IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

COMPUTATIONAL ANALYSIS OF PCM BASED SOLAR DRYER

[1]Prajwal Jha, [2]Aakash Deep, [3]Pravin K Singh, [4]Mayank Srivastava

[1,2] Student, [3,4] Assistant Professor,

[1,2,3,4] Mechanical and Automation Engineering Department,

[1,2,3,4] AMITY University, Jharkhand, INDIA

Abstract: Solar energy is one of the renewable and sustainable sources of power that can be utilized for different applications in today's world. It is largely available abundance in both direct and indirect forms. As such the growth of efficient and low-cost equipment for the drying of agricultural products using solar energy grown thereby enlightening the quality of the products as well as enlightening the quality of life. The use of solar dryers in the drying of agricultural products can significantly reduce or remove wastage of product, food destroying, and at the same time's enhances the production of the farmers to better revenue resulting. The main aim of this paper is to design and optimization of a solar dryer and also to enhance the efficiency of a solar dryer as it focuses on cheap and high efficient solar dryers. The direct type natural convection solar dryer was designed and for increasing the efficiency of solar dryer Phase change material (PCM) was used. The designed and analysis was done using Ansys software using CFD as it will reduce the material wastage and also gives very accurate result in less time. For enhancing the efficiency PCM was effective material that stores solar energy in the form of latent heat. PCM is isothermal in nature, and thus it offers higher density energy storage and the capability to function in a different range of temperature conditions. Using PCM we can use solar dryer any climate condition.

***Index Terms* - CFD, Computational Analysis, Effectiveness, PCM, Solar dryer.**

I. INTRODUCTION

This Sun-drying under the open skies for preservation of food and agricultural crops has been practiced since ancient times. On the other hand, the process has many problems, e.g., products are disturbed due to rain, wind, humidity and dust etc. Apart from this, the process is labor-intensive and time-consuming, and requires a lot of product distribution to dry. Recently the output of the powerplant has been immense. But ultimately it increases the cost of the product. The modern practice of solar drying equipment offers a unique way that can process vegetables and fruits in clean, pest-free and hygienic conditions at national and international levels at zero energy costs. It consumes a lot of energy and time and takes up less space. Improves product quality. It makes the process more efficient and protects the environment. Solar drying may be used either in a complete quenching process or as an additive in the drying process. Solar dryer technology can be used in small food processing industries to produce healthy and high quality food products. This can also work to promote renewable energy sources.

Many countries produce large quantities of fruits and vegetables for local use and export. It was approximately 341.9 million metric tonnes in the year 1990 (FAO 1991) [1]. Even in Asia, India has the capacity to produce 27.8 million tons, while China has the capacity to produce 21.5 million tons [2]. Many types of fruits and vegetables contain large amounts of moisture. As a result, it has a high tendency for rapid deterioration in quality, up to the level of looting, if not stored in custom-managed storage areas. The food industry responsible for the food products market uses high-tech drying equipment, such as ice creams, dryers, drum dryers and steam dryers. The market value of such dryers is relatively high and only large commercial companies can afford them. Due to the high cost of large start-up prices, most companies with small-scale groceries that deal directly with farmers cannot afford the price. Therefore, inexpensive and easy-to-use drying systems have become popular with such companies and farmers. In many, far-flung agricultural regions of the Asian continent, a large number of natural materials and bio-fuel are abundant. However, you do not use the modern practice of having solar dryers due to a lack of scientific and technological know-how. Agriculture and other food products are dried by the sun and air in the open air for millions of years.

Solar drying is one of the most powerful and efficient ways of using solar energy in developing countries. However, there is little progress in the field of sun-drying technology [14]. Solar drying technology in developing economies (tobacco, tea, jaggery, coffee, gramom grapes, small and large Cardamom, chilli, coriander seeds, ginger, turmeric, black pepper, onion, garlic flakes, etc.) It has great potential. In such food products, even if large amounts of solar drying are invested, the cost of solar drying units is expected to be a small fraction of the retail price of the dry product.

Solar drying is different from an "open sunset." In solar drying, machines are used to collect solar radiation to activate the radiative power of the drying application. In many countries of the South East Asian continent, spices and herbs are regularly dried. However, due to weather conditions, the use of sun drying is limited due to loss due to the body's retaliation on unexpected rainy days. It is also noted that the direct exposure of agricultural products to the sun's rays during high-temperature days can create a hardening of cases. In the event of hardening, the hard shell hardens without agricultural products. It puts moisture inside the shell, which can cause the handling of agricultural products.

For these reasons, the use of the available solar panels can be used. Dry solar panels also guarantee good quality of dry product. Some of the literature review has been presented below.

Hii et al. [1] have demonstrated that sun drying (laying the yields under direct daylight) is practical, however the item got by it is of lower quality because of pollution by dust, bugs, feathered creatures, pets and downpour. Additionally, loss of nutrients, supplements and unsuitable shading changes because of direct presentation to bright beams, and it sets aside long effort to dry. Sunlight based dryers are specific gadgets that control the drying procedure and shield horticultural items from harm by creepy crawly bugs, residue and downpour. Umogbai et al. [2] made a correlation between sun drying and sun based drying and acquired that sun based dryers create higher temperatures, lower relative moistness, lower item dampness content and diminished deterioration during the drying procedure than sun drying. Rajeshwari and Ramalingam [3] have exhibited that the drying time if there should be an occurrence of sun oriented dryers contrasted with outside drying diminished by around 20 % and creates better quality dried items. Sun based dryers are accessible in a scope of size and plan, for example, burrow dryers, half and half dryers, even and vertical-type dryers, multi-pass dryers and dynamic and uninvolved dryers [4-11]. Hii et al. [1] arranged sunlight based dryer as indicated by their warming modes and the way in which the sun oriented warmth is used, to be specific constrained air flow or dynamic sun powered dryers and normal air dissemination or latent sun based dryers. Three unmistakable sub-classes of either the dynamic or aloof sunlight based drying framework can be distinguished relying on the plan or working rule of the dryer, method of drying and kind of item to be dried, in particular essential or direct mode, appropriated or circuitous mode and blended mode sun based dryers. It ought to be noticed that daylight may influence certain fundamental segments in the item, for example chlorophyll is immediately decayed. On the off chance that accessible spots are rare, aberrant mode sorts of dryers are favored for drying bigger amounts. In such instance of circuitous mode, nutritive estimation of the food item and shading is held. Chandrasekar et al. [12] designed the performance of an indirect forced convection solar drier integrated with heat storage material and investigated for chili drying. The drier with heat storage material enables to maintain consistent air temperature inside the drier. The inclusion of heat storage material also increases the drying time by about 4 hrs per day. The chili was dried from initial moisture content 72.8% to the final moisture content about 9.2% and 9.7% (wet basis) in the bottom and top trays respectively. Toshwani et al, [13] designed and fabricated direct natural convection solar dryer to dry tapioca in rural areas. According to his research it has been found that, A minimum of 7.56 m2 solar collector area is required to dry a batch of 100 kg tapioca in 20 hours (two days drying period). The initial and final moisture content considered were 79 % and 10 % wet basis, respectively [15]. The average ambient conditions are 32ºC air temperatures and 74 % relative humidity with daily global solar radiation incident on horizontal surface of 13 MJ/m2/day [14].

As per the literature review it has been found that no research has been done on the software analysis part to check the effectiveness of Solar dryer. The main objective of present investigation is: To optimize the design parameter od Solar Dryer which leads to Enhancement the efficiency of Solar Dryer. The whole analysis was performed using ANSYS Software.

II. RESEARCH METHODOLOGY

We have used Ansys 2019 R15 software for designing and analyzing solar dryer. Computational fluid dynamics, usually abbreviated as CFD, is a branch of fluid mechanics that uses numerical analysis and algorithms to solve and analyze problems that involve fluid flows. Computers are used to perform the calculations required to simulate the interaction of liquids and gases with surfaces defined by boundary conditions [15]. With high- speed supercomputers, better solutions can be achieved. Ongoing research yields software that improves the accuracy and speed of complex simulation scenarios such as transonic or turbulent flows. Initial experimental validation of such software is performed using a wind tunnel with the final validation coming in full-scale testing, e.g. flight tests. Computational Fluid Dynamics (CFD) provides a qualitative (and sometimes even quantitative) prediction of fluid flows by means of:

- Mathematical modeling (partial differential equations)
- Numerical methods (discretization and solution techniques).
- Software tools (solvers, pre- and post-processing utilities)

During analysis fluent Structural from Analysis system have been selected, then the materials property has added from engineering data or material library. The selection of material was based upon the literature review. The material which has been selected for analysis was wood as base part, glass which produce green effect and paraffin wax for storage of energy. The 3D sketch was designed in Geometry and open design modeler. The dimension of box is (800 × 600 × 500) mm one side, and 100 mm another side. **Fig.** 1 is showing the 3D structure of Solar dryer.

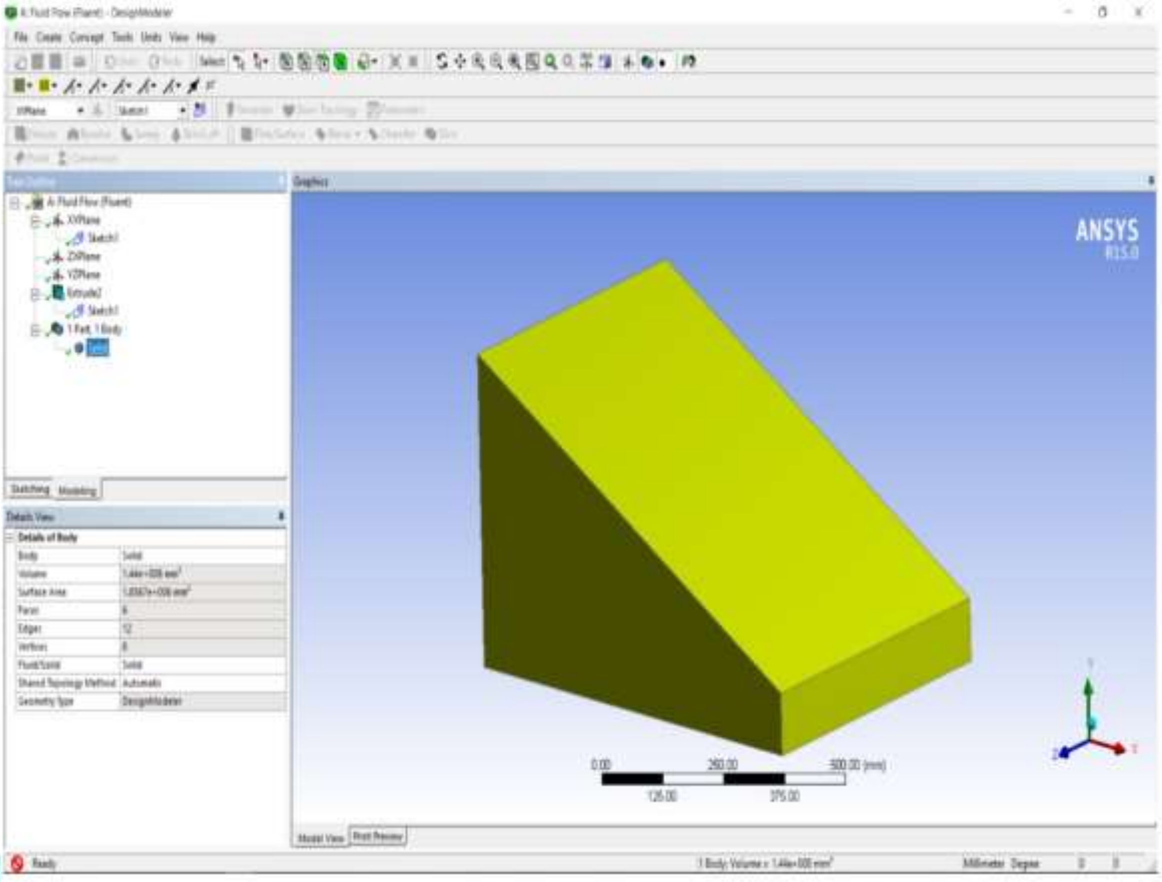

Figure 1: 3-D Structure diagram of Solar dryer having dimension (800 × 600 × 500) mm.

After 3-D plotting the next step was Meshing. The main function of meshing is to provide iteration method to get best result. So, with an aim to get best result, the meshing was generated on the object, fine meshing with 80,000 elements were selected during ANSYS Software. The fine meshing is helpful for getting the accurate result. **Fig.**3 is showing the flow chart of the procedural steps of the analysis. **Fig.** 2 is showing the object with meshing of 80,000 grids.

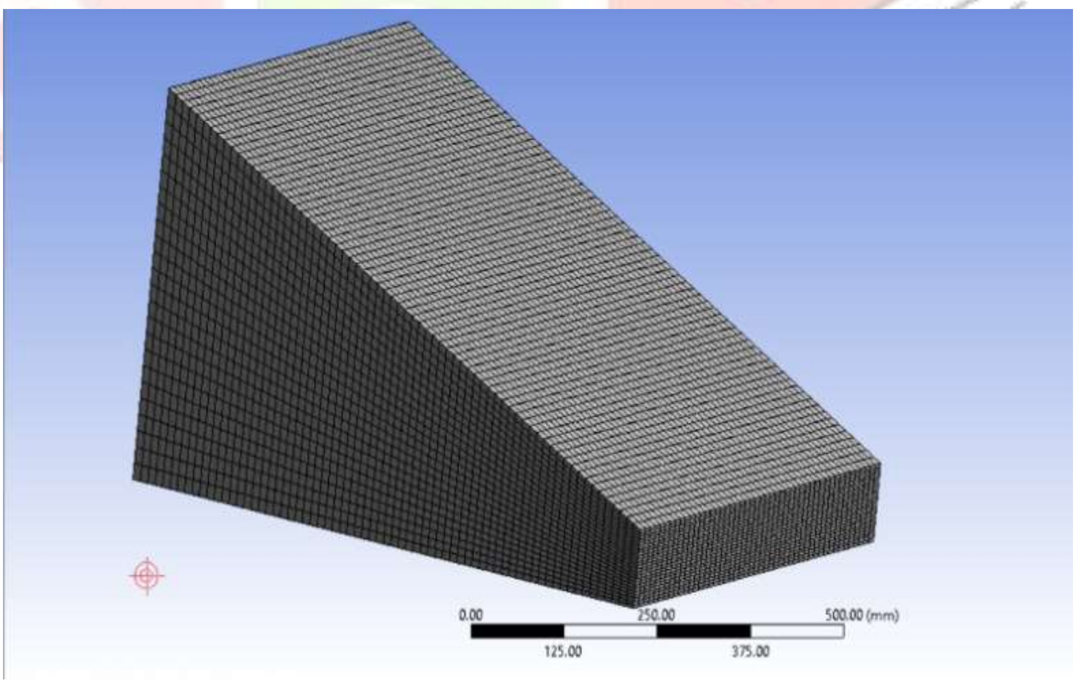

Figure 2: Meshing of solar dryer object

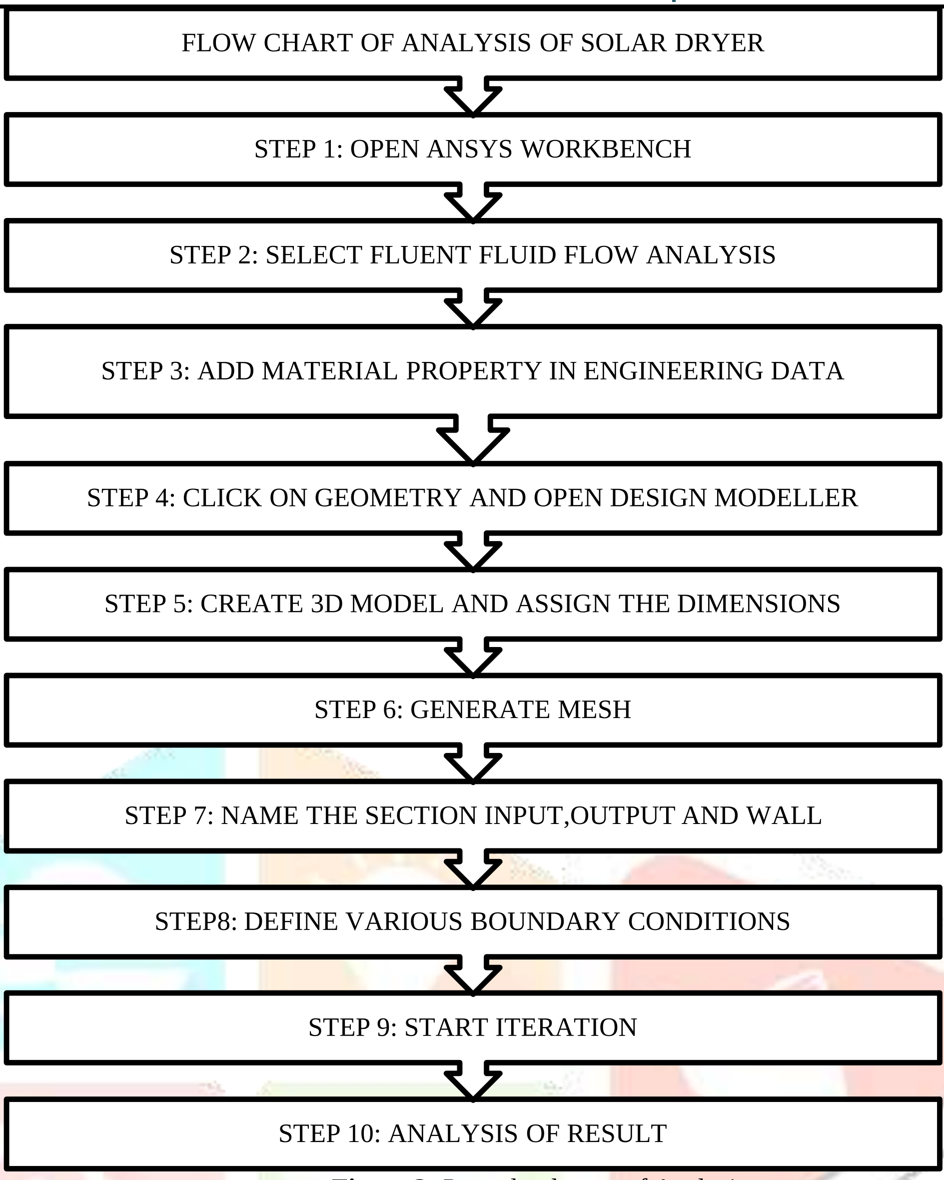

Figure 3: Procedural steps of Analysis

III. RESULTS AND DISCUSSION

A 3D CFD modeling and simulation is performed to predict the flow and temperature of solar dryer distribution within the drying chamber. Total 80,000 elements have been generated to get the accurate results. The color of wooden box is selected as in a black color as black is a good absorber of heat. The boundary condition shows that the designed solar dryer can produce maximum 315ºC temperature at the middle portion of a solar dryer as shown in **fig.** 4. As shown in figure the colored portion is the middle part of the dryer box. The red zone shows the maximum temperature which is 315 ºC. The analysis shows that the temperature distribution in solar dryer are in different colors. The red color indicates the maximum temperature which is in the middle of solar dryer and yellow indicates quite less than max temperature, green indicates less than yellow, and blue denotes the minimum temperature. **Fig.** 5 shows the color difference during the analysis.

The high temperature can be stored in the Solar dryer box and produce a Green effect. This solar food dryer will be operated by using the help of the solar energy. In a nation like India 300 days out of 365 days are sunny have a huge valuable thing of solar energy. The government is likewise effectively promising the utilization of inexhaustible wellsprings of vitality like sun-based vitality by the condition endowments on sun powered boards, sun powered siphons, sun-based water warmers, sunlight-based devices and sun-based lights and so on. So, it's a decent chance to apply these plans.

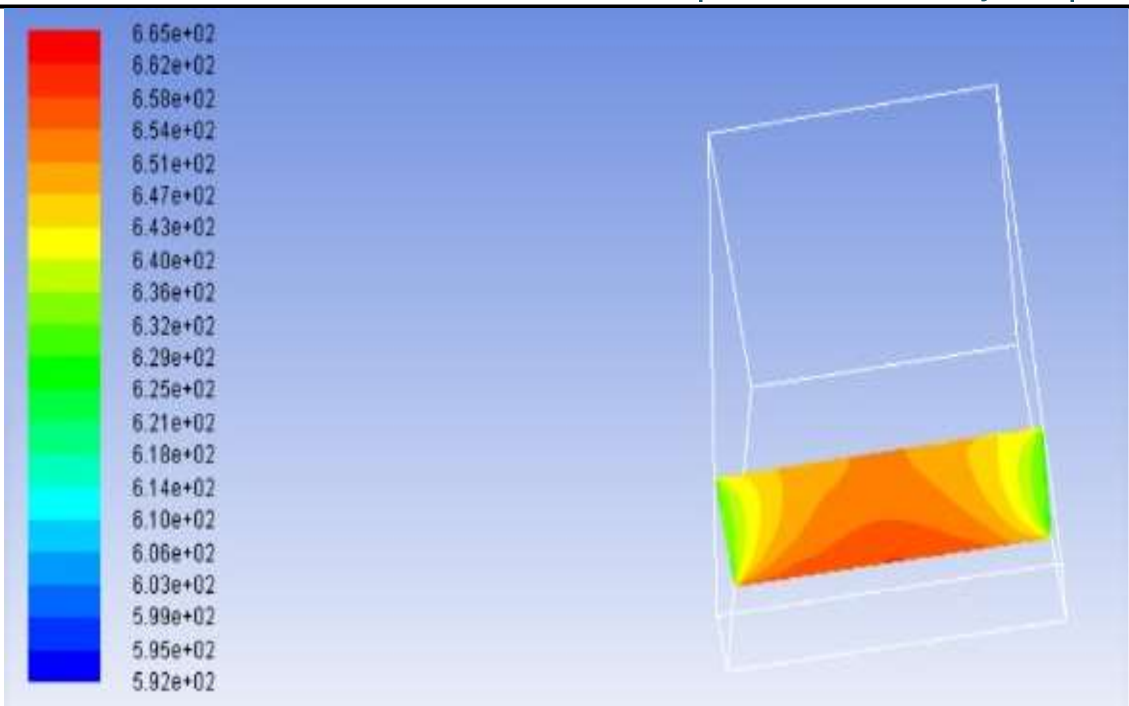

Figure 4: Temperature contour inside the middle of the solar dryer

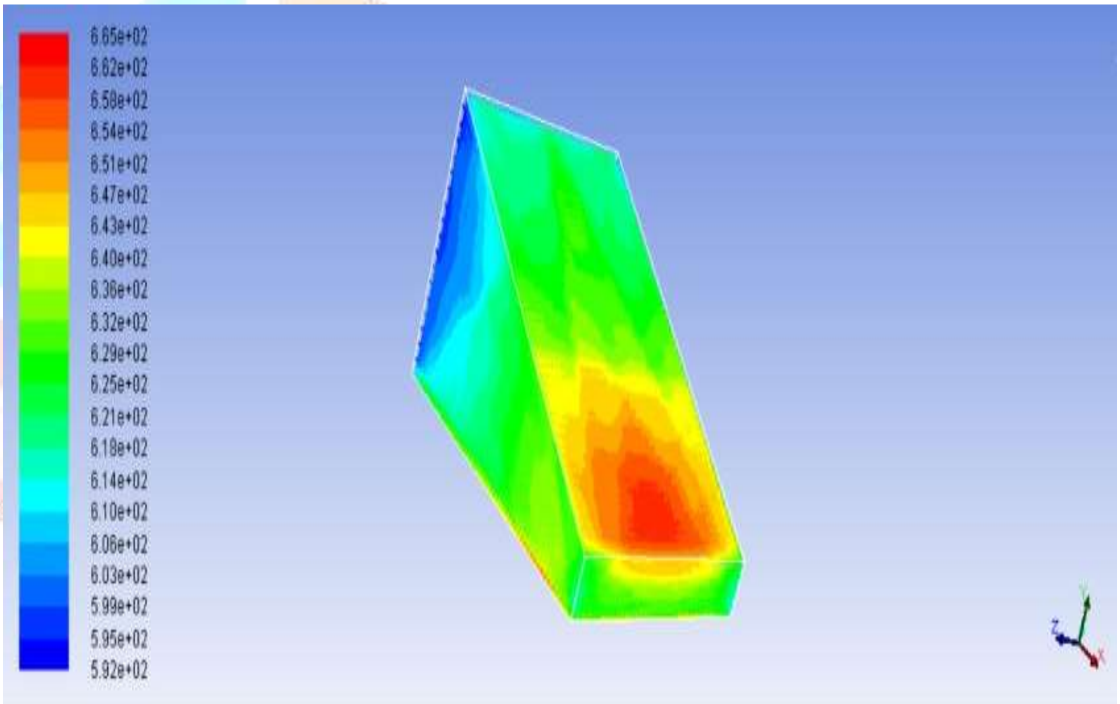

Figure 5: Analysis of temperature variation in the solar dryer

IV. CONCLUSION

The CFD analysis shows that the Solar dryer can produce maximum of 315 ºC which is much effective as compare the Sun drying system. Various types of solar dryer have also been discussed in the manuscript and based on the research the CFD analysis was performed. The present analysis provokes for the practical implementation of this developed solar food dryer can still be made better upon especially in the feature of reducing the drying time, and also the probable energy storage system of heat energy within the complex mechanism by compact vary in degree in the physical size of the solar energy collector. We also take the pre calibrated meteorological data which is readily able to be used to the users of solar substances to ensure empowered efficiency for effectiveness working of the network. Such facts provided will doubtless guide the associated farmers on when to dry their agricultural substances and when not to dry those useful substances in the solar dryer's.

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