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Soft Computing Simulation of Different Shapes of Solar Greenhouse Dryers For Resin Coated Marble

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Abstract: *An experiment was conducted in the 4th week of May 2018, for drying of resin coated marble at Udaipur climatic conditions (Latitude: 24.59^{0}N, Longitude: 73.73^{0}E, Mean Sea Level: 598m) in Southern Rajasthan, India. Three different shapes of solar greenhouse dryers (Insulated North Wall Type, Raised Arch Type and Solar Tunnel Type) with 200 micron polyethylene sheet were taken for thermal modelling using software solidworks 2018. The thermal models were developed for each greenhouse dryer. Each model so developed was evaluated and validated experimentally. Out of the said greenhouses, the solar tunnel type greenhouse dryer was selected which fulfils thermal need of the resin coated marble, of raising the temperature above 45^{0}C but below 60^{0}C. Evaluated on the basis of thermal need of the resin coated marble if the temperature falls below the lower limit or exceeds the upper limit then north wall and south wall of the dryer were insulated respectively. It was found that the solidworks 2018 is a good tool for simulation of the greenhouse dryers as the simulated temperatures differed from their experimental values by ±2^{0}C. Now the design and development of solar greenhouse dryers of different sizes and shapes at different climatic conditions is feasible without practical demonstration of the projects.*

Keywords: *resin coated marble, insulated north wall type, raised arch type, solar tunnel type, solar greenhouse dryers, thermal modelling, ambient temperature, simulated temperature, and solidworks 2018.*

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I. Introduction

Energy is a critical factor for socio-economic development of the human being. There is a direct relation between consumption of energy and economic growth. The living standard of a human being is evaluated by per capita consumption of energy. For production of low temperature of the range of 25–45^{0}C, the solar greenhouse dryers are the best solution than open sun drying and Resin line machine. Three different shapes of dryers were examined for drying of resin coated marble.

Kokate et al. (2017) developed a solar dryer to assist plastic industry. For preconditioning and dehydration of Nylon–6 and Polypropylene (PP) about 3–5% of total energy was required. For PP material the maximum temperature rise was up to 70ºC hence with the same dryer design preheating can be done. They developed a mathematical model of solar dryer. Many parameters were responsible for predicting air temperature. Psychrometric chart was used to explain it. The temperature of 55–60ºC was achieved inside the dryer. The following parameters namely solar intensity and the outside wind velocity of absorber were responsible for inside air drying temperature.

Kumar et al. (2017) observed the need of greenhouse dryer and its functioning. Where the small wavelength light enters the greenhouse and is soaked by internal walls of the greenhouse, and the high temperature air then is retained by walls and roof. Hence the practical working of the greenhouse dryer whether passive or active is justified.

Prakash et al. (2016) focused on different techniques of solar drying where efficiency of drying, prediction of temperature, moisture in crop, rate of drying, varied colors and variety in crops and their quality were studied. Computational fluid dynamics (CFD) is used for analysis using ANFIS software. Mathematical modeling suggests accurate results.

Sahdev and Dhingra (2016) successfully designed greenhouse with desired Quonset shape which is widely used for agricultural purpose. The direction of west–east is highly suitable because it is highly open to the sun. The results evaluated are good in quality as it provides protection from dirt, insects, rains etc.

Chauhan et al. (2015) studied the areas of software usage for solar dryer processes. Dynamics of fluid can be done by ANSYS and FLUENT. MATLAB and FORTRAN can be helpful in mathematical modeling. For statistical analysis SPSS can be used.

Aghbashlo et al. (2015) analyzed a greenhouse for chamomile flowers, they used TRNSYS software. They wrote the program in Compaq visual FORTRAN programming language. The root normalized mean square error was less than 9.3%. They found that TRNSYS is a good tool for simulation of solar dryers' designs. Now we can design and develop a solar greenhouse dryer with large range of materials at variety of climate conditions without requirement of the practical demonstration projects.

II. Method, Material And Modelling

The thermal modelling of the greenhouse is done by taking some assumptions into account. Modelling is done by the use of dimensionless numbers. The type of flow (laminar or turbulent) of air inside the greenhouse is determined by two methods, by using direct formula of calculating Rayleigh number and another by calculating the Rayleigh number using Grashof number and Prandtl number. The energy balance of the glaze of the greenhouse is done by using absorptance, reflectance and transmittance of the incoming radiations. The collector area of the greenhouse is calculated by two methods, one by using extreme temperature method and second by using aspect ratio method. In extreme temperature method the three temperatures highest, medium and lowest at the Udaipur climatic condition is selected namely 0^0C, 25^0C and 50^0C. In this way, the minimum collector area is calculated which will maintain the required temperature inside the greenhouse round the year. By using aspect ratio method the floor area of the greenhouse is calculated. The ergonomics involved in loading of the sample of marble in the greenhouse, decides the height. By using calculated dimensions of floor area, minimum area of the glaze material and height of the greenhouse, the final dimensions of the greenhouse are obtained. The three different shapes of greenhouses (Insulated North Wall Type, Raised Arch Type and Solar Tunnel Type) are taken for thermal modelling using software Solidworks 2018. Polyethylene sheet of 200 micron is used as a glaze material for all the three shapes of greenhouses.

III. Results And Discussion

The geometry of the solar greenhouse dryers were modelled in Solidworks and the created models were simulated and analyzed in Solidworks Flow Simulation 2018 SP0.0. Electronic data logger was used for measuring the heating air temperature above the marble samples, digital lux meter for intensity of solar radiations, digital thermo-hygrometer for temperature and relative humidity of the ambient air and vane type digital anemometer for velocity of ambient air. The least count of the electronic data logger was 0.1^0C, the least count of the digital lux meter was 1 w/m^2, the least count of the digital thermo-hygrometer was 0.5^0C and the least count of the vane type digital anemometer was 0.1 m/s. The measurements other than heating air temperature will be useful in calculating the thermo-hydraulic performance parameters and very useful in developing the simulation software.

3.1 Insulated North Wall Type Greenhouse Dryers (GHD)

Size of GHD : 0.6m × 0.42m × 0.86 m

Glazing material : Polyethylene sheet of 200 micron thickness

The experiment was conducted in peak sun shine hours from 11.00 AM to 3.00 PM on 24th May 2018 at Udaipur climatic condition. The observations were taken for an interval of one hour. The time of drying is given in the form of range because the average values of the observations are taken. The average rise in heating air temperature inside the greenhouse above its ambient value is 39.07^0C. At every hour the simulation is done in Solidworks 2018 and the simulated (predicted) values of the temperatures are shown.

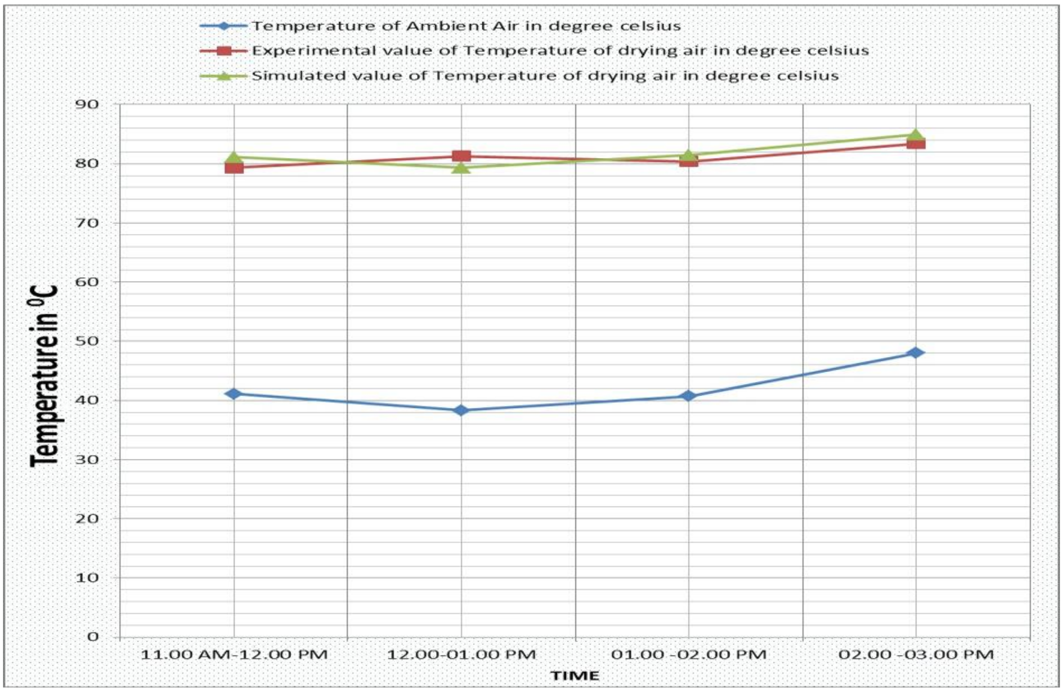

Figure 1. **Variation of Ambient Temperature, Experimental Temperature and Simulated Temperature of Air inside Insulated North Wall Type Greenhouse Dryer with Time**

The variation of ambient temperature, experimental temperature and simulated temperature of air inside the insulated north wall type greenhouse dryer with time of the day from 11.00 AM to 3.00 PM is presented in the graphical form for an interval of one hour. (Fig.1) Average temperature difference between experimental values and the simulated values is only 0.6^0C.

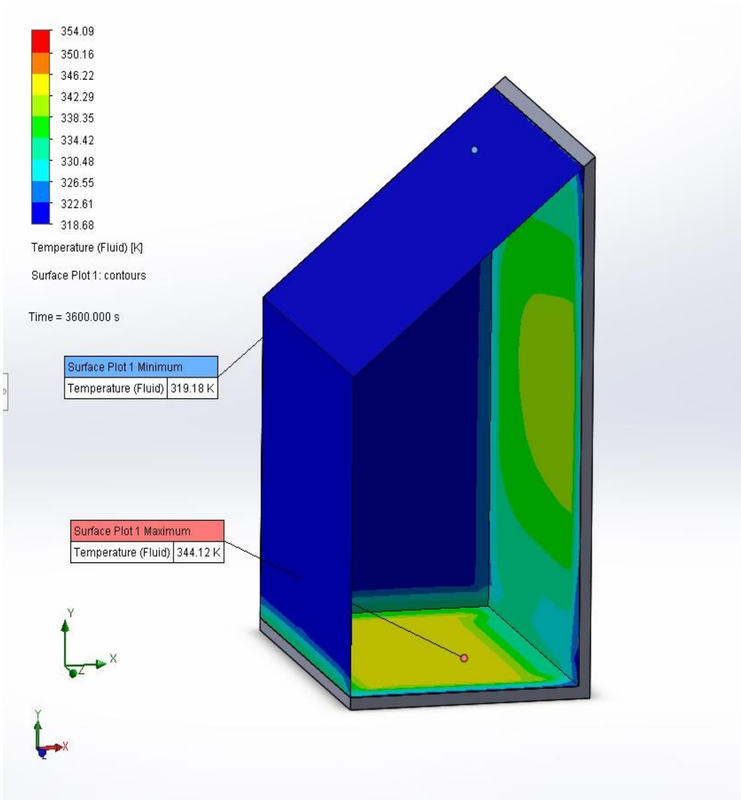

Figure 2. **Temperature Distribution of Air inside the Insulated North Wall Type Greenhouse Dryer for 11.00 AM To 12.00 PM**

The thermal performance of the dryer is shown by the temperature distribution of air inside the insulated north wall type greenhouse dryer for 11.00 AM to 12.00 PM. The maximum and minimum temperature of the air inside this greenhouse dryer is 344.12K (71.12^{0}C) and 319.18K (46.18^{0}C), respectively. (Fig. 2)

3.2 Simulation of Raised Arch Type Greenhouse Dryer

Size of GHD : 0.66 m x 0.60 m x 1.14 m
Glazing material : Polyethylene 200 micron sheet

The experiment was conducted in peak sun shine hours from 11.00 AM to 3.00 PM on 25th May 2018 at Udaipur climatic condition. The observations were taken for an interval of one hour. The average rise in temperature of air inside the greenhouse above its ambient value is 37.42^{0}C. The time of drying is given in the form of range because the average values of the observations are taken. For every hour the simulation is done in solidworks 2018 and the simulated (predicted) values of the temperatures are shown.

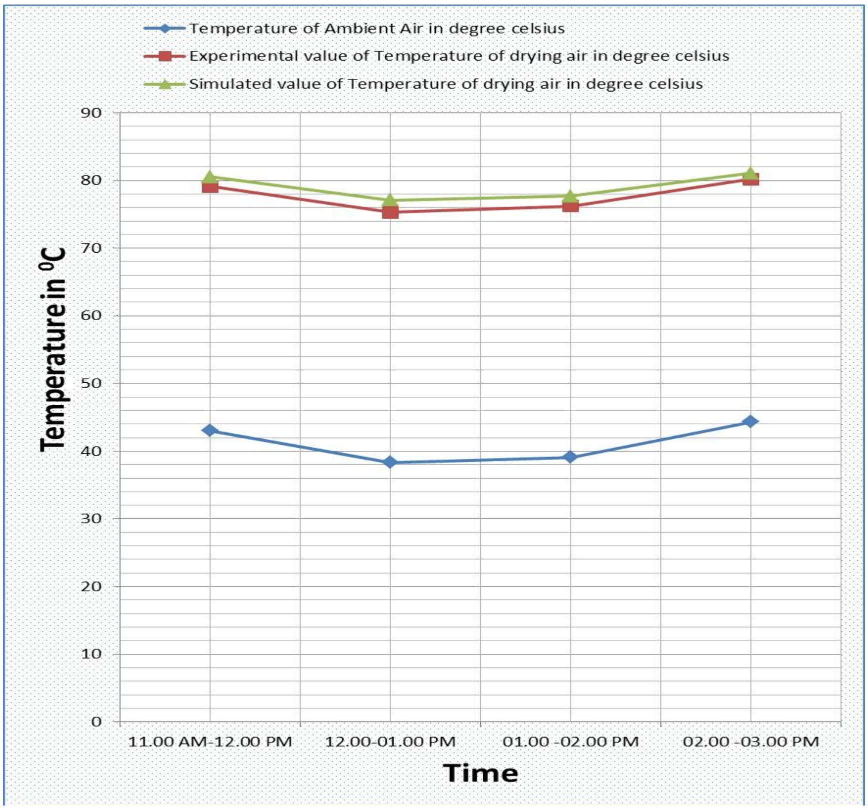

Figure 3. **Variation of Ambient Temperature, Experimental Temperature and Simulated Temperature of Air Inside Raised Arch Type Greenhouse Dryer with Time**

The variation of ambient temperature, experimental temperature and simulated temperature of air inside the raised arch type greenhouse dryer with time of the day from 11.00 AM to 3.00 PM is presented in the graphical form for an interval of one hour. (Fig.3) The average temperature difference between experimental values and the simulated values is only 1.34^{0}C.

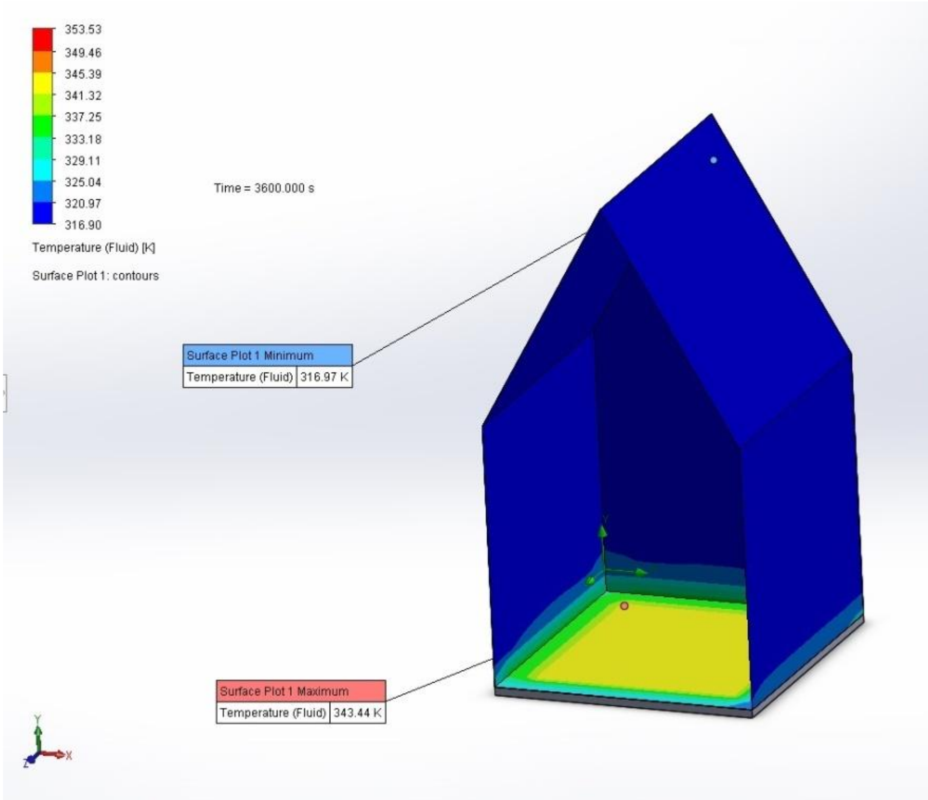

Figure 4. **Temperature Distribution of Air inside the Raised Arch Type Greenhouse Dryer for 11.00 AM to 12.00 PM**

The thermal performance of the dryer is shown by the temperature distribution of air inside the raised arch type greenhouse dryer for 11.00 AM to 12.00 PM. The maximum and minimum temperature of the air inside this greenhouse dryer is 343.44K (70.44^{0}C) and 316.97K (43.97^{0}C), respectively. (Fig.4)

3.3 Simulation of Solar Tunnel Type Greenhouse Dryer

Size of GHD : 5m x 3.75m x 2.75m
Glazing material : Polyethylene 200 micron sheet

The experiment was conducted from 11.00 AM to 3.00 PM, peak sun shine hours on 26th May 2018 at Udaipur climatic condition. For every hour the simulation is done in Solidworks 2018 and the simulated (predicted) values of the temperatures are shown. The variation of ambient temperature, experimental temperatures and simulated temperatures of air inside the solar tunnel type greenhouse dryer with time of the day from 11.00 AM to 3.00 PM is presented in the graphical form for an interval of one hour. (Fig.5). Average temperature difference between experimental values and the simulated values is only 1.10^{0}C.

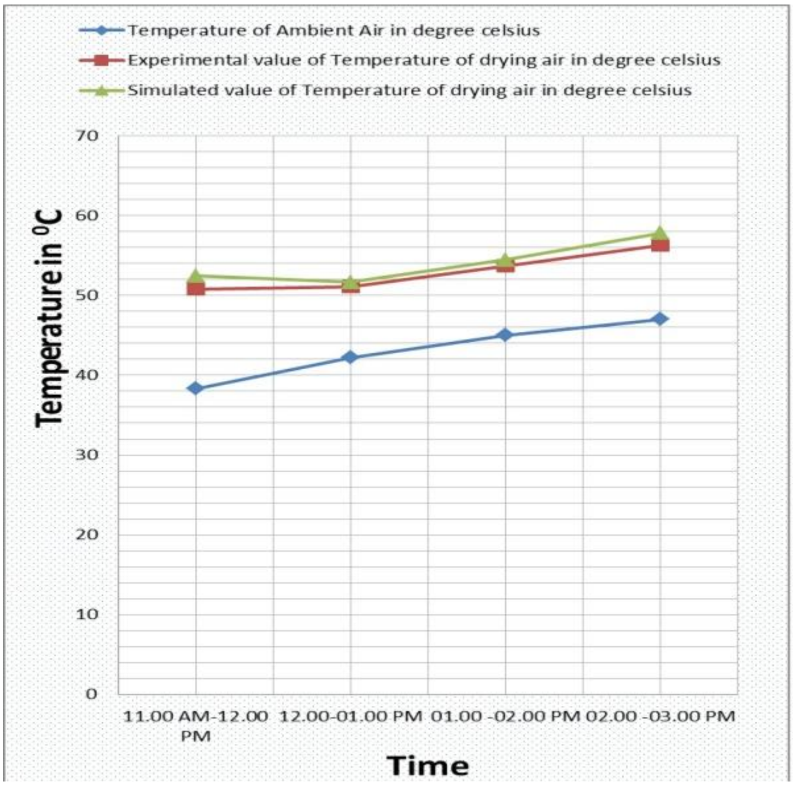

Figure 5. **Variation of Ambient Temperature, Experimental Temperature and Simulated Temperature of Air inside Solar Tunnel Type Greenhouse Dryer with Time**

Here and the similar figures for the other two dryers, the red line shows experimental values and green line shows the simulated values of the temperatures of the inside air of the greenhouse. The overlapping of these temperatures shows that the developed thermal model in Solidworks 2018 gives excellent results and can be used for different shapes and sizes of the greenhouses.

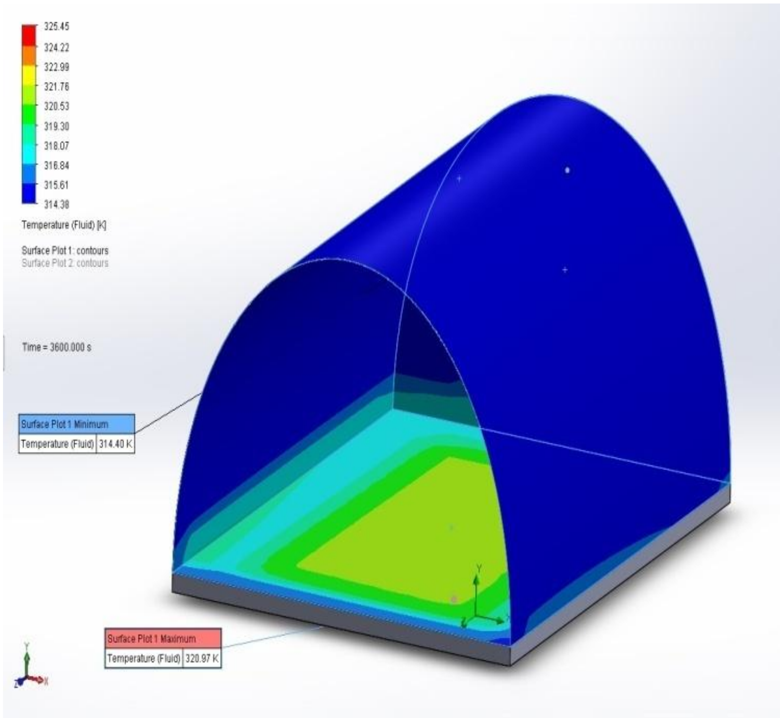

Figure 6. **Temperature Distribution of Air inside the Solar Tunnel Type Greenhouse Dryer for 11.00 AM to 12.00 PM**

The thermal performance of the dryer is shown by the temperature distribution of air inside the solar tunnel type greenhouse dryer for 11.00 AM to 12.00 PM. The maximum and minimum temperature of the air inside this greenhouse dryer is 320.97K (47.97^{0}C) and 314.40K (41.4^{0}C), respectively. (Fig.6)

IV. Conclusion:

The thermal model developed in Solidworks 2018 software for the simulation of the greenhouse dryer is capable of predicting the inside drying air temperature. The developed model demonstrated the greenhouse effect very effectively and visualizing the distribution of temperature due to natural convection. The experimental results were analyzed and validated by using computational fluid dynamics software Solidworks 2018 SP0.0. The simulated results of inside air temperature were in good agreement with experimental results during peak sunshine hours (11 AM to 3 PM). Thus, we can simulate solar greenhouse dryer of various shape and structure before actually made on ground. So, we can save lot of time and energy for making solar dryer for various purposes. The advantage of using the proposed strategy is that solar drying system can be most effectively designed and developed for industrial purposes at different climatic conditions. The thermal models are developed for each greenhouse dryer. Each model so developed is evaluated and validated experimentally. Out of the above three greenhouses, the solar tunnel type greenhouse dryer is selected on the basis of thermal need of the resin coated marble, of raising the temperature of air inside the dryer above 45^{0}C but not more than 60^{0}C. Evaluated on the basis of thermal need of the resin coated marble, if the temperature falls below the lower limit or exceeds the upper limit then north wall and south wall of the dryer were insulated respectively.

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