Dr. PRITAM DAS

Mob: **+91 8917358125**

Address: **AT: SIRIGIDA, PO: GURUJANG PS: TALCHER, DIST: ANGUL STATE: ODISHA, PIN- 759100**

Email: **iampritda@gmail.com**

SOFTWARE SKILLS

ANSYS Fluent	CATIA
AutoCAD	MATLAB
Origin	Scilab
Techplot	Minitab
MS Excel, Office	ICEM CFD

OTHER SKILLS

Academic research and development

Technical writing

Selection/procuring instruments

Prototype design and development

Data handling

LANGUAGES

English	✪ ✪ ✪ ✪
Hindi	✪ ✪ ✪ ✪
Odia	✪ ✪ ✪ ✪ ✪
Bengali	✪ ✪

EDUCATION

Ph.D., Mechanical Engineering, NIT Warangal

July 2018 – February 2022

Thesis: "Experimental and numerical analysis of flow and performance parameters of solar updraft tower plant."

(Supervisor: *Dr. Chandramohan V.P. Associate Professor, MED, NITW*)

Modelling and simulation, Computational fluid dynamics, Parametric studies, Heat and fluid flow analysis, Energy and exergy analysis, Design and fabrication of laboratory scale prototype, Measurement and analysis of datasets, Optimization and development of correlations.

M.Tech, Thermal Engineering, CET Bhubaneswar

September 2015 – August 2017; CGPA: 8.93

Thesis: "Heat and Fluid flow Analysis of a Naturally Ventilated Poultry Shed & Implementation of Solar Thermal system in it"

(Supervisor: *Dr. Prasanta Kumar Satapathy Associate Prof., and Dr. Sudhansu Sekhar Sahoo. Assist. Prof, MED, CET Bhubaneswar)*

Heat and fluid flow analysis, Live-stock building simulation, Solar thermal, Modelling and simulation, Parametric studies, Solar air heater sizing, Economic analysis

B. Tech, Mechanical Engineering, DRIEMS, BPUT Odisha

August 2009 – July 2013; CGPA: 7.63

RESEARCH INTERESTS

Solar thermal, Algae-biofuel, Comfort conditioning, Heat enhancement, Hybrid energy systems, Energy storage, Heat and fluid flow, Vortex generation, PV, Building simulation, Desalination, CO_2 mitigation, 4-E (Energy-exergy-environmental, economic) Analysis.

RELEVANT COURSEWORK

Advanced Heat and mass transfer

Solar Energy and storage systems

Computational methods in Thermal engineering

Advanced fluid dynamics

REVIEW ACTIVITY FOR JOURNALS

Journal of thermal analysis and calorimetry, Springer publication (SCI)

Journal of thermal engineering, Yildiz Technical University Press, Turkey, (ESCI)

Sadhana (SCI)

Thermal science and engineering progress, Elsevier (SCI)

Sustainable energy technologies and assessment, Elsevier (SCI)

RESEARCH COLLABORATIONS

Department of Energy and Environment, NIT Trichy, INDIA

Ton Duc Thang University, VIETNAM

EXPERIENCE

Junior Research Fellow, NIT Warangal

Oct 2017 – Oct 2019

DST-SERB sponsored project entitled "Design and Development of Solar updraft tower (SUT) plant."

Senior Research Fellow, NIT Warangal

Oct 2019 – Nov 2020

DST-SERB sponsored project entitled "Design and Development of Solar updraft tower (SUT) plant."

Teaching Assistantship, NIT Warangal

July 2019 – Oct 2021

B.Tech (Mechanical), M.Tech (Thermal/Automobile) Labs: EG Lab, Thermal Engineering Lab, Simulation Lab, Heat and Fuels Lab.

PROFESSIONAL TRAINING/COURSE:

AutoCAD, CIPET Bhubaneswar, Odisha

11th August 2011 – 9th Sept 2011

CATIA, CTTC Bhubaneswar, Odisha

1st Feb 2012 – 29th Feb 2012

GIAN Course, Exergy analysis of Industrial processes, NIT Warangal; (Resource person: Prof. Ibrahim Dincer, University of Ontario Institute of Technology, Canada)

11th Feb 2019 – 15th Feb 2019

RESEARCH PUBLICATIONS

No. of Articles in (SCI/SCIE) indexed Journals	No. of International conferences attended	Patents (Filed/Granted)
15	**07**	**01** (Filed and published online)
Cumulative IF	Highest/Lowest IF	Average IF
91.928	**9.709/2.172**	**6.128**
Citation	h-index	i-10 index
120 +	**07**	**07**

Google Scholar:
https://scholar.google.co.in/citations?user=URcRTboAAAAJ&hl=en
ResearchGate:
https://www.researchgate.net/profile/Pritam-Das-6

RESEARCH ARTICLES PUBLISHED IN INTERNATIONAL JOURNALS:

1. **Das P.,** Chandramohan VP "Experimental studies of a laboratory scale inclined collector solar updraft tower plant with thermal energy storage system" *Journal of Building Engineering,* (2021); 41:102394, https://doi.org/10.1016/j.jobe.2021.102394. **(Elsevier, SCI, IF: 5.318; Q1)**
2. **Das P.,** Chandramohan VP "Estimation of flow parameters and power potential of solar vortex engine (SVE) by varying its geometrical configurations: A numerical study" *Energy conversion and management* (2020) 223:113272. https://doi.org/10.1016/j.enconman.2020.113272. (**Elsevier, SCI, IF:9.709, Q1**)
3. **Das P.,** Chandramohan VP "3D numerical study on estimating flow and performance parameters of solar updraft tower (SUT) plant: Impact of divergent angle of chimney, ambient temperature, solar flux and turbine efficiency" *Journal of cleaner production* (2020),120353. https://doi.org/10.1016/j.jclepro.2020.120353. (**Elsevier, SCI, IF:9.297, Q1**)
4. **Das P.,** Chandramohan VP., Mathimani T., Pugazhendhi A. Recent advances in thermochemical methods for the conversion of algal biomass to energy. *Science of the Total Environment,* 766 (2021),144608, 10.1016/j.scitotenv.2020.144608. **(Elsevier, SCI, IF: 7.963, Q1)**
5. **Das P.,** Chandramohan VP., Mathimani T., Pugazhendhi A. Comprehensive review on the factors affecting thermochemical conversion efficiency of algal biomass to energy. *Science of the Total Environment*, 766 (2021), 144213, 10.1016/j.scitotenv.2020.144213. **(Elsevier, SCI, IF: 7.963 Q1)**
6. **Das P.,** Chandramohan VP "Computational study on the effect of collector cover inclination angle, absorber plate diameter and chimney height on flow and performance parameters of solar updraft tower (SUT) plant" *Energy* (2019),172: 366-379 https://doi.org/10.1016/j.energy.2019.01.128. (**Elsevier, SCI, IF:7.147, Q1**)
7. **Das P.,** Chandramohan VP "Performance evaluation of solar vortex engine and optimization of number of air entry slots and turbine location" *Energy sources part A: Recovery, utilization and environment effects*, (2020) https://doi.org/10.1080/15567036.2020.1845879. (**Taylor and Francis, SCI, IF:3.447, Q2**)
8. **Das P.,** Chandramohan VP "Performance characteristics of divergent chimney solar updraft tower plant" *International Journal of Energy Research* (2020) https://doi.org/10.1002/er.5304. (**Wiley, SCI, IF: 5.164, Q1**)
9. **Das P.,** Chandramohan VP "Effect of chimney height and collector roof angle on flow parameters of solar updraft tower (SUT) plant: A 3D numerical analysis" *Journal of Thermal Analysis and Calorimetry* (2018), https://doi.org/10.1007/s10973-018-7749-y. (**Springer, SCI, IF:4.626, Q2**)
10. **Das P.,** Chandramohan VP "CFD analysis on flow and performance parameters estimation of solar updraft tower (SUT) plant varying its geometrical configurations" *Energy sources part A: Recovery, utilization and environment effects*, (2018),40:12,1532-1546. (**Taylor and Francis, SCI, IF:3.447, Q2**)
11. Praveen V., **Das P**., Chandramohan VP "A novel concept of introducing a fillet at the chimney base of solar updraft tower plant and thereby improving the performance: A numerical study" *Renewable energy,* (2021); 179:37-46, https://doi.org/10.1016/j.renene.2021.07.038. **(Elsevier, SCI, IF: 8.001, Q1)**

12. Keshari S.R., Chandramohan VP, **Das P.** A 3D numerical study to evaluate optimum collector inclination angle of Manzanares solar updraft tower power plant. *Solar energy*. DOI: 10.1016/j.solener.2021.08.062. (**Elsevier, SCI, IF:5.742, Q1**)
13. Mugi, VR, **Das P**., Balijepalli R, Chandramohan VP "A review of natural energy storage materials used in solar dryers for food drying applications. *Journal of energy storage,* (2022); 49:1-15, https://doi.org/10.1016/j.est.2022.104198. **(Elsevier, SCI, IF: 6.583, Q1)**
14. **Das P.,** Chandramohan VP. A review on solar updraft tower plant technology: Thermodynamic analysis, worldwide status, recent advances, major challenges and opportunities. *Sustainable Energy Technologies and Assessments*, 52(5). DOI: 10.1016/j.seta.2022.102091 **(Elsevier, SCI, IF: 5.353 Q1)**
15. **Das P.,** Chandramohan VP. A review on solar updraft tower plant technology: Thermodynamic analysis, worldwide status, recent advances, major challenges and opportunities. *Heat Transfer Engineering*, Accepted for special issue (**Taylor and Francis, SCI, IF: 2.172 Q1**)

INTERNATIONAL CONFERENCES:

1. **Das P.**, Chandramohan V.P "Effect of chimney height and collector roof angle on flow parameters of solar updraft tower (SUT)plant: A 3D numerical analysis." International Conference on Thermal Analysis and Energy Systems (ICTAES- 2018). 12-13th April, 2018. Hindustan College of Engineering and Technology, Coimbatore.
2. **Das P.**, Chandramohan V.P "Numerical investigation of flow and performance parameters of divergent chimney solar updraft tower." 11th International Exergy, Energy and Environment Symposium (IEEES-11), July 14-18th, 2019, SRMIST, Chennai, India.
3. **Das P.**, Chandramohan V.P "Impact of chimney outlet to inlet area ratio on the performance of solar updraft tower (SUT) plant" 25th National and 3rd International ISHMT-ASTFE Heat and Mass Transfer Conference (IHMTC-2019), 28-31st December 2019, IIT Roorkee, India.
4. **Das P.**, Chandramohan V.P "Performance improvement of truncated conical collector solar updraft tower plant using guide vanes: Experimental study" 26th National and 4th International ISHMT-ASTFE Heat and Mass Transfer Conference (IHMTC-2021), 17-20th December 2021, IIT Madras, India.
5. **Das P.**, Chandramohan V.P "An experimental study on performance assessment of solar updraft tower (SUT) plant with guide vanes" 3rd International conference on recent advances in mechanical Infrastructure (ICRAM-2021), 6-8th August 2021, IITRAM Ahmedabad, India.
6. Praveen V., **Das P.**, Chandramohan V.P "Influence of chamfering near the chimney base of solar updraft tower on flow and performance parameters" 2nd National & 1st International conference on fluid flow and thermal sciences (ICAFFTS-2021), 24-25th September 2021, SVNIT Surat, Gujarat, India.
7. Praveen V., Chandramohan V.P, **Das P.**, "A numerical analysis on performance enhancement of solar updraft tower plant by a fillet near the chimney base" 26th National and 4th International ISHMT-ASTFE Heat and Mass Transfer Conference (IHMTC-2021), 17-20th December 2021, IIT Madras, India.

PATENT

Dr. Chandramohan V.P., B. Ramakrishna, Pritam Das, Dr. K. Kirankumar. (2019, May, 6th) "Design and Development of Solar Updraft Tower (SUT) Plant for Generating Electrical Power" **Indian Patent Application No. 201941018001, [Accessed on: Dec. 20, 2021**]

INTERESTS

Writing short stories, Travelling,

Scripting and direction, Cooking

AWARDS/SCHOLARSHIPS

Fellowship from DST-SERB (5th Oct 2017- 15th Sept 2020)

MHRD fellowship through GATE-2017 (16th Sept 2020 to 15th Nov 2021)

89th All India Rank in 7th National Cyber Olympiad

First Prize in various Drama competition

REFEREES

Dr Chandramohan V.P. (Associate Professor), Mechanical Engineering Department, National Institute of Technology Warangal, Telangana- 506004, vpcm80@nitw.ac.in, 8332969329

Dr Sudhansu Sekhar Sahoo, Assistant Professor, Dept. of Mechanical Engineering, Odisha University of Technology and Research (Formerly known as CET. Bhubaneswar), Odisha, PIN-751003, sudhansu@cet.edu.in, 9337645056

Dr V Rajesh Khana Raju (Associate Professor), Mechanical Engineering Department, National Institute of Technology Warangal, Telangana- 506004, vrkraju@nitw.ac.in,870246 2316

PERSONAL DETAILS

Father's Name: Mr. Pradyumna Das

Mother's Name: Mrs. Jyotirmayee Das

Date of Birth: 25/05/1992

Gender: Male, Marital Status: Single

Cast: UR, Religion: Hindu

Nationality: Indian

DECLARATION

I, Dr. Pritam Das hereby declare that above information is true to the best of my knowledge & nothing has been concealed herein. All the documents in original/attested copy will be produced whenever required.

Date: 26/02/2022 Place: Talcher, India

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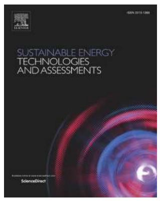

Review article

A review on solar updraft tower plant technology: Thermodynamic analysis, worldwide status, recent advances, major challenges and opportunities

Pritam Das, Chandramohan V.P. [1,*]

Mechanical Engineering Department, National Institute of Technology Warangal, Warangal, Telangana 506004, India

ARTICLE INFO

Keywords:
Solar chimney power plant
Solar updraft tower
Power potential
Challenges
Flow parameters
Turbine pressure drop

ABSTRACT

In the 21st century, utilization of solar energy takes a new peak due to the increase in global energy demand, environmental concerns and scarcity of fossil fuel. Among various technologies, the solar updraft tower plant generates intensive interest among researchers in recent years. Remarkably advancements in the plant were achieved over the decades through various numerical, analytical and experimental studies. In this review work, the thermodynamic principle behind the plant and energy balance equations needed for different components were reviewed as these are useful for design calculations. Also, exergy analysis and cost estimation were discussed. The worldwide status of the plant in the last two decades was reviewed and observed that the power potential of the system was in the range of 0.053–27 MW. The summary of each mathematical analysis and research gaps were reported as these are useful for future studies. The factors affecting the performance of the plant such as surface transfer coefficients, pressure profile and turbine pressure drop were also reported. Lower thermal efficiency, land requirements for commercial plant and building tall chimney were the major challenges on the plant which are also discussed. Lastly, the recommendations and future perspective of the plant is outlooked.

Introduction

The utilization of solar energy over the past decades has taken a remarkable leap worldwide. Scarcity of fossil fuel sources and to meet the growing energy demand, researchers and industrialists are looking forward to various alternative energy sources. More focuses were given on renewable energy options which leads to the sustainable development of the human race. At present 80–84% of world energy usage comes from fossil fuel resources [1,2] that creates huge environmental issues. If renewable sources were encouraged instead of fossil fuels, the problem of polluting the environment can be avoided. Moreover, overdependence on other resources such as oil, gas, coal can be avoided. Thus, the best possible solution is to move towards renewable energy sources which can avoid potentially vulnerable problems.

Though various forms of renewable energy are available, solar thermal is the most abundant form of energy which is available in direct and indirect forms. Solar energy and its utilization are the promising way for carbonless power generation, resolve pollution issues and climate change mitigation. Several developed and developing countries like India, Brazil, China, etc. have taken steps to uplift the share of the utilization of solar energy in their respective country's energy utilization portfolio. India being second populated country, the energy demand increases at an alarming rate [3]. The renewable energy installed capacity was increased 226 % over the last five years in India [4]. There are three major technologies by which solar energy is harnessed, these are photovoltaics (PV), concentrating solar power (CSP) and solar heating and cooling (CHC) technology [5]. Though a major share of global renewable energy production was captured by PV technology [5,6] other solar thermal technologies also contribute to power production. Among that solar chimney power plant or solar updraft tower (SUT) plant also gets huge attention. SUT plant is another promising technology that utilizes direct and diffuse solar radiation for power generation applications. This is another large-scale power technology that generates electricity free of greenhouse gas emissions [7,8].

Limited usage of raw materials or simple building construction materials along with less maintenance makes the SUT technology more simple, economically viable and accessible [9]. The carbonless power

* Corresponding author.
E-mail address: vpcm80@nitw.ac.in (V.P. Chandramohan).
[1] ORCID: 0000-0002-8680-8363.

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Experimental studies of a laboratory scale inclined collector solar updraft tower plant with thermal energy storage system

Pritam Das, V.P. Chandramohan *

Mechanical Engineering Department, National Institute of Technology Warangal, Warangal, Telangana, India, 506004

A R T I C L E I N F O

Keywords:
Solar updraft tower
Flow parameters
Performance parameters
Uncertainty
Thermal energy storage

A B S T R A C T

In this study, a solar updraft tower (SUT) plant was developed with a thermal energy storage system. It has the chimney height, diameter, inlet gap and absorber plate diameter of 6 m, 0.6 m, 0.1 m and 3.5 m, respectively. A novel canopy-shaped (inclined) collector cover with an inclination of 30° and an in-built TES system that is structurally different from existing studies are the innovation of the study. Experiments were carried out and the data is presented in this work. The study focuses on the time-temperature relationship of ambient air, absorber plate and storage system. Hourly solar flux variation, air velocity, power potential and efficiencies of the system were also investigated. The average temperatures of the collector cover and storage were estimated and these were 45.93 and 42.67 °C, respectively. A maximum air velocity of 2.66 m/s was observed at the chimney base at a maximum solar flux of 938 W/m^2. A temperature difference of 25.47 °C was noticed between the absorber plate and air. The maximum theoretical and actual power outputs were 3.45 and 2.3 W, respectively. The overall, chimney and collector efficiencies of the system were estimated and these were 0.02682%, 0.0186% and 44.1%, respectively. Uncertainty analysis was also carried out to verify the reliability of the measured and estimated data. The power potential per collector area for the present SUT plant was 0.239 W/m^2 which is 305–505% higher than the similar scale SUT plants.

1. Introduction

Solar updraft tower (SUT) is one of the effective methods to generate electrical power using solar energy. There are three major components in the system: collector cover, absorber plate and chimney. A wind turbine coupled with a generator is used for the generation of electricity. The working principle of SUT is based on the greenhouse effect and buoyancy effect. Solar energy which falls on the collector cover is transmitted through it and absorbed by the absorber plate; thus, solar energy is converted to thermal energy. The shorter wavelength solar flux inside the collector cover is converted into a longer wavelength results an increase in temperature. As the air gets warmer, it becomes lighter and moves upward; to fill the space inside the domain, fresh air enters the system due to the buoyancy effect. Thermal energy is converted to kinetic energy and this energy can be converted to electrical energy by placing a wind turbine coupled to a generator. This concept was developed by Hans Gunther in 1931 [1,2]. Major advantages of the system are; air functions as working fluid; there is high operational reliability, low maintenance cost, simple design and structure and the model can be made with easily available material and enjoys a long life span. The first plant was built in Manzanares, Spain in 1981 [3]. The height of the chimney (H_c), the diameter of the chimney (φ_c) and absorber plate diameter (φ_{ab}) of the Spanish prototype were 194.6 m, 10.8 m and 244 m, respectively. The capacity of the plant was 50 kW and it was able to produce 36 kW. After a successful run period of 7 years, the plant collapsed due to a wind storm. Since then, a lot of studies have been carried out on this plant and its flow and performance characters.

An extensive literature study was carried out in this regard to trace further developments. Schlaich et al. [4] investigated the commercial and economic viability of large scale SUT plants having power capacity of 200 MW. Ghalamchi et al. [5] performed experiments for optimizing SUT geometric parameters. It had φ_{ab} and H_c of 3 m each. The inlet gap (i_g) varied from 0.04 to 0.14 m and φ_c varied from 0.1 to 0.3 m while flow parameters such as velocity and temperature were measured. It was observed that the system performed at its best at i_g of 0.06 m and φ_c of 0.1 m, respectively.

Xu et al. [6] carried out 2D numerical simulations to perform fluid, heat flow analysis and power output by considering the turbine and

* Corresponding author.
E-mail address: vpcm80@nitw.ac.in (V.P. Chandramohan).

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3D numerical study on estimating flow and performance parameters of solar updraft tower (SUT) plant: Impact of divergent angle of chimney, ambient temperature, solar flux and turbine efficiency

Pritam Das , Chandramohan V.P.*

Mechanical Engineering Department, National Institute of Technology Warangal, Warangal, Telangana, 506004, India

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Keywords:
Solar updraft tower
Divergent chimney
Flow analysis
Performance study
Overall efficiency
Correlations

ABSTRACT

A 3D numerical model was made to analyse the effect of divergence angle of chimney (Φ_{ch}), ambient temperature (T_a), solar flux (I) and turbine efficiency (η_{tur}) on wind flow and performance parameters of a solar updraft tower (SUT). A parametric study was carried out by varying Φ_{ch} from 1 to 5° for different I (600–900 W/m^2) and the results were compared with results for existing cylindrical chimney SUT (CC-SUT) plants. The range of T_a selected was 293–318 K and η_{tur} was 0.54–0.9%. Five different configurations of divergent chimney SUT (DC-SUT) plants were modelled. It was noticed that at Φ_{ch} of 2°, the average velocity of air at chimney base was enhanced by 58.9% compared to CC-SUT plant. The average absorber plate temperature increased from 316.4 to 332.85 K with an increase in I from 600 to 900 W/m^2 for Φ_{ch} of 2°. The maximum overall efficiency, theoretical and actual power output of the DC-SUT plant were 0.0307%, 3.99 W and 2.67 W, respectively. The exergy of DC-SUT was 58% higher when Φ_{ch} was increased from 1 to 2° at I = 900 W/m^2. Correlations were generated to calculate performance parameters as functions of geometrical parameters.

1. Introduction

Energy is the lifeblood of economy for developing countries such as India and China. With increase in population and technological advancement, energy plays a vital role in every sector. Increasing cost of fossil fuels and their rapid depletion have led to increasing interest in alternate sources of energy. Therefore, much attention has been paid by researchers to the use of non-conventional sources of energy. Solar updraft tower (SUT) plant is one of the methods to harvest solar power from the sun. SUT is also used for other applications such as ventilation, desalination, generating electrical power and agricultural food processing. It has three basic accessories. They are: absorber plate, solar collector cover and solar chimney. Also, a small wind turbine coupled with generator is needed near the chimney base (CB) to convert kinetic energy of air into electric power. The power generation options enable carbon-free electric generation which further leads to sustainable growth and development towards a green economy and safer environment. The theoretical concept of SUT plant was first developed by Hanns Gunther at the beginning of 19th century (Haaf et al., 1983), based on buoyancy effect. The first plant was built in Manzanares, Spain in 1981 under the supervision of German structural engineer J. Schlaich and the theoretical description of SUT was reported by Haaf et al. (1983). Later Schlaich et al. (2005) investigated the commercial and economic viability of a large scale plant (up to 200 MW).

There have been umpteen studies (both analytical and numerical) on the flow and performance estimation by varying geometrical configurations. Ramakrishna et al. (2017) theoretically estimated the performance characteristics of solar collector, absorber plate and chimney of SUT plant. Energy balance equations were used to estimate the radiation and convection heat lost from the solar collector. An extensive analysis on storage and chimney materials was made and suggestions were given to select materials appropriately. In another study by Ramakrishna et al. (2018) two different velocity ranges were chosen and the optimized design factors of a turbine blade were calculated for an SUT plant. Cao et al. (2013) investigated the effect of environmental conditions on the performance of SUT. They took geographical data such as solar intensity, air velocity and ambient temperature (T_a) of particular

* Corresponding author.
E-mail address: vpcm80@nitw.ac.in (V.P. Chandramohan).

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Estimation of flow parameters and power potential of solar vortex engine (SVE) by varying its geometrical configurations: A numerical study

Pritam Das, Chandramohan V.P.*

Mechanical Engineering Department, National Institute of Technology Warangal, Warangal, Telangana 506004, India

ARTICLE INFO

Keywords:
Solar vortex engine
Vortex generator
Solar updraft tower
Air entry slots
Flow parameters
Power output

ABSTRACT

Solar vortex engine (SVE) is a novel concept for creating artificial vortices and airflow using solar energy. The working principle of SVE is similar to the solar updraft tower (SUT) plant, but SVE replaces the chimney of SUT plant. SVE consists of air entry slots (AES), guide blades and top and base plates having an outlet and base holes, respectively. In the present study, a 3D model of SVE with an external bounding structure (EBS) was developed to evaluate the flow parameters and visualize the flow and vortex generation inside the domain. The flow parameters were estimated by varying the top-hole diameter (0.2–0.5 m) and increasing inlet velocity at AES (0.2–0.7 m/s). The increase in top hole diameter from 0.2 to 0.5 m, flow parameters enhanced significantly and reached a maximum at 0.3 m and after it decreased. Higher inlet air velocity at AES enhanced flow parameters significantly. The optimum height was 0.702 m from base plate (0.1 m from the top plate) as it had the maximum velocity of 4.4 m/s and vorticity of 73.9 s^{-1}, so that a turbine can be fixed at this location to harness maximum energy. The average velocity, temperature, dynamic pressure, theoretical and actual powers of SVE with EBS for optimum case (top hole diameter of 0.3 m, inlet velocity at AES of 0.7 m/s) were 1.4 m/s, 311.1 K, 1.6 Pa, 3.5 and 2.3 W, respectively. The preliminary study results shown that, SVE is one of the potential options to replace the chimney of SUT plant for generating electric power.

1. Introduction

With growing energy demand due to an increase in population and modernization of the society, usage of renewable sources of energy is one of the most sustainable and economically viable options. Scarcity in fossil fuel and restriction in carbon production results in researchers looking for the potential of renewable energy sources such as solar, wind energy etc. Solar vortex concept can be used to harness energy by creating an artificial vortex to acquire mechanical energy while moving with upward convection. The device used to create the artificial vortex using solar energy is called a solar vortex engine (SVE). Tornados, hurricanes, waterspouts and dust devils have naturally created vortices. In SVE, artificial vortexes are generated using solar energy and these vortexes are used to run a turbine, so that the electrical energy can be harvested from the mechanical energy. The concept to increase the kinetic energy of wind by solar energy in a controlled manner and was first invented by Louis M. Michaud in 1975 [1]. Further investigations were carried out by Michaud [2,3] to get a detailed conclusion on heat to work energy conversion in the upward heat convection process.

The vortex created in SVE due to centrifugal force by the rotation of a mass of air and thus SVE drives the air upward like a solid structure. This solid structure alike generated vortex has a lot of kinetic energy and it can be useful to run a turbine. The pressure difference between the base of the vortex and ambient air has the potential to drive the turbine in SVE. A similar setup is used to generate electrical power called solar updraft tower (SUT) which consists of solar collector, absorber plate, turbine and a chimney. In SUT, a very tall chimney is needed so that the air uplifted in the canopy of SUT flows so that a turbine can run. The idea of an SUT plant was first reported by Hanns Gunther in 1931 [4]. Numerous theoretical investigations were performed and a first plant was erupted at Manzanares, Spain in 1981. The maximum air velocity at the chimney base was 15 m/s and a temperature gradient of 20 K was noticed inside the setup [5]. The chimney height of the Manzanares plant was 194 m and because of that, the plant collapsed after serving 7 years. It is a complex process to design such a chimney and maintenance of the plant is also tough. The design procedures and expenses involved in such a plant are plenty. As SVE technique is novel and unique which is the only method where tall chimney of SUT plant can be replaced so that the overall capital investment of SUT plant can be reduced and stability of the plant can be increased. Therefore, there is a vide scope on this plant and it needs to be investigated more by researchers. Before making

* Corresponding author.
E-mail address: vpcm80@nitw.ac.in (V.P. Chandramohan).

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Review Article

A review of natural energy storage materials used in solar dryers for food drying applications

Vishnuvardhan Reddy Mugi [a], Pritam Das [a], Ramakrishna Balijepalli [b], Chandramohan VP [a,*]

[a] *Mechanical Engineering Department, National Institute of Technology Warangal, Warangal, Telangana, 506004 India*
[b] *Mechanical Engineering Department, Rajeev Gandhi Memorial College of Engineering and Technology, Nandyala, Andhra Pradesh, 518501 India*

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ABSTRACT

The application of solar energy in food drying is a well-known technology. Open sun drying has some limitations but these limitations can be overcome in solar dryers. Thermal energy storage (TES) systems for solar dryers receive wide attraction as the TES system enhances the performance of dryers. Among TES materials, the natural energy storage materials are inexpensive and easy to collect in remote areas. This work extensively reviews solar dryers with various natural energy storage materials. It discusses thermo-physical properties of various natural energy storage materials. The performance analyses of direct, indirect, mixed-mode and hybrid mode solar dryers with and without natural energy storage materials are reviewed. natural energy storage materials placed in different locations such as kind 1, kind 2 and kind 3 are discussed. The performance of frequently used natural energy storage materials such as sand, sandstone, gravel, rocks, pebbles, limestone, clay, soil, bricks, quartz, reinforced concrete and water are reviewed. The drying time saving is in the range of 9.52–47.2% using natural energy storage materials compared to conventional solar dryers. The drying efficiency (η_d) and thermal efficiency (η_{th}) of the direct solar dryer with natural energy storage are in the range of 2.85–42% and 9.9 – 58.2%, respectively, for various food materials. The drying air temperatures inside the chamber are 5 to 20 °C higher than the atmospheric temperature even after sunset hours with the natural energy storage system. The progress, benefits, challenges and recommendations of natural energy storage materials for use in solar dryers are also addressed in this paper.

1. Introduction

To maintain harmony between the growing world population and food supply, food wastage must be controlled and minimized at the time of harvesting, processing, marketing and distribution. The quality, taste, color and flavor of food materials degrade because of inadequate storage units (cold storage) and lack of processing techniques. Many developing countries experience significant losses in agricultural food products. It is calculated that the total post-harvesting losses in fruits and vegetables are 30 to 40% of the total production [1] and this is one of the main reasons for the increase in food prices. Solar drying is one of the best food preservation techniques to dry agricultural food products because the energy from the sun is free and abundantly available. Open sun drying (OSD) is a century-old practice but the exposure of food products to direct solar radiation deteriorates the quality and color of end products. It has other limitations such as dust formation, wastage because of rain and disturbance from animals and birds. Solar dryers can overcome the limitations of OSD [2]. The solar dryers are classified into two main types such as natural and forced convection solar dryers (Fig. 1).

- Natural convection solar dryers – airflow is generated by buoyant forces
- Forced convection solar dryers - air is generated by a fan or blower powered by electricity or solar PV panels.

There are four groups of solar dryers in either natural or forced convection: direct, indirect, mixed-mode and hybrid solar dryers [3]

- Direct solar dryer (DSD): It contains a box or greenhouse covered by transparent cover under which the products are placed on a tray. Solar energy is transmitted through a transparent glass and reaches the products directly.
- Indirect solar dryer (ISD): It has a solar air collector (SAC) where the air is heated. SAC is fixed with a drying cabinet where the products are placed on trays. A chimney is on the top for moisture transfer.

* Corresponding author.
E-mail address: vpcm80@nitw.ac.in (C. VP).

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Review

Recent advances in thermochemical methods for the conversion of algal biomass to energy

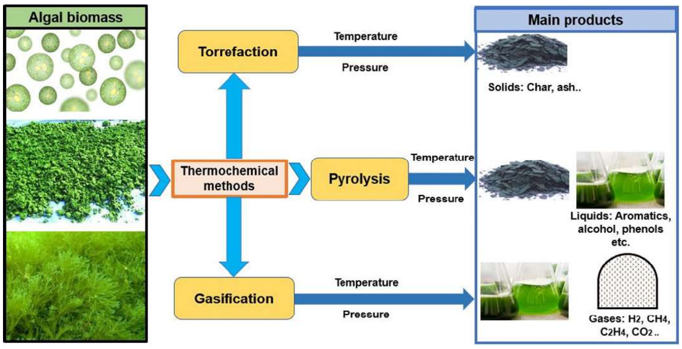
Pritam Das [a], Chandramohan V.P. [a,*], Thangavel Mathimani [b], Arivalagan Pugazhendhi [c]

[a] *Mechanical Engineering Department, National Institute of Technology Warangal, Warangal, Telangana 506004, India*
[b] *Department of Energy and Environment, National Institute of Technology Tiruchirappalli, Tiruchirappalli 620 015, Tamil Nadu, India*
[c] *Innovative Green Product Synthesis and Renewable Environment Development Research Group, Faculty of Environment and Labour Safety, Ton Duc Thang University, Ho Chi Minh City, Viet Nam*

HIGHLIGHTS

- A review is made on recent developments on thermochemical processes of algal strains.
- The common methods torrefaction, pyrolysis, and gasification processes were extensively reviewed.
- Different algal strains used in thermochemical methods and their conditions were compared and discussed.
- The yield, quality of solid, liquid and gaseous products obtained through thermochemical methods were reviewed.
- End product percentage, advantages and challenges of the torrefaction, pyrolysis, and gasification were summarized.

GRAPHICAL ABSTRACT



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ABSTRACT

Thermochemical techniques are being operated for the complete conversion of diverse biomasses to biofuels. Among the feedstocks used for thermochemical processes, algae are the promising biomass sources owing to their advantages over other feedstocks such as biomass productivity, renewability and sustainability. Due to several advantages, algal biomass is considered as a source for third generation biofuel. This review work aims to provide a state-of-the-art on the most commonly used thermochemical methods namely torrefaction, pyrolysis, and gasification processes. Furthermore, the production of biofuels from algal biomass was comprehensively articulated. Different algal strains used in thermochemical techniques and their conditions of operation were compared and discussed. The yield and quality of solid (char), liquid (bio-oil) and gaseous (syngas) products obtained through thermochemical methods were reviewed and analysed to understand the efficacy of each technique. End product percentage, quality and advantages of the torrefaction, pyrolysis, and gasification were summarized. It is found that the biofuel produced from the torrefaction process was easy to store and deliver and had higher utilization efficiency. Among the existing thermochemical methods, the pyrolysis process was widely used for the complete conversion of algal biomass to bio-oil or char. This study also revealed that the gasification (supercritical) method was the most energy efficient process for conversion of wet algal biomass. The reactor used in the thermochemical process and its subprocess was also highlighted. This study revealed that the fixed bed reactor was suitable for small scale production whereas the fluidized bed reactor could be scaled up for industrial production. In addition to that environmental impacts of the products were also spotlighted. Finally, the perspectives and challenges of algal biomass to bioenergy conversion were addressed.

* Corresponding author.
E-mail addresses: vpcm80@nitw.ac.in (C. V.P.), arivalagan.pugazhendhi@tdtu.edu.vn (A. Pugazhendhi).

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