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Thermal Analysis of Solar Air Heater in Natural Convection

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Abstract:

The study of natural convective heat transfer from horizontal rectangular solar air heater has been studied experimentally. It was found that due to green house effect air gets heated and resulting in the lower in density cause air to rise and flow. This also makes fresh air to come in and thus repetition in the procedure. Several parameters like Nusselt number, Rayleigh Number, Heat transfer rate, and temperature difference was calculated and found in good agreement with the results obtained by several correlations available in the literature.

Keywords — **solar air heater, duct, solar radiation Natural Convection**

INTRODUCTION

In the current era, when there is a continuous demand of energy for the economic progress and industrialization, renewable energy sources are playing vital role in this regard. They are used to design high performance heat transfer systems. Of the many alternatives, in India solar energy has high solar isolation. It is clean, natural and available in sufficient amount. Devices which are designed on the concept of utilization of this solar energy and works on a principle of conversion of solar energy into thermal energy are heat exchangers and solar air heaters.

Natural Convection

Natural convection is a mechanism, or type of heat transport, in which the fluid motion is not generated by any external source (like a pump, fan, suction device, etc.) but only by density differences in the fluid occurring due to temperature gradients. In natural convection, fluid surrounding a heat source receives heat, becomes less dense and rises. The surrounding, cooler fluid then moves to replace it. This cooler fluid is then heated and the process continues, forming convection current; this process transfers heat energy from the bottom of the convection cell to top. The driving force for natural convection is buoyancy, a result of differences in fluid density.

Application for Solar Air Heater

Industrial Purposes:

1. Air pre-heating for combustion processes, that means thousands of applications
2. Drying minerals, coal, paper, bricks, food industry products, etc.
3. Especially the drying of brown coal would be very important for power plants.
4. Space heating for warehouses, factories, etc.

Household Purposes:

1. Space heating
2. Small driers

Experimental setup

Setup consists of rectangular duct with tapered end. Proper arrangement was made to locate thermocouple on the duct. An aluminium plate was placed at the mid position inside the duct so that air could pass from upper and lower side of the plate. The internal dimensions of the rectangular duct of the test rig were 0.54-m width 0.075-m depth 1-m length. The bottom and side walls of the duct were made of 18 mm-thick wood. An acrylic glass cover of 3 mm thickness was used to cover the rectangular duct from top side. Inner side of the duct as well as plate was black colored to absorb maximum radiation. Total 8 no. of pt-100 type thermocouple was used to record various temperatures by using 8 channel temperature indicators. Anemometer was used to measure the discharge velocity of air to calculate mass flow rate. The setup was kept at an angle 11°with horizontal.

Experimental procedure

The experiment was performed at the P.K Technical Campus, Pune situated at 18.5204° N, 73.8567° E. The collection of data was done for 5 days to improve the reliability of the result by taking the average reading. The data was collected from 23rd March 2017 to 27th March, 2017. After switching on the setup it was run for 1 hour to obtain steady state and the readings were taken. The readings were taken at the interval of one hour beginning at 9:30AM in the morning up to 4:30 PM. in the evening. .The schematic diagram given below depicts the sensor arrangement and direction of air flow.

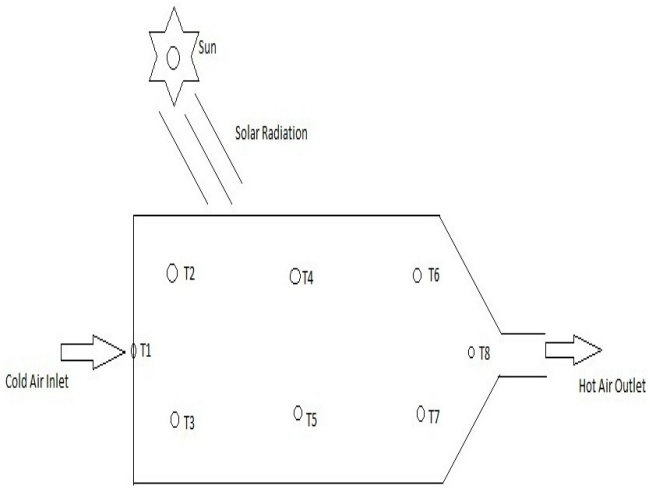


Fig (1) Schematic diagram of solar air heater

Sample observation

Below given table clearly depicts the reading of whole day. This data was collected on 23rd March 2017. T1 is the inlet temperature of fluid and T8 is the outlet temperature of fluid. T2 to T7 is the thermocouple positioned at the plate. For plate temperature average of all thermocouple positioned on the plate are taken. After every one hour discharge velocity of air is also recorded which show variation with change in temperature.

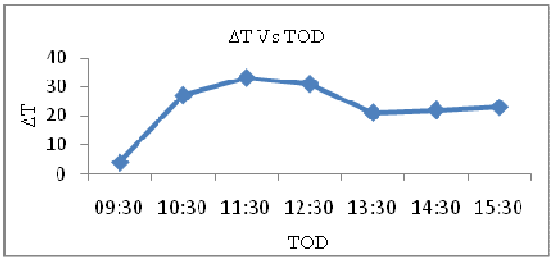
Table (1) sample observations

Time	T1	T2	T3	T4	T5	T6	T7	T8	Velocity
9:30	32	41	40	42	43	43	43	36	0.5
10:30	41	71	76	78	84	84	86	68	0.6
11:30	43	78	86	91	97	97	101	76	0.6
12:30	45	91	90	101	97	103	101	76	0.7
1:30	47	86	80	100	96	101	100	68	0.6
2:30	46	71	71	79	79	84	86	68	0.5
3:30	48	82	76	89	87	91	90	72	0.4

Table (2) Sample Results

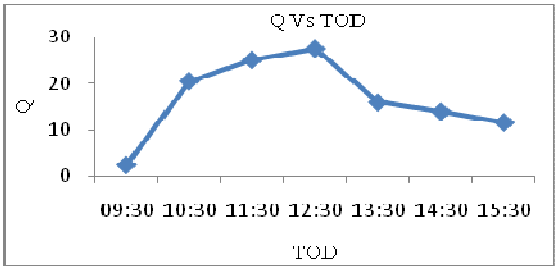
T_p	ΔT	T_f	$\dot{m}$	Q	ΔT_{pf}	h	Nu	Ra(×10^5)
42	4	34	0.00062	2.53	8	0.63	37.72	30.81
80	27	54.5	0.00075	20.49	25.33	1.61	96.49	97.59
92	33	59.5	0.00075	25.04	32.17	1.55	92.88	123.91
97	31	60.5	0.00088	27.45	36.67	1.49	89.30	141.27
94	21	57.5	0.00075	15.93	36.33	0.87	52.33	139.97
78	22	57	0.00062	13.91	21.33	1.30	77.80	82.13
86	23	59.5	0.00050	11.63	26.33	0.88	52.71	101.44

Results and discussions



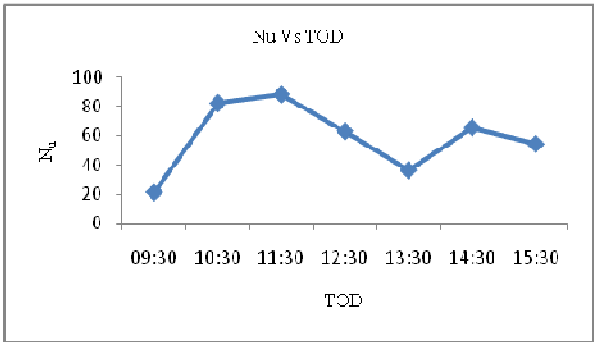
Graph (1) Temperature difference Vs Time of the day

Above graph depicts the variation of temp difference with respect to the time of the day. Initially it increases obtain maximum value and then decreases. Maximum temp difference obtained is 30 degree c.



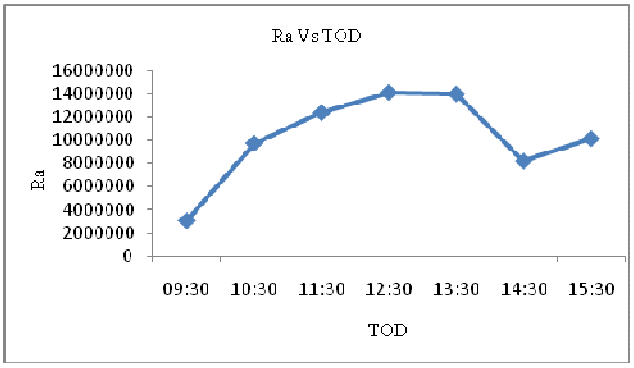
Graph (2) Heat transfer rate Vs Time of the day

Above graph depicts the variation of heat transfer rate with respect to the time of the day. Initially it increases obtain maximum value and then decreases. Maximum Q obtained is 27W at 12:30PM.



Graph (3) Nusselt number Vs Time of the day

Above graph depicts the variation of Nusselt number with respect to the time of the day. Initially it increases obtain maximum value and then decreases. Maximum Nu obtained is 96.49 at 11:30PM.



Graph (4) Rayleigh number Vs Time of the day

Above graph depicts the variation of Rayleigh number with respect to the time of the day. Initially it increases obtain maximum value and then decreases. Maximum Ra obtained is 1.4×10^7 at 1:00 PM which is clearly in the range of natural convection.

CONCLUSIONS

- The maximum temperature difference is obtained at 1:30 is about 33°c.
- It is concluded that temperature difference is dependent on solar intensity because maximum solar intensity is also seen at the same time.
- Nusselt number is the non dimensionlised form of convective heat transfer coefficient which is 96.49 at 11:30 PM.
- From the experimental study the Rayleigh number is depend on time of the day, as time of the day increases the Rayleigh number initially increased then decreased. it is observed that maximum Rayleigh number is observed in between 11:30 to 13:30
- The maximum Nusselt number obtained as 96.49 and Rayleigh no as 14.4366× 10^6.

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