



(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)



## Impact Factor: 8.699

## Volume 14, Issue 4, April 2025

⊕ www.ijirset.com ⊠ ijirset@gmail.com 🖄 +91-9940572462 🕓 +91 63819 07438





www.ijirset.com |A Monthly, Peer Reviewed & Refereed Journal| e-ISSN: 2319-8753| p-ISSN: 2347-6710|

#### Volume 14, Issue 4, April 2025

#### |DOI: 10.15680/IJIRSET.2025.1404666|

# **CFD** Analysis of Solar Tunnel Dryer

#### M.Chinnamaruthu, S.Jeyaseelan, S.Mohammed Imran Ali, A.Mohammed Saligh, M.N.Naveen

UG Student, Department of Mechanical Engineering, Adhiyamaan College of Engineering(Autonomous), Hosur,

Tamil Nadu, India

Asst.professor, Department of Mechanical Engineering, Adhiyamaan College of Engineering(Autonomous), Hosur,

Tamil Nadu, India

**ABSTRACT**: Energy plays a vital role in the economic, social, and industrial advancement of any country. Over the past few decades, global energy demand has been rising at an alarming pace due to factors such as population growth, industrialization, and transportation. The ongoing reliance on fossil fuels has led to an energy crisis and environmental degradation on a worldwide scale. Among various alternatives, solar energy stands out as a significant renewable resource capable of meeting all energy requirements. Key applications of solar energy include solar water heating, solar space heating and cooling, solar cooking, solar crop drying, and solar power generation. The most straightforward method to harness solar radiation is by converting it into thermal energy for heating purposes through solar collectors. Solar dryers, due to their inherent simplicity, are cost-effective and are utilized for numerous domestic and commercial applications, including space heating, crop drying, and wood seasoning. This paper examines the thermal characteristics of airflow within a solar tunnel dryer across different temperature zones. A two-dimensional numerical simulation of heat transfer, velocity, and temperature was performed using the CFD software FLUENT VERSION 16. The CFD modeling entails numerical solutions to the conservation equations for mass, momentum, and energy, which are employed to model the convective heat transfer process under the following assumptions: (a) the flow is steady, fully developed, turbulent, and two-dimensional; (b) the fluid is incompressible; and (c) the duct wall, absorber plate, and roughness material are homogeneous and isotropic.

#### KEYWORDS: Solar Drying Chamber, ANSYS FLUENT, CFD, Drying Chamber, Coriander.

#### I. INTRODUCTION

In recent years, the utilization of solar energy has achieved significant advancements. The ongoing quest for alternative energy sources, driven by the perceived depletion of fossil fuels, has propelled this trend. Its popularity has surged as fossil fuel prices continue to escalate. Among all renewable energy sources, solar energy stands out as the most plentiful, available in both direct and indirect forms. Solar energy applications are primarily categorized into two types: the first involves the direct conversion to electricity through solar cells (electrical applications), while the second encompasses thermal applications. These thermal applications include solar heating, cooling, drying, cooking, ponds, distillation, furnaces, thermal power generation, and water and air heating, among others. A comprehensive overview of the principles and prior research on solar dryers and solar air heaters highlights their importance in indirect and mixed-mode solar drying systems. A solar air heater functions as an energy collector that captures solar insolation through an absorbing medium to heat air. This renewable energy technology effectively dries agricultural products. A basic solar air collector comprises an absorber material, often featuring a selective surface, which captures solar radiation and transfers thermal energy to the air through conduction. The heated air is then directed to agricultural products such as chilies and grapes. The drying process involves removing moisture from the material's interior to the surface and subsequently eliminating it from the surface. Drying seeds is crucial to prevent germination and the growth of fungi and bacteria. Traditional methods of drying food crops in developing nations, such as India and Bangladesh, involve spreading products in the open sun, a practice known as open sun drying or natural sun drying.





www.ijirset.com |A Monthly, Peer Reviewed & Refereed Journal| e-ISSN: 2319-8753| p-ISSN: 2347-6710|

#### Volume 14, Issue 4, April 2025

#### |DOI: 10.15680/IJIRSET.2025.1404666|

#### **II. LITERATURE SURVEY**

#### 1. Computational fluid dynamics analysis of greenhouse solar dryer

Innovative technologies are needed to make the life easy. The innovations are best used using renewable source of energy. Greenhouse solar dryer is a device used for drying purpose. Computational fluid dynamics analysis simulation is performed on greenhouse solar dryer when exposed to an ambient temperature on a hot sunny day for free convection and forced convection processes. The mass flow rate and the thickness of polycarbonate roof sheet material vary. The average temperature of the dryer is analyzed using simulation. The maximum temperature obtained by forced convection is 71°C for 0.025 kg/s mass flow rate, which is 41% more than that obtained by natural convection.

#### 2. A Study on CFD Analysis of Solar Wood Dryer

Because of its low cost and simple operation, solar drying lumber is considered an attractive method to dry small quantities of lumber. Solar power can be very efficiently used for drying wood; a solar wood dryer is best example for such. Since designing, developing and testing of such a solar dryer physically is not economical, the same can be tested using CFD software 'ANSYS FLUENT' which gives satisfactory results however the results have to be verified. In this paper we carry out the CFD Analysis on a Solar Wood Dryer using the software ANSYS FLUENT and various parameters like the Velocity of air inside the dryer and the temperature distribution in the dryer are studied. However the further validation can be done by experimentation.

## 3. CFD and experimental analysis of solar crop dryer with waste heat recovery system of exhaust gas from diesel engine

Crop drying is the method used to preserve the seasonal food crops during the non-seasonal periods in agricultural sector. In olden days, solar energy was used to dehydrate and preserve the food. Nowadays many new advanced technologies have been introduced. But due to electricity unavailability in rural areas and to utilize the abundantly available solar energy and the waste heat recovery of exhaust gas from the diesel engines used in the agricultural fields for water pumping. Our present work focuses on the CFD and experimental analysis of the solar crop dryer attached with flat plate collector and attached with diesel engine exhaust pipe heat exchanger. A comparison study was made between the crop dryer with and without exhaust pipe heat exchanger and found that when the exhaust pipe was attached there was an improvement in the increase in temperature compared without exhaust pipe. The copper tubes of exhaust pipe were also added with the fins to improve its heat exchanging efficiency.

#### 4. Design, development and CFD modeling of indirect solar food dryer

In this study, a solar powered indirect food dryer is designed and developed. The dryer design consists of a solar collector unit, drying chamber with two columns of four rack shelves, chimney for the exhaust air, and a solar powered fan. The outlet of the dryer is designed in a truncated pyramid geometry so that precipitation of condensed water would be minimized and additional heating of the drying air is possible at the exit. The dryer is developed and manufactured in Mekelle, Ethiopia. Computational Fluid Dynamics, CFD is employed for predicting a transient three dimensional flow field and temperature distribution within the drying chamber using a symmetric flow domain. The predicted air flow distribution in the vicinity of the rack shelves showed that the mean flow velocity is 0.14 m/sec for the lowest shelf and 0.12 m/sec for the other shelves due to cooling of the air. A significantly uniform airflow distribution is observed on the top three shelves compared to the bottom shelf. The inside of the drying chamber evolves towards a steady operating temperature of 315K. The temporal temperature distribution reveals that the food to be dried will evolve to this temperature in about 35 minutes. For validating the model, the temperature distribution on each rack shelf is measured along with the global solar irradiation. The maximum average temperature difference between the measurement and the CFD simulation is found to be 4.3 °C. Hence, the CFD model is able to produce a good qualitative and quantitative insight into the temperature distribution within the drying chamber, rack shelves, and symmetry plane.





www.ijirset.com |A Monthly, Peer Reviewed & Refereed Journal| e-ISSN: 2319-8753| p-ISSN: 2347-6710|

#### Volume 14, Issue 4, April 2025

#### |DOI: 10.15680/IJIRSET.2025.1404666|

#### 5. Computational fluid dynamics and experimental analysis of direct solar dryer for fish

Fish preservation is the most important post-harvest process in commercial fishery. The traditional methods of fish preservation are inefficient and susceptible to contamination. Few existing solar fish dryers are not designed for optimal drying performance. In this study, a direct solar dryer for fish was numerically modeled, fabricated and evaluated for performance enhancement. The modeling was performed using Computational Fluid Dynamics code to simulate different dimensions of the designed dryer at varying fan speeds. By applying desirability function method,  $(70 \times 60 \times 40)$  cm3 drying chamber with a plane of 25 cm away from the base for tray location gives optimal temperature and the best uniform air flow distribution. The performance of the fabricated dryer using the numerical model results was experimentally evaluated during the dry season and the wet season of the year without load. Maximum collector efficiency of 77.2% and temperature elevation of 26.70 C was observed at natural convection (0 m s-1 fan speed) for both seasons. Using root mean square error and mean bias error, predictions were within acceptable limit (10%) and there were no significant differences between the experimental and numerically predicted values by statistical t-test (p $\leq 0.05$ ) at fan speeds considered.

#### **III. METHODOLOGY**

#### RESULTS OF SOLAR TUNNEL DRYER AT 35°C



#### SECTION VIEW OF TEMPERATURE DISTRIBUTION



STREAM LINE RESULT OF TEMPERATURE DISTRIBUTION



STREAM LINE RESULT OF VELOCITY DISTRIBUTION





www.ijirset.com |A Monthly, Peer Reviewed & Refereed Journal| e-ISSN: 2319-8753| p-ISSN: 2347-6710|

#### Volume 14, Issue 4, April 2025

#### |DOI: 10.15680/IJIRSET.2025.1404666|



STREAM LINE RESULT OF PRESSURE DISTRIBUTION

#### RESULTS OF SOLAR TUNNEL DRYER AT 40°C



SECTION VIEW OF TEMPERATURE DISTRIBUTION



STREAM LINE RESULT OF TEMPERATURE DISTRIBUTION





www.ijirset.com |A Monthly, Peer Reviewed & Refereed Journal| e-ISSN: 2319-8753| p-ISSN: 2347-6710|

#### Volume 14, Issue 4, April 2025

### |DOI: 10.15680/IJIRSET.2025.1404666|

RESULTS OF SOLAR TUNNEL DRYER AT 50°C



SECTION VIEW OF TEMPERATURE DISTRIBUTION





#### **IV. CONCLUSION**

Due to the time-consuming and costly nature of physical experimentation for testing purposes, Computational Fluid Dynamics (CFD) offers a more efficient and cost-effective alternative for conducting tests on models and analyzing results with minimal investment of time and resources. Consequently, after evaluating the outcomes using CFD Ansys Fluent, satisfactory and practical results have been achieved. This study employed CFD analysis through FLUENT to investigate the fluid flow and heat transfer characteristics of a solar tunnel dryer at varying solar temperatures. The combined effects of turbulence and fluid reattachment were identified as key factors contributing to the enhancement of the heat transfer rate. The results and discussions clearly indicate that an increase in solar radiation temperature leads to a gradual rise in system temperature, thereby heating the air within the system, which facilitates the drying process of stored items. Additionally, it was observed that the heat source does not disrupt the airflow paths within the chamber, maintaining velocity and pressure distributions within acceptable limits. Undoubtedly, a primary objective of the CFD analysis of the solar tunnel dryer is to improve the design process related to heat transfer and fluid flow.





www.ijirset.com |A Monthly, Peer Reviewed & Refereed Journal| e-ISSN: 2319-8753| p-ISSN: 2347-6710|

#### Volume 14, Issue 4, April 2025

#### |DOI: 10.15680/IJIRSET.2025.1404666|

#### REFERENCES

- [1] Akinola A. Adeniyi, Abubakar Mohammed, KehindeAladeniyi, "Analysis of a Solar Dryer Box with Ray Tracing CFD Technique" International Journal of Scientific & Engineering Research Volume 3, Issue 10, October-2012.
- [2] S. D. Rajkotia, V. H. Modi, "Performance Improvement of Solar Dryer, Ijsr International Journal Of Scientific Research".
- [3] C.V.Papade, M.A.Boda, "Design & Development of Indirect Type Solar Dryer with Energy Storing Material" International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2163 Volume 1 Issue 12 (December 2014).
- [4] Sandeep Lutade, Dr. S.B. Thombre, "A Cfd Analysis Of Air Flow In A Stationary Drum Partially Filled With Solid Material" International Journal Of Research In Aeronautical And Mechanical Engineering.
- [5] Prof. P.W.Ingle, Dr. A. A. Pawar, Prof. B. D. Deshmukh, Prof. K. C. Bhosale," CFD Analysis Of Solar Flat Plate Collector" International Journal of Emerging Technology and Advanced Engineering
- [6] M. T. Madhav and M. R. Malin "The numerical simulation of fully developed duct flowsAppl. Math. Modelling, 1997, Vol. 21, August.
- [7] Ze-gao YIN\*1, Xian-wei Cao1, Hong-da SHI1, Jian MA2 "Numerical simulation of flow past circular duct" Water Science and Engineering, Jun. 2010, Vol. 3, No. 2, 208-216.
- [8] K.J. Chuaand S.K."ChouLow-cost drying methods fordevelopingcountries" Trends in Food Science & Technology 14 (2003) 519–528.
- [9] Madhlopa, A. and Ngwalo G. "convective solar dryer with a wood waste backup heater for dehydration of food"University of Malawi The Polytechnic, Private Bag 303, Chichiri, Blantyre 3.









# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY





www.ijirset.com