COMPUTATIONAL FLUID DYNAMICS (CFD) SIMULATION OF TRIPLE EXPOSURE SOLAR OVEN

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ABSTRACT

This study presents the simulation study on triple exposure of solar oven, which inspired on design features from common solar oven that has been used widely by some places in this world. Some deficient in renewable energy is contributed on this study to find a new solution to maximize utilization of renewable energy in our daily life. The objective of this project is to determine the distribution of temperature air inside of solar oven for a period of time. This triple exposure represent that the glass oven have three surfaces to be exposed on solar radiation. The simulation is conducted using Computational Fluid Dynamic (CFD) software, CD ADAPCO STAR-CCM+. The duration time of the solar oven exposed to the solar radiation is due to the total normal daylight time which estimated from 8 am to 6 pm. Therefore, the CFD simulation is simulate by each an hour from the total hour was exposed to the solar radiation. In order to validate the CFD results, theoretical analysis of triple exposure solar oven was calculated to obtain the result. The results show that the distribution of temperature air inside of triple exposure solar oven by CFD shows a fairly good agreement with the theoretical results. The results obtained will be useful as additional database on the study of triple exposure solar oven.

INTRODUCTION

Nowadays, variety option of renewable energy is available to be used by human. The solar thermal energy is the most abundant energy either in an indirect forms or direct forms to supply it. The sun is emits energy in a rate of 3.8 x10^{23} kW, of which, approximately 1.8 x 10^{14} kW is intercepted by the earth. About 60% of this amount or 1.08 x 10^{14} reaches the surface of the earth. The amount of that energy is become a renewable energy which is one of the popular subjects of researches to be explored very well. Many of the researchers have made a research towards solar technology developments. This research is focusing on the development of the triple exposure solar oven which having three glasses oven surfaces to be exposed by solar radiation. The performance and temperature distribution of solar oven is extensively investigated with the suitability of Malaysia climate (Shah Alam).

OBJECTIVE

- To determine the maximum temperature gain by triple exposure solar oven using CFD software
- To compare the analysis of simulation results with the theoretical results and experimental results
- To investigate the different volume averaged temperature between sunny season and cloudy season in solar oven.

SCOPE

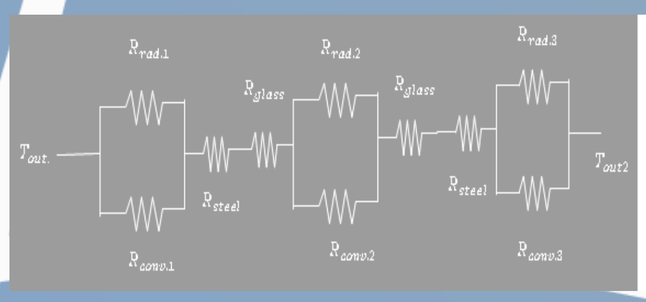
I. The solar oven is a box type solar oven.
II. The location is specified at UiTM Shah Alam which is the coordinate is E101 30, N 3 04
III. The solar oven is exposed to solar radiation during total normal daylight time only (8am-6pm)
IV. The CFD simulation is to determine the temperature distribution of air inside triple exposure solar oven.

METHODOLGY

Preliminary study: Involve in gathering the information of the project. Searching related journal, article, books in a field of heat transfer (solar oven). Determine the objective, and scope of the project with supervisor. Planning the route to achieve the objective of research.

Project Execution: Starts by gathering the physical information of solar oven to be developed. Theoretical analysis is execute to determine the temperature distribution of air inside solar oven by thermal resistance method. The CFD simulation is started by modeling 3-D model. At this stage, the model will be simulated by each day which is solar oven exposed to the solar radiation at normal daylight time. This simulation also are run for different of days There are essentially three stages in STAR-CCM+ simulation process: meshing, simulation and analysis.

Analysis of the Results: This stage will be analyzed and discuss all the results obtain from the CFD simulation. The analyses are including the temperature distribution of air inside triple exposure solar oven and the comparison between the simulation and theoretical results. Then, the conclusions and recommendation are made for this research and compile it in a thesis report.



$$\dot{Q}_{cond} = -kA\frac{\Delta T}{\Delta x} \quad \text{------- equation (1)}$$

$$\dot{Q}_{conv} = hA_s(T_s - T_\infty) \quad \text{------- equation (2)}$$

$$\dot{Q}rad = \varepsilon\sigma A_s\,(T_s^4 - T_{surr}^4) \quad \text{------- equation (3)}$$

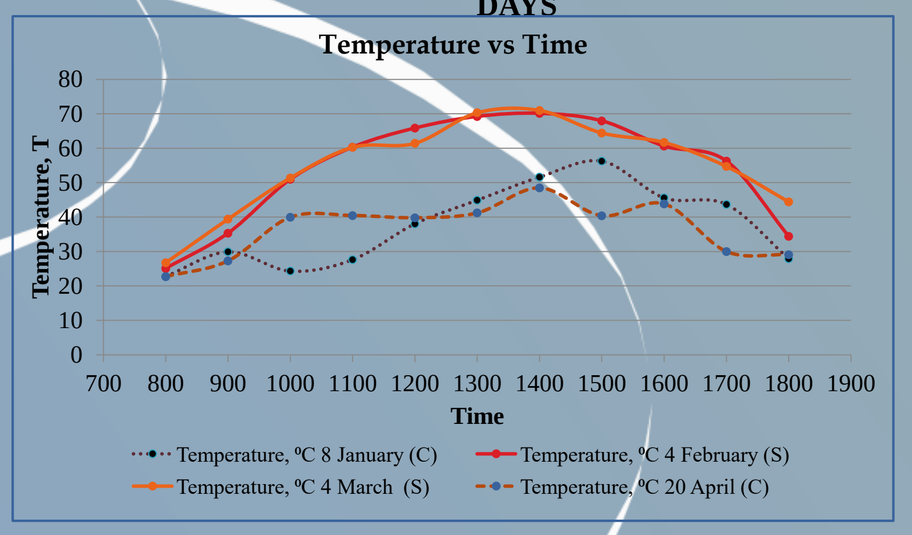
$$R_{eq} = R_{out,1} + R_{out,2} + R_{in} + 2(R_{steel}) + 2(R_{glass})$$

$$R_{eq} = R_{out,1} + R_{out,2} + R_{in} + R_{glass} + R_{glass}$$

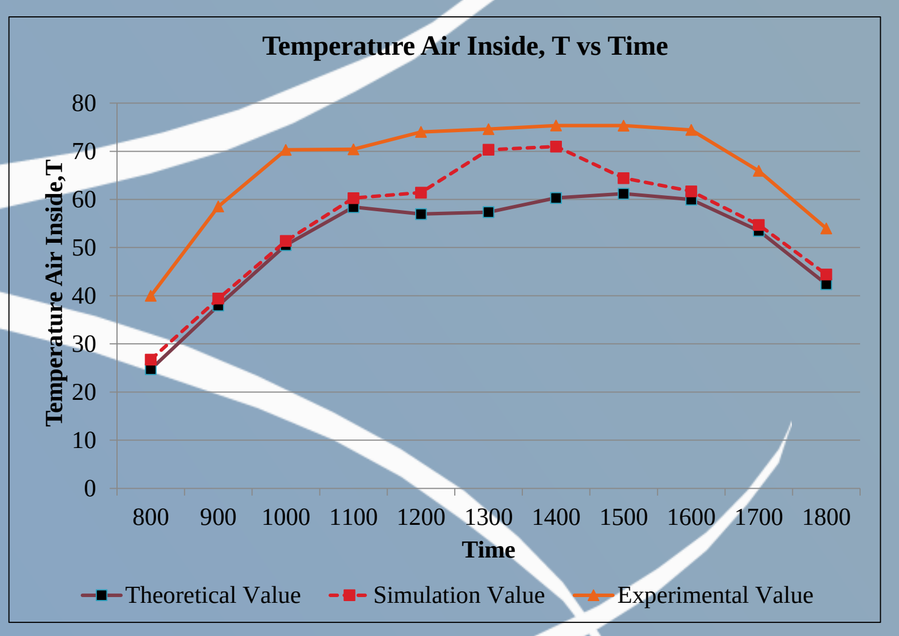
$$R_{eq} = R_{out,1} + R_{out,2} + R_{in} + R_{mirror} + R_{glass}$$

ANALYSIS

COMPARISON OF TEMPERATURE RESULTS BY DAYS

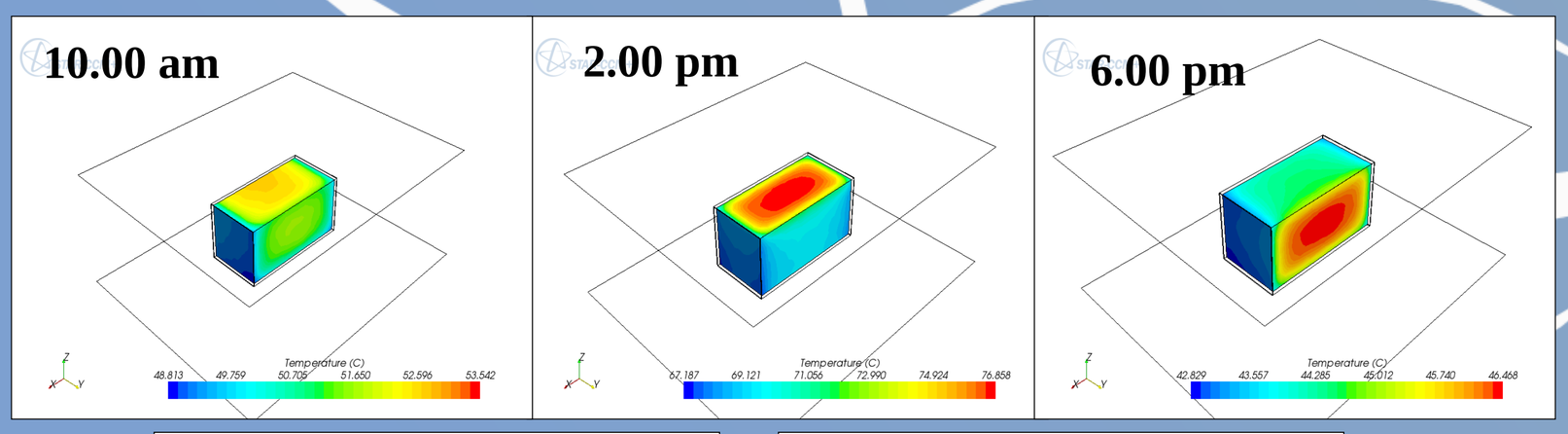


COMPARISON OF RESULTS BETWEEN SIMULATION, THEORETICAL AND EXPERIMENTAL ON 4TH MARCH 2010

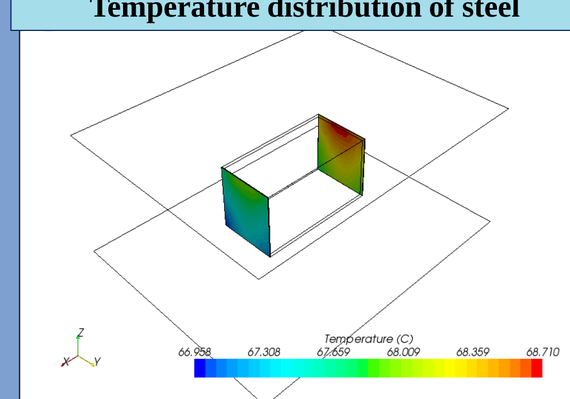


- In the dry (wet) season solar radiation and sunshine duration increase (decrease) to their highest (lowest) degree.
- The triple exposure solar oven can rise up more than 30 ˚C above ambient temperature.
- The different of distribution of temperature between the sunny season and cloudy or rainfall season are around 10 ◦C to 15 ◦C.

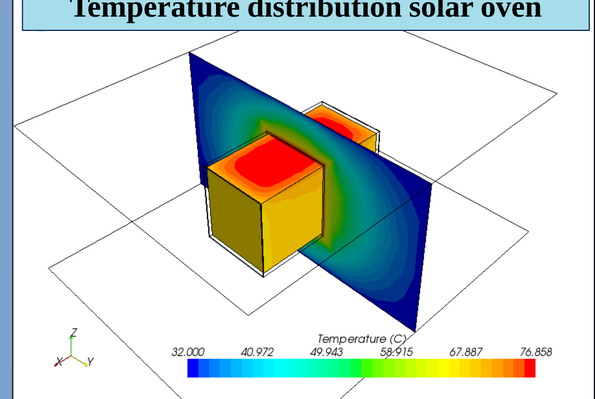
SIMULATION RESULTS



Temperature distribution of steel



Temperature distribution solar oven



CONCLUSIONS

As a conclusion, the CFD simulation of triple exposure solar oven is successful to determine the maximum temperature of air inside (70.9 ºC) by this type of solar oven at Shah Alam climate The simulation results are proved and fairly good agreement with the theoretical results for different days which is sunny season and cloudy season due to the average of percentage error is below than 10%. Irradiance and ambient temperature of solar oven are important factor to determine the temperature of air inside of solar oven.