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Viability of Solar chimney Technology in Central Region of India

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Abstract— A solar chimney power plant which can provide off -grid electricity in central region of India particularly in Vidarbha region is studied in this paper.The regions like Amravati and Nagpur have high temperature in the range of 40 to 50^{0}c in summer but still there is a loadsheading of 10 to12 hours because of lack of solar to electrical energy conversion sources in large extent.In this paper data of small scale solar chimney model which fabricated for experimental and analysis purpose is presented which has collector of 1.8 m diameter and maximum chimney height of 2 m.The parameters such as temperature,velocity,and density are considered for study.The maximum value of velocity recorded was 1.4 m/s.The variation of velocity is higher as compared to other process parameters.

Index Terms— Solar energy, solar chimney, collector, solar insolation, metrology, up-draft tower, high altitude, Turbine,green house effect.

1 INTRODUCTION

The solar chimney power plant consist of green house cooector which is supported by vertical chimney of large height.Turbine is located at the bottom of the collector.The collector usually made of fibre sheet or glass material so that high amount heat can be trappd inside the collector to create upword air draft from collector inlet to chimney outlet.chimney is made up of concrete or metal as per requirment.Turbines are mount at the central portion of rhe collector and exactly below chimney. The air velocity generated inside the cooector is sensed by turbine which is coupled to turbine for the generation of electricity.

solar chimney is compartively old technology inveted in early of 1980.The experimental results obtained in Manzanares Spain demonstrated that power can be produced with large height of chimney and large diameter of collector[1,2].

Number of experimental,therotical and numerical studiesare carried out to test viabilty of solar chimney power plant in different part of the world.Fei Cao et el. carried out performance analysis of conventional and sloped solar chimney power plants in china.They conclude that the size of chimney various as per region because of different metrological conditions[3].Alex Yong Kwang Tan done the study in singapore to study the infulance of ambient air speed on air temperature within the solar chimney[4].Johannes P.Pretorius et el. evaluate the performance of solar chimney in south Africa.he shows that plant output is a function of chimney height and cooector roof shape[5]. Y.J.Dai et el. performed the casestudy of solar chimney in china.He concluded that the capacity of power power generation is dependent on solar irradiance and ambient temperature[6].

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A.Asnaghi provided the performance analysis of solar chimney in Iranian central region.From obtained resuts it was clear that solar chimney of 244m diameter can produce up to 40MWh of electricity in different of the year[7].Mohammad O.Hamdan has presented thermal model of steady state flow inside a solar chimney power plant to predict that collector radius, the solar irradiance and the rurbine are the important parameters for the design of solar chimney[8].MiqdamT. Chaichan et el.[8]tested the performance of solar chimney in Baghdad by using the collector made of trnsparent plastic cover instead of glass.He used various basments for installing the collector.the xaximum temperature diierance observed was 220c and chimney efficiency attained was 49.7%.Jorg Schlaich et el.[9]presented the technical issues for setting solar chimneyin Australia.He also presented the economical fesibility for sctting solar chimey.Atit Koonsrisuk et el.[10]performed mathematical modeling of solar chimney power plant.he perducted the optimum pressur ratioof 2/3 of turbine extraction pressure**.**A.B.Kasaeian et el.[11] provided the simulation for performance evaluation of solar chimnet power plant in Iran.He predicted the performanceby comparing clamatic comparision of five cities of Iran.O.C.Aja et el.[12] done the Experimenral invistigation of solar chimney power plant for wind speed and wind direction.he predict that the use of inlet guide vanes at periphery of solar chimney reduces the heat loss because the wind sweeping off the hot air in the collector.Tahar Tayebi et el.[13] persent the effect of the ambuent temperature and solar radiation on the floe in a solar chimney collector.He validated the mathematical model with the experimental data from manzanares prototype and concluded that by decrasing collector radius the velocity and temperature of the collector can be increased.A.A.Mostafa et el.[14] done the experimental validation of solar chimney in Egyptian Weather conditions.He predict that there is no exact physical size for solar chimney,it depends on economical consideration.Hitesh N.Panchal et.el.provided the productivity of energy absorbing plates.Mohammad.Tingzhen Ming et el.[15] done the numerical study of chimney shape of solar chimney power plant.

2 WORKING PRINCIPLE OF SOLAR CHIMNEY

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Solar chimney is heat energy conversion system which cinsit of three technologies that is collector,Turbine and chimney.It works on the principle which involves absorption heat of sun rays using solar air collector to heat air inside.The heated air rises due to density differance from inlet to outlet of collector.Chimney is supported in collector by using quadrilateral connector whch provide air tight joint between collector and chimney.At the chimney base Turbine is located which sense this density variation and high pressure airdraft inside the collector.Turbine converts the kinetic energy of air into electricity when it is get coupled to the Generator[16].The working principle of solar chimney power plant is shown in fig.1.

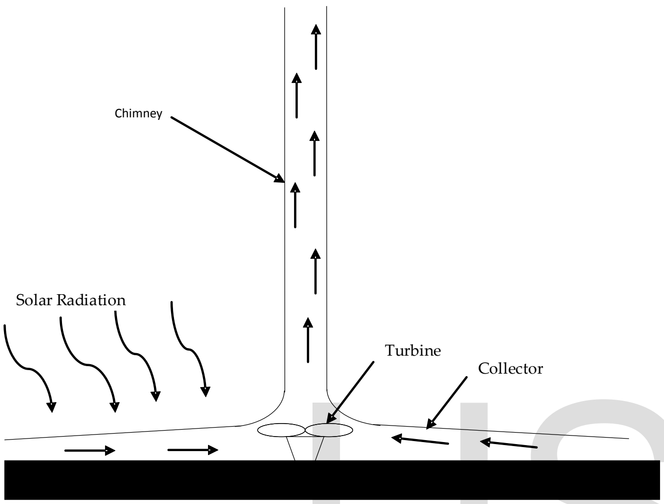

Fig. 1. Working Principle of solar chimney

3 Experimental set up of solar chimney

The solar chimnety performance evaluation is done by constructing a small protptype in Amravati which is located in central regin of India.Amravati is located at an Elevation of 401 meters.Its latitude is 20.93 and longitute is 77.78[17]. It has high temperature in summer in the range of 40 to 45^{0}c.Even though such a high temperature still tere is shorate of electricity in Summer.There a loadsheading of 10-12 hours in these months of summer.It is urgent requirement of some device which can converted this high temerature energy into electricity.Solar chimney has that potential that can solve almost all the problems face by the people in this region.

The experimental setup consist of collector of 1.8m diameter mounted on the wood support.Wood supports are made in the form of frames of 12mm thickness.The inlet height of collector is 0.03m and out let height is 0.07m.The quadrilateral shape connector made of sheet metal is used to connect chimney and collector.Material used for collector is transparent glass of soda lime.The efficiency of collector can be increase by providing black absorbing material inside the collector.A PVC pipe is usd as chimney material of 0.5 to2.0m doameter.As per requirement four small pieces of 0.5 diameter each can be used and flange of same mater is used so that testing can be made on the required height.Thermocouples of PT-100 are used at suitable location on chimney and collector so that the reading of temperature at various location can be taken.Density meter is used for measuring density variation and Pyrometer of Lutron make AM-4201 is used to measure the velocity variation.The exerimental setup of solar chimney power plant is shown in Fig.2 with its various parts.

Fig. 2. Experimental setup of solar chimney

4 Observations

The follwing observations are recorded in the month of may which is the hostest month in Amravati to get exact idea of the maximum amount of powr can be produced.The reading are taken in the time duration of 10 AM to 5 m with density and mass flow rate. Table shows the observations recorded.

TABLE 1
OBSERVATION RECORDED FROM SOLAR CHIMNEY FOR CHIMNE HEIGHT OF 0.5m

Time	**T1**	**V_{max} m/s**	**ρ_{coll} kg/m^3**
10.00	41	***0.8***	***1.12***
10.30	43	***1.4***	***1.11***
11.00	48	***0.9***	***1.11***
11.30	45	***1.3***	***1.09***
12.00	43	***1.0***	***1.11***
12.30	47.5	***0.5***	***1.09***
1.00	50	***0.6***	***1.09***
1.30	45	***1.0***	***1.08***
2.00	40	***1.0***	***1.08***
2.30	43	***1.4***	***1.09***
3.00	42	***1.3***	***1.10***
3.30	43	***1.1***	***1.10***
4.00	48	***0.9***	***1.11***
4.30	47	***0.6***	***1.11***
5.00	41	***0.8***	***1.12***

The following abbreviation are used in observation Table
T1- Outlet Temperature in 0c
Vmax- Maximum Velocity m/s
ρcoll- Density of collector Kg/m3

5 Result and Discussion

The various graphs ate plotted with the time duration and as follows

1) Time Vs Temperature

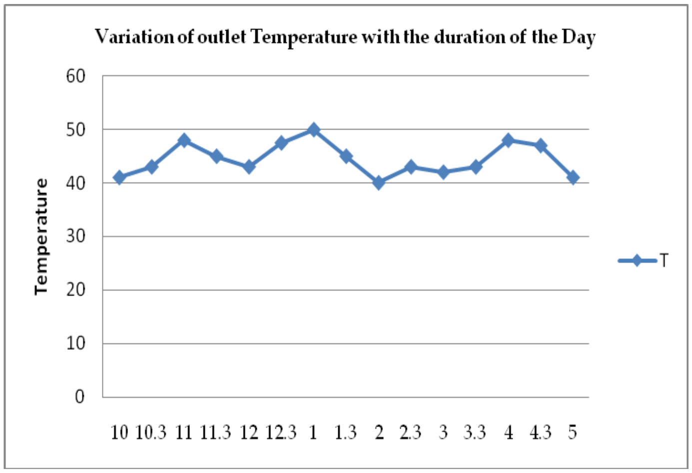

Fig. 3. Variation of temperature with time

From the Fig.1 it is observed that there is a continuous variation of temprature through out the day.In early morning and in the evening the temperature is less.The highest time which is recorded is 1.30 PM and 3.30 to 4 PM.

2) Time Vs Maximum Velocity

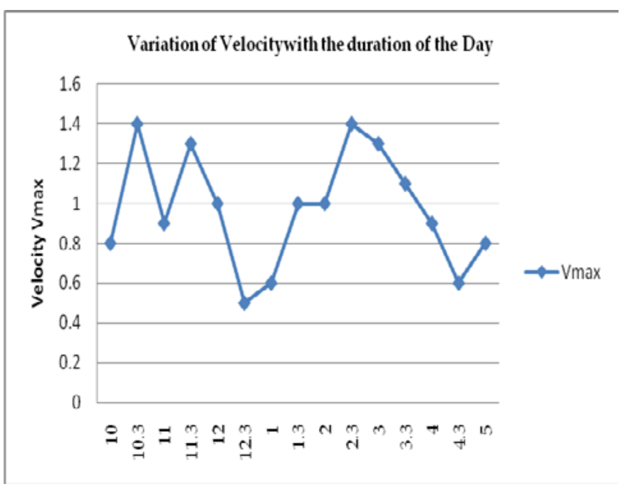

Fig. 4. Variation of Velocity Vs time

From the Fig.4 it is observed that the velocity varies from minium to maximum from morining duration of the day.The same variation is observed in the noon. which is 1.4 m/s.but the variation reduces continuously after noon it continuously reduces from maximum to minimum value.There is some increase in velocity is recorded during the end of the day.The minimum value of velocity is recorded at 12.30 PM.

3) Variation of Temperature with mass density

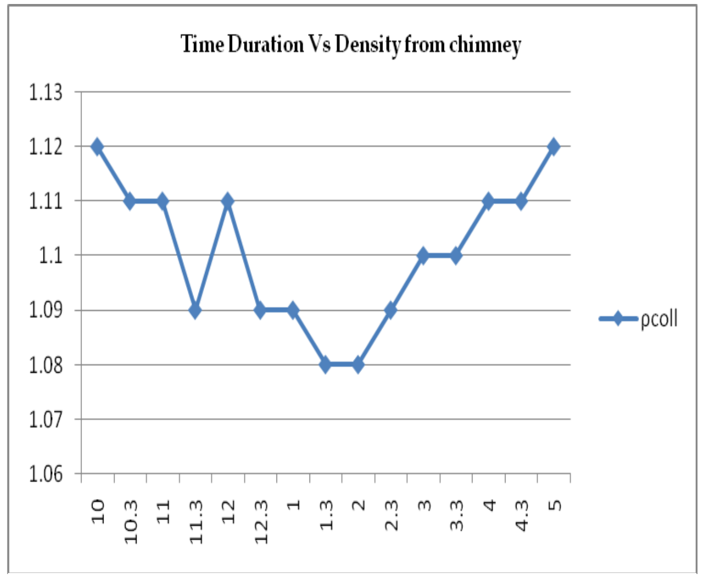

Fig. 5. Variation of Density with time

From fig.5 it is observed that there is a continuous variation of density from inlet to outlet of collector and chimney.The maximum value of density recorded is early in the morning and late in the day. The maximum value recorded is 1.12 kg/m³ .the minimum value of density recorded is 1.08 kf/m³which is recorded in noon between 1.30 PM to 2.00 PM.

4) Comparitation of Variation of Temperature, Velocity and density

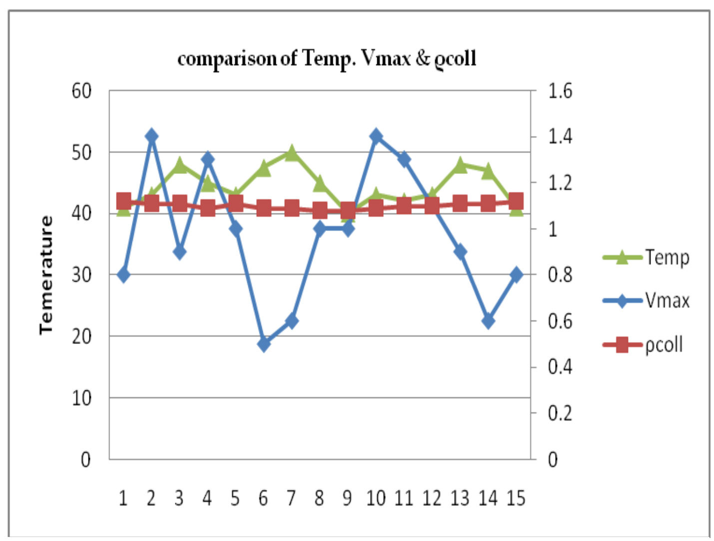

Fig. 6. Comparitation of Variation of Temperature, Velocity and density of collector

From Fig.6 it is observed that there is a variation of density which varying some what less as compaired with temperature and velocity of Air.The maximum variation observed in the velocity of air. There is moderate variation of temperature during the day.

4 Conclusion

The following conclusions are drawn from the experimental investigation which is carried out.
1) The maximum solar Insolation is observed in the noon so maximum power can be generated during this time duration
2)The value of velocity is hifger in the morning and in the afternoon due to high wind speed during this duration
3)The value of density is almost constant during the Peak insolation period which is in the noon.
4) When temperature,velocity and density are compaired with each other it is observed that the variation of density is much less but variation of velocity is quite high.

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