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Enhancement in the thermal performance of Solar Collector using Fresnel lens

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ABSTRACT

an actual solar air dryer for collector covering, normal glass, tempered glass or acrylic glass are the options available. By aiming to reduce surface area of collector Fresnel lens are introduced. In the present work the thermal performance of a solar collector is analysed experimentally, using Fresnel lenses. The experiment consist of 6 Fresnel lens of an area of 4873.5 cm2. With the help of focused rays air is heated through copper tubes of 7 mm diameter and length 890 mm at varying Reynolds no. A single and double pass arrangement has also been made and analysed in the collector. At Reynolds no 1000, the maximum temperature of 62°C has been observed in the single pass arrangement, whereas in double pass arrangement we found a maximum temperature of 105°C.

Keywords— **Focal Length, Fresnel Lenses, Heat Transfer Coefficient, Reynolds No, Solar Drier,Thermal Conductivity.**

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I. INTRODUCTION

Solar technology offers great potential in terms of fulfilling the energy needs in India. To utilize sunlight in an effective way and to concentrate solar energy concentration technology Fresnel lens is used here. The present status of application, the ongoing research and development works suggest that Fresnel lens solar concentrators will bring a breakthrough of commercial solar energy concentration application technology in the near future. This project is focused on the solar energy high temperatures using Fresnel lens. This project will provide an up-to-date review of solar Fresnel lenses and its benefits to make solar technology affordable. It will also analyze on some of the existing solar concentrators used in the solar technology for the past four decades and performance of each concentrator will be explained and compared. Solar radiation is concentrated by reflection or refraction through mirrors or lenses. The mirrors can be plane, called heliostats, or parabolic; the lenses can be simple lenses or Fresnel lenses (FL). Concentrators are used to improve the solar energy caption in specific applications. In a lens, the refraction phenomenon is produced in the surface, while the bulk material between the two surfaces doesn't have any influence in the refraction. In 1748 Georges- Louis Leclerc had the idea of reducing lens weight and size acting on the lens surface, but it was a French mathematician and physicist, Augustin-Jean Fresnel, who built, in 1820 the first lighthouse using Leclerc's design. The FL is a flat optical component where the bulk material is eliminated because the surface is made up of many small concentric grooves.Each groove is approximated by a flat surface that reflects the curvature at that position of the conventional lens, so each groove behaves like an individual prism. There are two basic FL configurations: linear and circularA linear FL has linear parallel grooves and the focus is a line. A circular FL has circular concentric grooves and the focus is a small circle. FL manufacture processes have developed. First designs were cut and polished in glass.[1] In 1950 they started to be made by pressing hot glass in metal molds, and since the eighties they are made of plastics. Modern plastic FL, cheaper and lighter than a conventional lens of the same size, has high optical quality.The Fresnel lens reduces the amount of material required compared to a conventional lens by dividing the lens into a set of concentric annular sections. An ideal Fresnel lens would have infinitely many such sections. In each section, the overall thickness is decreased compared to an equivalent simple lens. This effectively divides the continuous surface of a standard lens into a set of surfaces of the same curvature, with stepwise discontinuities between them. In some lenses, the curved surfaces are replaced with flat surfaces, with different angle in each section. Such a lens can be regarded as an array of prisms arranged in a circular fashion, with steeper prisms on the edges, and a flat or slightly convex center. In the first (and largest) Fresnel lenses, each section was actually a separate prism. 'Single-piece' Fresnel lenses were later produced, being used for automobile headlamps, brake, parking, and turn signal lenses, and so on. In modern times, computer-controlled milling equipment (CNC) might be used to manufacture more complex lenses. Fresnel lens design allows a substantial reduction in thickness (and thus mass and volume of material), at the expense of reducing the imaging quality of the lens, which is why precise imaging applications such as photography still use conventional bulky lenses. Fresnel lenshas been widely used in many applications, such as solar collector, Light Emitting Diode (LED), magnifier, lighting and camera lens.[2]

II. LITERATURE REVIEW

a The early Fresnel lenses made of glass were used soon after their practical discovery by Augustin Jean Fresnel in 1822 as collimators in lighthouse. Glass is an attractive option when lenses are to be used at high temperatures or when they are used for glazing. In 1951, Miller made the world’s first plastic material Fresnel lenses with high precision and excellent surface quality. The prismatic elements were very fine and were not visible to the average unaided eye and a high degree of correction for spherical aberration had been achieved by moulding with the help of high precision moulds. It was shown that these lenses had many applications as light collecting elements where weight and space were limited such as large condensers, large field lenses in finders, camera viewing screens, and translucent screens for projection which were considered as the early imaging systems. Boettner described the design and construction of Fresnel-type optics particularly suitable for use with area-type photoelectric receivers which was a point-focus system. Szulmayer and Nelson both presented and investigated a solar concentrator based on linear Fresnel lens, which could reach temperatures between 60 and $143^{\circ}C$ for water heating, steam production, desiccants (silica gel) regeneration, as well as thermoelectric power generation. The daily collection efficiencies were typically 50% at concentration ratios of near 5. Rice also proposed a solar concentrator with linear Fresnel lens which has series of elongated, generally rectilinear, side-by-side, parallel solar ray focusing surfaces.[3]Various solar collectors has been made by researchers all over the globe. Some of them are:

M. Hasan Nia 2014,Fresnel lens and thermoelectric module (TE module) were utilized in order to concentrate solar beam and generate electrical power. The energy of concentrated sunlight on the heat absorber of TE module is transferred to cold water reservoir. Heat transfer in TE module leads to temperature difference in its both sides and finally electrical power is generated. The main components of this system consist of a mono axial adjustable structure, a thermoelectric generator (TEG) and a Fresnel lens with an area of 0.09 m2. Results revealed that matched load output power is 1.08W with 51.33% efficiency under radiation intensity of 705.9 W/m2. In order to apply TE module capacity optimally for electrical generation, it is recommended to employ an array of Fresnel lenses which transfer heat to TE module by an intermediate fluid.[4]

M. Ouannene (2009) designed, built and studied a parabolic solar concentrator. The characteristic equations and the experimental results showed that the favourable conditions of getting better solar concentrations are; first is the best hour of getting maximum solar energy is 13h: 30 to 14h:30 and second is the concentrator is more effective if the solar tracking is perfect.[5]

Preservation of fruits, vegetables, and food are essential for keeping them for a long time without further deterioration in the quality of the product. Several process technologies have been employed on an industrial scale to preserve food products; the major ones are canning, freezing, and dehydration. Among these, drying is especially suited for developing countries with poorly established low-temperature and thermal processing facilities. It offers a highly effective and practical means of preservation to reduce postharvest losses and offset the shortages in supply. Drying is a simple process of moisture removal from a product in order to reach the desired moisture content and is an energy intensive operation. The prime objective of drying apart from extended storage life can also be quality enhancement, ease of handling, further processing and sanitation and is probably the oldest method of food preservation practiced by humankind (Mujumdar, 2007)[6]

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III.NUMERICAL ANALYSIS

The collector efficiency, η, is a measure of the collector performance and is defined as the ratio of the useful heat energy gain over a time period to the incident solar radiation over the same time period.

$$\eta = \frac{Q}{IA}$$

The following equations have been used for the evaluation of relevant parameters:

The rate of useful energy collected is expressed by considering enthalpy rise of the air as

$$Q = mC_p(T_{outlet} - T_{inlet})$$

Heat transfer coefficient of air is calculated by using the formula

$$h = Q/[A_c \times (\overline{t_s} - \overline{t_b})]$$

Surface Temperature of copper tube is taken average of the temperature sensors placed at six different points

$$T_s = \frac{T_1 + T_2 + T_3 + T_4 + T_5 + T_6}{6}$$

To calculate the temperature of fluid, generally average of inlet and exit temperature of fluid is taken as given below-

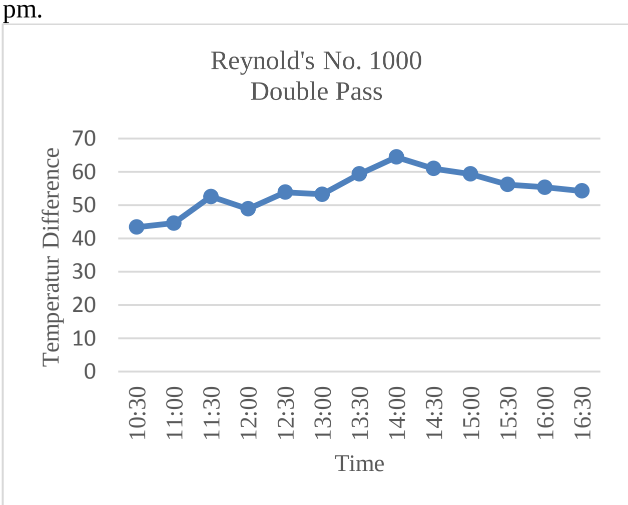
$$T_b = \frac{T_{inlet} + T_{outlet}}{2}$$

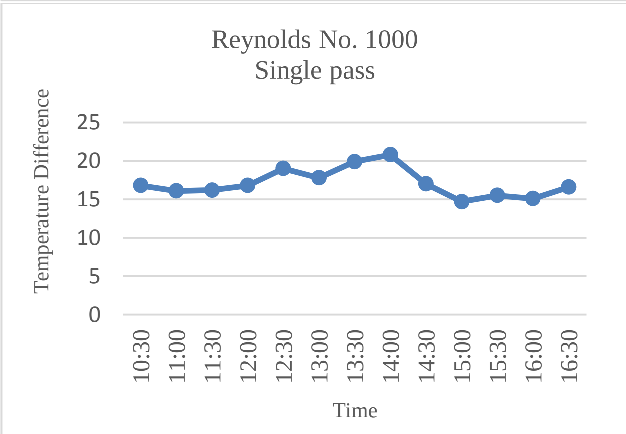
IV. EXPERIMENTAL SETUP

In this experiment, copper tube is located at the focal point of the Fresnel lens .Fresnel lens concentrates sunlight on its focal point and enhances solar Density in this zone. As a result of this heating the air temperature will increase. The exposure of lens exactly under sun rays is considered manually over the copper tubes. The main component of this system consists of wooden frame, wooden box, two copper tubes, Fresnel lens, and valves. The lens can be adjusted manually in appropriate direction with the help of wheel at the base and the screw that connects the frame and the box. The Fresnel lens is of order 28.5 x 28.5 cm^2. To prevent heat losses the copper tubes are enclosed inside the wooden box with a transparent glass covering on one of the side in order to verify that the focus is on the cu pipe. Also, to increase the absorptivity of the whole system the wooden box is painted black from inside. A blower is utilized for forced draught. Two passes arrangement were made inside the collector unlike a heat exchanger, a single pass, in which air comes through the blower and passes through both the tubes separately then passes out. The other arrangement is of double pass in which air enters through one copper pipe, heated up and then the same air passes through the other copper tube and heated up again. The experiments were carried out from May 25, 2015 to June 8, 2015 in Parandwadi, located near somatnephata, Pune(latitude: 18.698 and longitude: 73.658).Experiments were performed from 10.30 am to 4.30 pm on every sunny day on varying Reynolds no. Temperature is measured with the help of thermocouple at inlet, outlet and over the cu pipe at six different locations so as to obtain the average surface temperature. Ambient temperature of air is also recorded, for necessary calculations and investigations.

V. RESULT & DISCUSSION

At the Reynolds no. 1000, air is passed through the tube and we evaluated the temperature at outlet on both passes. To reduce manual error, during tracking, the readings were observed at an interval of 30 minutes from 10:30 am to 4:30 pm.





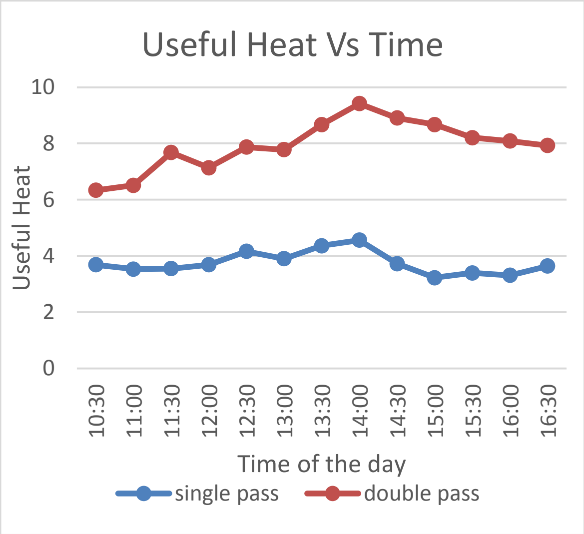


TABLE I

VARIOUS TEMPERATURE RECORDED AND USEFUL HEAT GAIN FOR DOUBLE PASS

Time	$T_{ambient}$	T_{inlet}	T_{outlet}	ΔT	Q
10:30	29.9	38.7	82.1	43.4	6.3364
11:00	30.7	39.5	84.1	44.6	6.5116
11:30	31.1	39.8	92.4	52.6	7.6796
12:00	33.2	42.4	91.3	48.9	7.1394
12:30	35.7	41.4	95.3	53.9	7.8694
1:00	34	42	95.3	53.3	7.7818
1:30	36.4	44.4	103.8	59.4	8.6724
2:00	33.9	44.5	109	64.5	9.417
2:30	33.5	44.7	105.7	61	8.906
3:00	32.7	44.2	103.6	59.4	8.6724
3:30	33.1	43.5	99.7	56.2	8.2052
4:00	33.7	42.7	98.1	55.4	8.0884
4:30	32.3	39.3	93.6	54.3	7.9278

TABLE III

VARIOUS TEMPERATURE RECORDED AND USEFUL HEAT GAIN FOR SINGLE PASS

Time	$T_{ambient}$	T_{inlet}	T_{outlet}	ΔT	Q
10:30	30.1	35.1	51.9	16.8	3.681888
11:00	30.9	36	52.1	16.1	3.528476
11:30	31	36.3	52.5	16.2	3.550392
12:00	33.7	40.1	56.9	16.8	3.681888
12:30	35.4	39.2	58.2	19	4.16404
1:00	35.2	39.9	57.7	17.8	3.901048
1:30	36.1	40.1	60	19.9	4.361284
2:00	36.5	41.2	62	20.8	4.558528
2:30	35.5	45.4	62.4	17	3.72572
3:00	35.1	46.1	60.8	14.7	3.221652
3:30	35.2	43.5	59	15.5	3.39698
4:00	33.9	40.6	55.7	15.1	3.309316
4:30	33.1	39.8	56.4	16.6	3.638056

VI. CONCLUSIONS

A new solar concentrator is investigated experimentally by the help of Fresnel lens in order to reduce the area of a regular solar collector. Experimentally it has been found that maximum available temperature in single pass system for a Reynolds no 1000 is 62.4˚C.Also the maximum temperature available for the double pass is 105.7˚C. The obtained result shows that in the arrangement for laminar flow the thermal performance of a double pass arrangement is better than the single pass arrangement.Also it is very much clear by calculation and data sheet that in double pass we get more useful heat as compared to that of single pass for less mass flow rate.

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