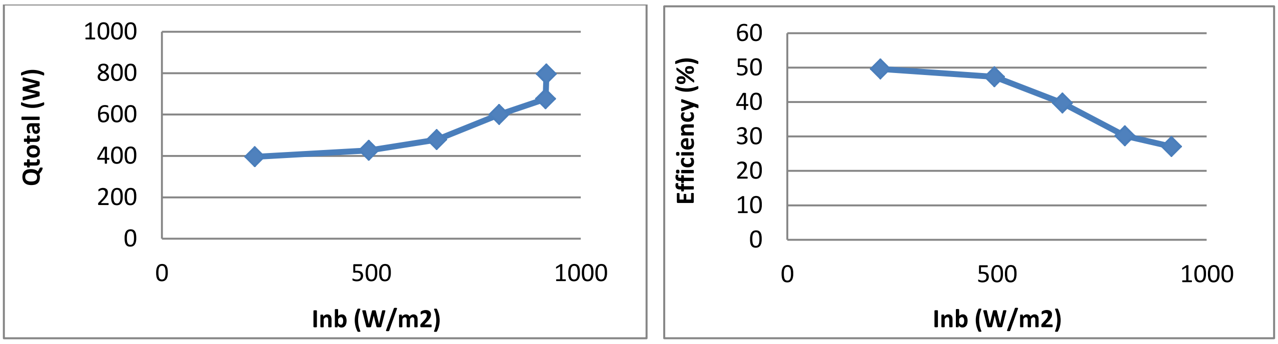


Fig.4.3 Variation of convective heat loss (a) and radiative heat loss (b) with normal beam radiation

During the experiment the measure heat loss is convective heat loss. It totally depends on receiver temperature and air velocity. Convective heat loss is measure with the help of various expressions. It is found that convective heat loss is increase with increasing the normal beam radiation over a day.

4.2.3 Total heat loss and Efficiency of system



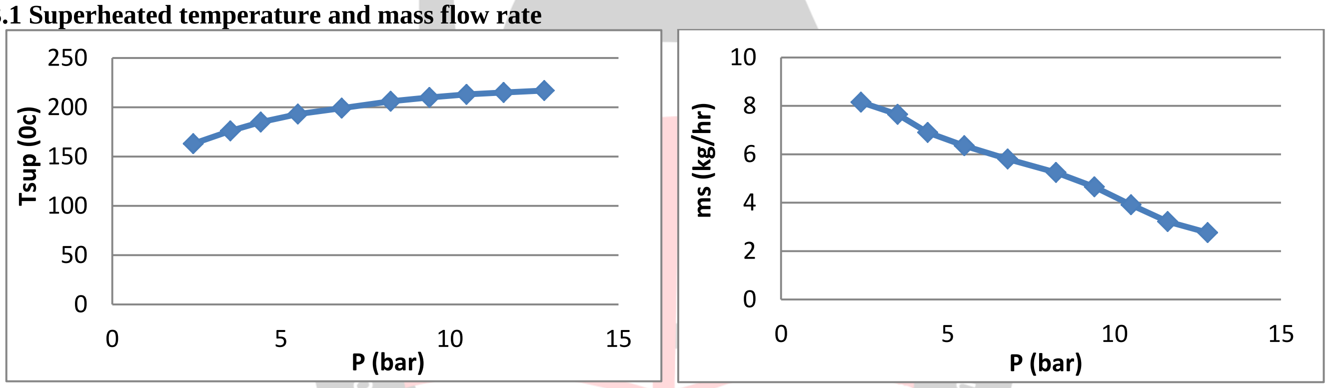
(a) **(b)**

Fig. 4.4 Variation of total heat loss (a) and efficiency (b) with normal beam radiation

The performance of system is specified with the help of its efficiency. It is variable quantity over a day due to variation normal beam radiation. It is found that, is reduced with increasing the normal beam radiation.

4.3 Analysis for different operating pressure

4.3.1 Superheated temperature and mass flow rate



(a) (b)

Fig4.5 Variation of superheated temperature (a) and mass flow rate (b) with operating pressure

For determining dryness fraction of wet steam, it needs to convert wet steam into superheated steam. A degree of superheat is required for that purpose. Also, saturation temperature is increase with increasing the operating pressure. Superheated temperature also increases with increasing operating temperature. The mass rate of steam generated totally depends on its operating pressure. It is reduced with increasing operating temperature.

4.3.2 Efficiency

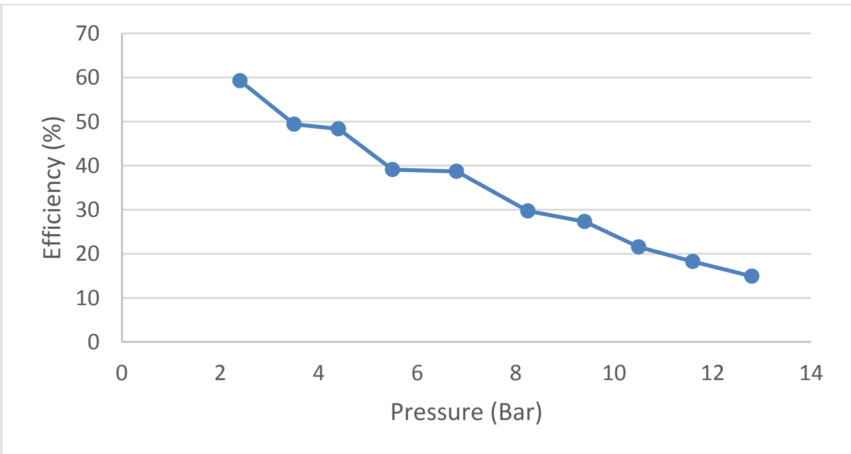


Fig. 4.6 Variation of efficiency with operating pressure

The performance or efficiency of a system is varying with operating pressure. It is maximum at minimum pressure and reduced with increasing operating pressure, because of increasing saturation position of steam.

4.4 Analysis for different wind velocity

4.4.1 Convective heat loss

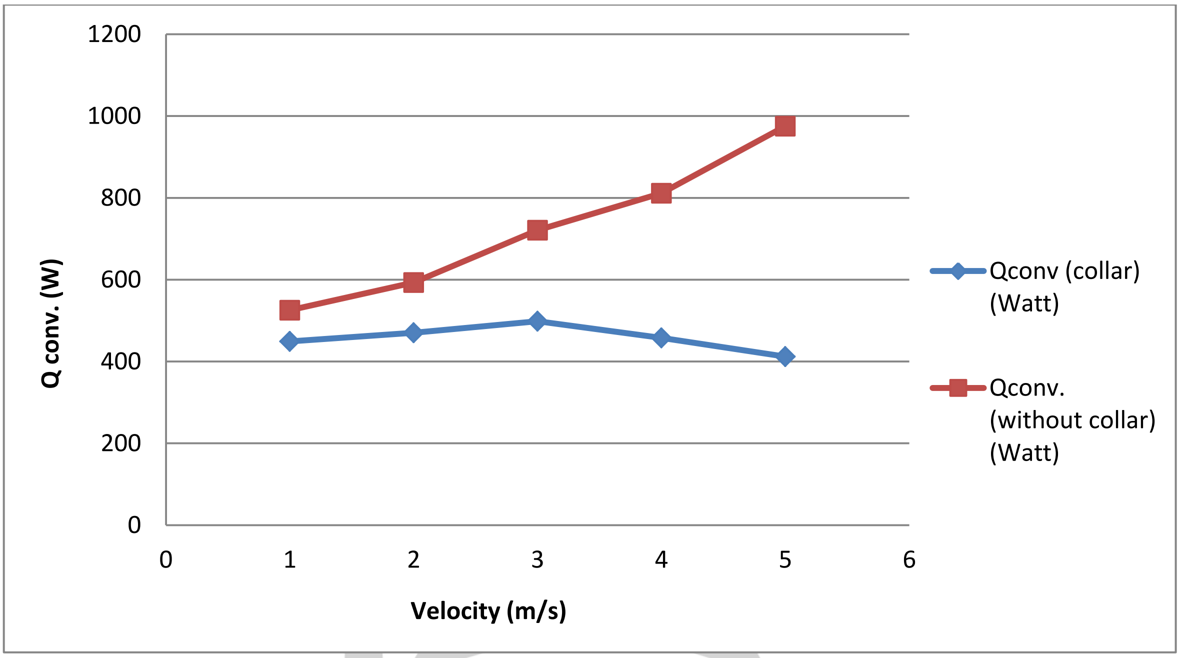


Fig. 4.7 Variation of convective heat losses with wind velocity

The convective heat loss is the measured heat loss, and it mainly depends on air velocity that was flowing over the receiver temperature. The convective heat loss increases with increasing air velocity. In without collar case, the variation of convective heat loss is very large. But in collar case, the convective heat loss variation is less as compare to without collar case and this difference is very large.

V. CONCLUSION

1. Depending on incident beam radiation, the efficiency of Scheffler concentrator is better at moderate normal beam radiation. At low normal beam radiation, it results in less heat losses due to lower surface temperature and lower operating pressure inside the receiver system.
2. It is found that the convective and radiative heat losses increase with an increase in normal beam radiation, due to the increase of surface temperature of the receiver. Radiation heat loss is proportional to forth power of the receiver temperature, and thus it is dominating at a higher temperature.
3. It is seen that with an increase in pressure, the efficiency of Scheffler concentrator reduces and it is maximum at low operating pressure. At lower pressure, the saturation temperature of working fluid remains lower, and therefore, the heat transfer to working substance is effectively large. The amount of heat required for generation of steam reduced and it results in a large amount of steam formation from the water. At pressure increases the saturation temperature of working fluid decreases, it lower the temperature difference between receiver surface and working fluid, causes lower heat transfer to fluid and increases the temperature difference between receiver surface and ambient, cause more heat loss to ambient through convection and radiation mode.
4. The system gives better efficiency at low wind speed. It is seen that if the velocity of air increases, the convective heat loss also increases. When the collar is fitted it reduces convective heat losses, because collar restricts this air movement and hence efficiency increases. System efficiency is better, when wind direction is north-west that is wind direction parallel to a receiver. At this angle, air makes minimum contact with a receiver. Receiver taper collar obstruct air and convective heat loss is minimized.
5. The system gave better efficiency in the month of December, and lower in summer. In winter the air remains dry, free from moisture and dust. The very clear sky during the winter season and also the wind has steady slow speed.

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