



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

# IJRSET

International Journal of Innovative Research in  
**SCIENCE | ENGINEERING | TECHNOLOGY**



# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 13, Issue 4, April 2024

**ISSN** INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
INDIA

Impact Factor: 8.423

 9940 572 462

 6381 907 438

 [ijirset@gmail.com](mailto:ijirset@gmail.com)

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# Structural and Thermal Analysis of Solar PV Cell Panel

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**ABSTRACT:** Solar thermal power plants with central receiver and thermal storage are expected to be one key technology in future electricity generation, because they are renewable and due to the thermal storage independent of the current solar radiation. State-of-the-art solar power plants often use molten nitrate salts as heat transfer fluid. The paper presents the static structural analysis and Thermal analysis of Solar PV cell Panel by air cooling using Ansys Workbench static structural analysis and Thermal analysis. The 3cm x 3cm Solar PV Cells are mounted on a Wooden Panel Box 33 cm long and 21 cm wide with 3 cm spacing between two adjust PV cells. The modelling is done with air velocity of 0.5 m/s and temperature variation along the length is plotted. The inlet air temperature is taken 300K while average outlet temperature is found to be 312K. The temperature variation along the length and cross section is also discussed and the performance is evaluated. The thermal efficiency is found to be 11.73%.

## I. INTRODUCTION

Due to depleting fossil fuel, the renewable energy sources find a great importance to meet the world's future energy demand. Solar Energy is found to be one of the most prominent sources to meet this demand as it is clean source of energy which is available freely in almost all parts of the world. Thus, electric generation using solar energy finds utmost importance in meeting the energy demand. The Solar Photovoltaic technology directly converts the incident solar energy into electricity and emerged as a promising technology today. But, the performance of the solar pv electricity generation decreases with increase in the temperature of pv cell surface. The solar PV thermal systems remove this heat energy from pv cell surface to cool it and improve its performance and simultaneously transfer this heat energy to fluid usually air which can be utilize in a particular application. A PV Thermal collector is the collector which produced electricity and hot water or hot air at the same time and working as solar cells and solar heaters. Ahmed et al studied the performance of hybrid solar PVT system with water cooling and the effect of reflective mirror is also determined. The heat energy from the pv cell is removed using thermal heat exchanger placed at the lower part of the cells with different flow rates using using reflective mirror and glass cover. The existence of the reflectance mirrors lead to increase the temperature of the solar cell, therefore, its value was (92.7 °C) when using lower and upper mirrors with a glass cover(76.1 °C) when using only a lower mirror, and (71.35 °C) without reflecting mirrors[1]. Ali el al reviewed and explained the current status and future aspects of the solar PV thermal technology. Research thus far has been successful in validating the importance of such studies in the effective adoption of PV/T as a reliable means of harnessing solar energy. However, the PV/T system is still under development and has many points and gaps that require intensive future studies[2].Aghassi et al modelled and experimentally investigated the thermal behaviour of solar pv module[3]. Khelifa et al modelled and studied hybrid solar PV thermal collector. In the study, the photovoltaic panel temperature significantly reduced by 15–20% due to the flow of water through the manifold to the rear of the PV panel[4].Good et al simulated and studied three alternative solar energy systems which are covered PV thermal , uncovered PV thermal, and only pv module. The results suggest that covered PV/T could give an increased output compared to solar thermal collectors. The system with uncovered PV/T modules holds up well in this comparison where electricity is favored, but the thermal output is small and of low temperature, which means that an auxiliary energy source is necessary also during summer [5] . Zaraket et al studied the performance of pv module under the influence of thermal stresses. Different levels of temperature were applied into the solar cell and C-V characteristics were measured. Experimental results concluded that increasing the temperature of pv cell decreases the efficiency, power and performance of the solar cell module. The paper contributes to the research on the adverse effect of temperature on the capacitance and normal functioning of the cells and solar module [6]. Rosa Clot et al studied the possibility of solar pv module submerged in water or simply covered by a water veil suggest the possibility to use this

renewable energy source (RES) integrated with swimming pools or with decorative pools and fountains. Solar heating together with electrical energy production coming from PV effects can be naturally coupled to water basins such as swimming pools, fountains etc. The possibility to capture solar radiation efficiently to produce both electric power and heat is proved in several tests already done and documented in the scientific literature. The most interesting aspect however is the possibility to use already existing structures with a specific use (recreational or aesthetic) for producing power without any visible impact and without changing the basic function of the structures [7].

## 1.1 SOLAR POWER

This article is about the conversion of energy from sunlight into electricity. For a broader range of human uses for sunlight, see solar energy. For the unit of light from stars and galaxies, see Solar luminosity. For other uses, see Solar Power. **Jean Baptiste et.al (2018)**: “A review of the solar energy situation in Rwanda and Uganda”. In this paper authors review the solar energy development and future in Rwanda and Uganda. In these two countries, solar energy sector plays an important role in supporting socio-economic development. The paper examines the development of solar energy market in both countries since their beginnings in the 1980s. This peer review paper also identified that supports from donors, investors and government to promote development of solar energy in these two countries. Finally, the challenges and opportunities facing Rwanda and Uganda in development of solar energy are presented in this study. **Farhard Taghizadeh-Hesary (2018)**: “Empirical analysis of factors influencing price of solar modules”. In this paper authors examined the influence of wage, interest rate, exchange rate and oil price on the price of solar modules for five major solar module producing countries. For that they focused mainly on the consideration of potential economic factors would give us new insights into the mechanism surrounding the recent cost reduction in solar modules. And they concluded using corporate R&D expenditure as an independent variable may give us a better understanding of the role of solar R&D in reducing technology cost. **Mohd Rizwan et.al (2017)**: “A review paper on electricity generation from solar energy”. In this article authors reviewed about the solar energy from sunlight and discussed about their future trends and aspects. They also try to discuss working, solar panel types; emphasize the various applications and methods to promote the benefits of solar energy. And authors concluded it has more benefits compared to other forms of energy like fossil fuels and petroleum deposits. It is an alternative which is promise and consistent to meet the high energy demand. Research on solar cell and solar energy is promise has future worldwide. **Abdullah et.al (2017)**: “Solar photovoltaic system: A case study of Akure Nigeria”. In this paper authors assessed the level of awareness, adoption and barriers as related to solar PV system in Akure by assessing one hundred and fifty residential buildings randomly with a structured questionnaire administered to the occupants/ owners. The findings revealed that; a large percentage of the residential buildings make use of diesel/petrol generating set as an alternative to the national grid, that the level of awareness of solar photo voltaic is significantly low, the willingness to adopt is high but it's hindered by cost implication of the system. The study findings contribute to the growing literature in the adoption of renewable energy for electricity generation, highlighted the major barriers hindering this effective solution to be proffer. It also provides a prospective market for those interested in the solar energy market.

## II.METHODOLOGY FOR SOLAR PLATE

**Solar Flat Plate Collector** The major component of any solar system is the solar collector. A solar collector is a device designed to absorb incident solar radiation and to transfer the energy to a fluid passing in contact with it. Of all the solar thermal collectors, the flat plate collectors though produce lower temperatures, have the advantage of being simpler in design, having lower maintenance and lower operational cost. Solar air heater is type of solar collector which is extensively used in many applications such as residential, industrial and agricultural fields. Solar collectors are the key component of active solar-heating systems. They gather the sun's energy, transform its radiation into heat, and then transfer the heat to a fluid (usually water or air). The solar thermal energy can be used in solar water heating systems, solar pool heaters, and solar space heating systems. Flat-plate collectors are the most common solar collector for solar water-heating systems in homes and solar space heating. A typical flat-plate collector is an insulated metal box with a glass or plastic cover (called the glazing) and a dark-colored absorber plate. These collectors heat liquid or air at temperatures less than 80°C.

### 2.1 Objective

The objective of present study is to perform static structural analysis and Thermal analysis on four different types of absorber plate for solar collector. These results are to be compared and absorber plate giving best result is selected for fabrication. The results obtained by static structural analysis and Thermal analysis have to validate with experimental

results.

The experimental conditions taken for solar air collector, the same have been used for static structural analysis and Thermal analysis. The overall aim of this work is to increase the efficiency of flat plate solar collector.

## 2.2 PROBLEM STATEMENT

The main aim is to simulate the different shapes of flat plate collector and then fabricate the best model to validate the results. The overall dimension for solar air collector is 1882×960×93 mm<sup>3</sup> with 3 mm thick glass plate which is placed at around 25mm above the absorber plate of thickness 2 mm. Inlet of solar air collector is of circular cross section with diameter of 50 mm. There are two outlets to the solar collector with circular cross section having diameter 40 mm.

### Material Data

Magnetic alloy; silicon core iron A Structural Steel; Aluminum alloy, wrought, 6061, T6

## 2.2 INTRODUCTION TO CATIA V5R20

Welcome to **CATIA (Computer Aided Three-Dimensional Interactive Application)**. As a new user of this software package, you will join hands with thousands of users of this high-end CAD/CAM/CAE tool worldwide. If you are already familiar with the previous releases, you can upgrade your designing skills with the tremendous improvement in this latest release. CATIA V5, developed by Dassault Systems, France, is a completely re-engineered, Next-generation family of CAD/CAM/CAE software solutions for Product Lifecycle Management. Through its exceptionally easy-to-use and state-of-the-art user interface, CATIA V5 delivers innovative technologies for maximum productivity and creativity, from the inception concept to the final product. CATIA V5 reduces the learning curve, as it allows the flexibility of using feature-based and parametric designs. CATIA V5 provides three basic platforms: P1, P2, and P3. P1 is for small and medium-sized process-oriented companies that wish to grow toward the large scale digitized product definition. P2 is for the advanced design engineering companies that require product, process, and resource modeling. P3 is for the high-end design applications and is basically for Automotive and Aerospace Industry, where high quality surfacing or Class-A surfacing is used. The subject of interpretability offered by CATIA V5 includes receiving legacy data from the other CAD systems and even between its own product data management modules. The real benefit is that the links remain associative. As a result, any change made to this external data gets notified and the model can be updated quickly. CATIA V5 serves the basic design tasks by providing different workbenches. A workbench is defined as a specified environment consisting of a set of tools that allows the user to perform specific design tasks. The basic workbenches in CATIA V5 are Sketcher, Part Design, Wireframe and Surface Design, Assembly Design and Drafting.

## 2.4 Getting started with CATIA V5R20: -

Install CATIA V5R20 on your system and then start it by double-clicking on the shortcut icon of **CATIA V5R20** on the desktop of your computer. You can also choose **Start > All Programs > CATIA > CATIA V5R20** from the taskbar to start the program design applications and is basically for Automotive and Aerospace Industry, where high quality surfacing or Class-A surfacing is used. The subject of interpretability offered by CATIA V5 includes receiving legacy data from the other CAD systems and even between its own product data management modules. The real benefit is that the links remain associative. As a result, any change made to this external data gets notified and the model can be updated quickly. A rectangle is a pattern that occurs on price charts. A rectangle is formed when the price reaches the same horizontal support and resistance levels multiple times. The price is confined to moving between the two horizontal levels, creating a rectangle. The concept of a rectangle is similar to a Darvas Box.

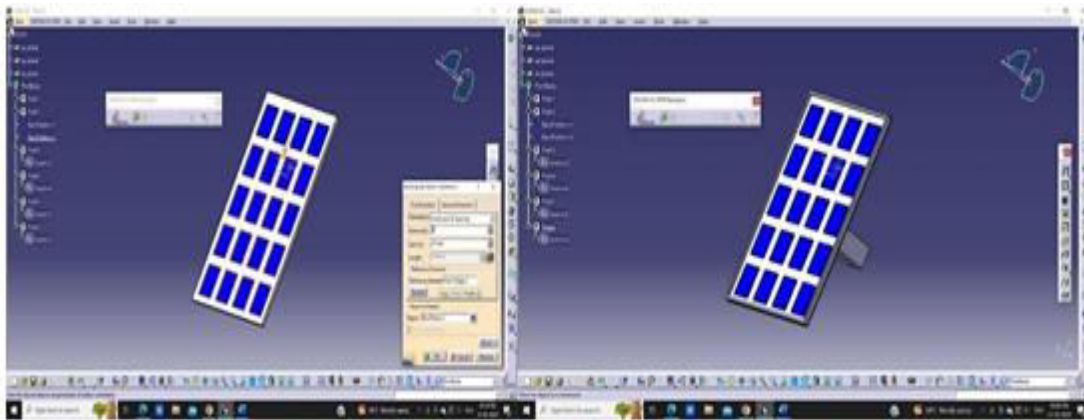


Fig.1 solar panel a rectangle is a pattern in CATIA v5

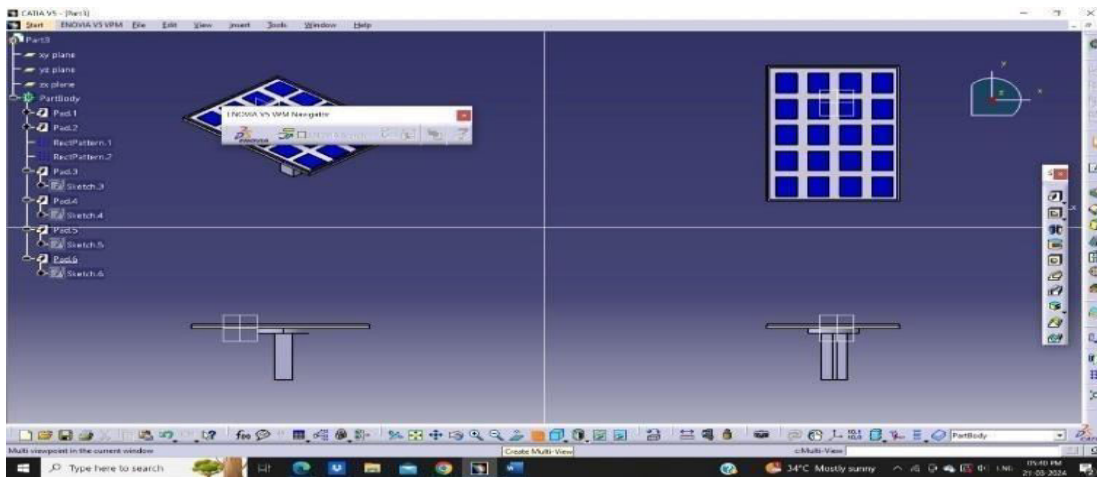


Fig.2 Multi Section Plate

### III.MATERIAL AND METHODOLOGY

#### 3.1 Nodes and Elements

Red dots represent the element's nodes. Elements can have straight or curved edges Each node has three unknowns, namely, the translations in the three global directions. The process of subdividing the part into small pieces (elements) is called meshing. In general, smaller elements give more accurate results but require more computer resources and time. Ansys suggests a global element size and tolerance for meshing. The size is only an average value, actual element sizes may vary from one location to another depending on geometry. It is recommended to use the default settings of meshing for the initial run. For a more accurate solution, use a smaller element size.

#### 3.2 analyzing the bearing – step by step procedure

The 3D model of the crank shaft is designed by using pro-e software and it is converted as IGES format.

The IGES (Initial Graphic Exchange Specification) format is suitable to import in the ANSYS Workbench for analyzing

Open the ANSYS workbench Choose static structural Go to engineering data

Provide the required materials. Go to geometry

File – import external geometry file – generate Close the window

Click mesh

Under mesh details, choose sizing – relevant center – fine To capture the figure use the option new figure in tool bar. The all results are taken in a picture – and save it to the Required folder in the system

### 3.3 Meshing in ANSYS

Ansys meshing capabilities help reduce the amount of time and effort spent to get to accurate results. Since meshing typically consumes a significant portion of the time it takes to get simulation results, Ansys helps by making better and more automated meshing tools.

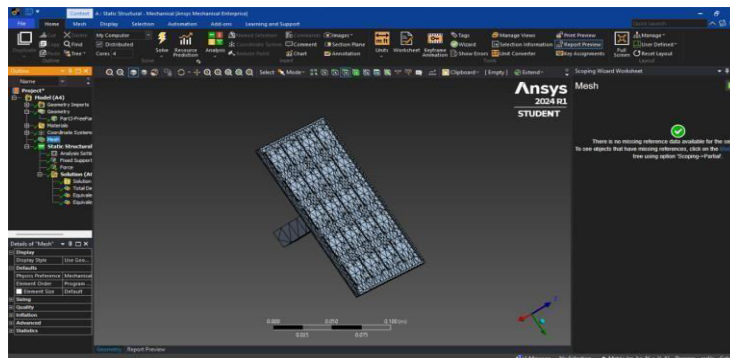


Fig.3 Meshing in ANSYS

### 3.4 Fixed Support

Fixed Support. A fixed support is the most rigid type of support or connection. It constrains the member in all translations and rotations (i.e. it cannot move or rotate in any direction). The easiest example of a fixed support would be a pole or column in concrete.

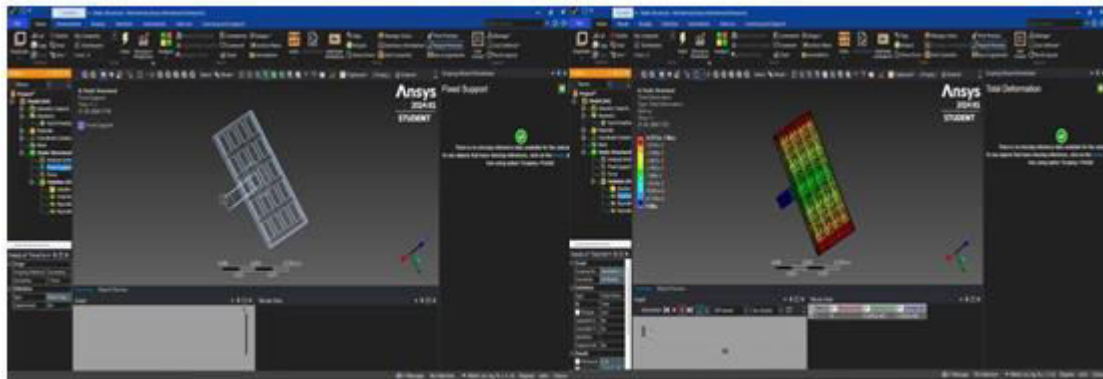


Fig.4 Fixed Support

### 3.5 Static Structural Analysis

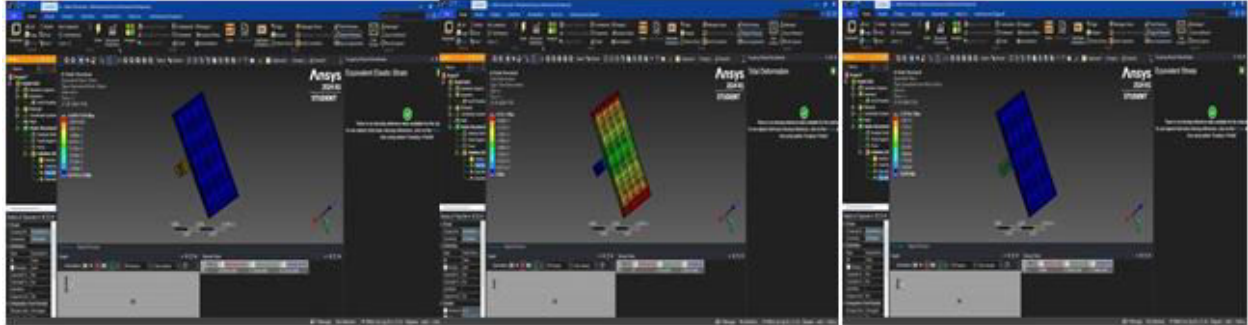


Fig.5 Static Structural Analysis (a) Equivalent Strain (b) Equivalent Stress (c) Total Deformation in ANSYS

### 3.6 Thermal analysis Structural Steel

#### Temperature

Ansys thermal analysis solutions help engineers solve the most complex thermal challenges to predict how their designs will perform with temperature changes. Account for temperature fluctuations. Prevent overheating issues. Improve product reliability across environments.

#### Heat flow rate

The amount of heat that passes from one substance to another per unit of time, is the heat flow with the unit of measure Joule per second [J/s]. This is the unit of measure Watts [W] that is commonly used to indicate power.

#### Heat Flux

A heat flux or thermal flux is the amount of heat energy passing through a certain surface. In clothing system a heat flux sensor can provide information on the heat exchange between the body and the environment and thus give direct input to improve the thermal comfort of the garment.

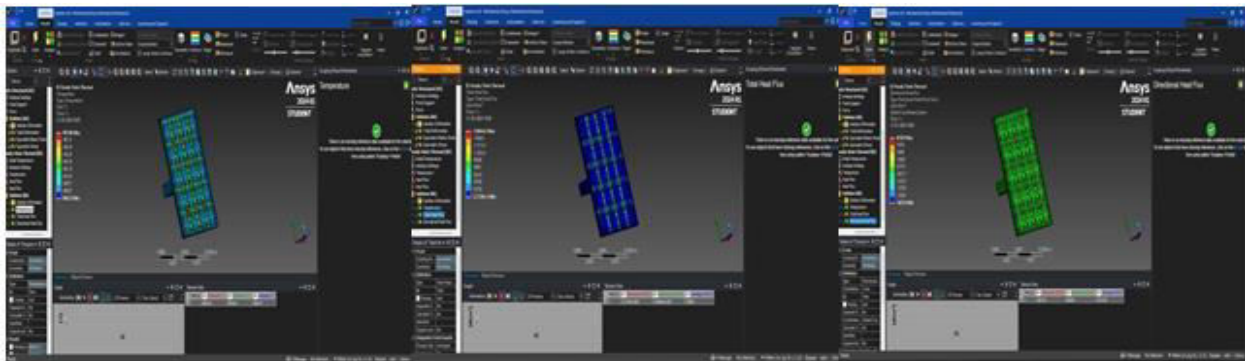


Fig.6 Thermal analysis Structural Steel (a) Temperature (b) Heat flow rate (c) Heat Flux



IV. RESULT AND DISCUSSION

4.1 Static Structural Analysis

Definition				Definition				Definition			
Type	Total Deformation	Equivalent Elastic Strain	Equivalent (von-Mises) Stress	Type	Total Deformation	Equivalent Elastic Strain	Equivalent (von-Mises) Stress	Type	Total Deformation	Equivalent Elastic Strain	Equivalent (von-Mises) Stress
By	Time			By	Time			By	Time		
Display Time	Last			Display Time	Last			Display Time	Last		
Separate Data by Entity	No			Separate Data by Entity	No			Separate Data by Entity	No		
Calculate Time History	Yes			Calculate Time History	Yes			Calculate Time History	Yes		
Identifier				Identifier				Identifier			
Suppressed	No			Suppressed	No			Suppressed	No		
Results				Results				Results			
Minimum	0. m	8.9707e-008 m/m	10492 Pa	Minimum	0. m	8.6686e-008 m/m	10499 Pa	Minimum	0. m	2.7221e-007 m/m	13117 Pa
Maximum	4.2953e-005 m	1.1545e-004 m/m	2.2979e+007 Pa	Maximum	4.15e-005 m	1.1155e-004 m/m	2.2979e+007 Pa	Maximum	1.2393e-004 m	3.3613e-004 m/m	2.3086e+007 Pa
Average	3.0302e-005 m	4.1223e-006 m/m	7.1697e+005 Pa	Average	2.9277e-005 m	3.9828e-006 m/m	7.1696e+005 Pa	Average	8.7266e-005 m	1.1894e-005 m/m	7.1428e+005 Pa
Minimum Occurs On	Part3-FreeParts PartBody			Minimum Occurs On	Part3-FreeParts PartBody			Minimum Occurs On	Part3-FreeParts PartBody		
Maximum Occurs On	Part3-FreeParts PartBody			Maximum Occurs On	Part3-FreeParts PartBody			Maximum Occurs On	Part3-FreeParts PartBody		

Fig.7 Static Structural Analysis (a) Structural Steel (B) Silicon (C) Aluminum Alloy, Wrought, 6061, T6

4.2 Thermal analysis

Definition				Definition				Definition			
Type	Temperature	Total Heat Flux	Directional Heat Flux	Type	Temperature	Total Heat Flux	Directional Heat Flux	Type	Temperature	Total Heat Flux	Directional Heat Flux
By	Time			By	Time			By	Time		
Display Time	Last			Display Time	Last			Display Time	Last		
Separate Data by Entity	No			Separate Data by Entity	No			Separate Data by Entity	No		
Calculate Time History	Yes			Calculate Time History	No			Calculate Time History	Yes		
Identifier				Calculate Time History	Yes			Identifier			
Suppressed	No			Identifier				Suppressed	No		
Orientation				Suppressed	No			Orientation			
Coordinate System	X Axis Global Coordinate System			Orientation				Coordinate System	X Axis Global Coordinate System		
Results				Results				Results			
Minimum	889.24 °C	2.2728e-006 W/m²	-68126 W/m²	Minimum	889.37 °C	2.7423e-006 W/m²	-68126 W/m²	Minimum	889.7 °C	2.9479e-006 W/m²	-68126 W/m²
Maximum	895.86 °C	1.6864e+005 W/m²	69583 W/m²	Maximum	894.86 °C	1.6864e+005 W/m²	69583 W/m²	Maximum	892.28 °C	1.6864e+005 W/m²	69583 W/m²
Average	890.47 °C	15088 W/m²	-89.128 W/m²	Average	890.18 °C	15088 W/m²	-89.128 W/m²	Average	890.18 °C	15088 W/m²	-89.128 W/m²
Minimum Occurs On	Part3-FreeParts PartBody			Minimum Occurs On	Part3-FreeParts PartBody			Minimum Occurs On	Part3-FreeParts PartBody		
Maximum Occurs On	Part3-FreeParts PartBody			Maximum Occurs On	Part3-FreeParts PartBody			Maximum Occurs On	Part3-FreeParts PartBody		

Fig.8 Thermal Analysis (a) Structural Steel (B) Silicon (C) Aluminum Alloy, Wrought, 6061, T6

V. CONCLUSION

After conducting thermal analysis of solar panel by varying four materials, from our observations we can evaluate that the least high temperature value was observed in the case of crystalline silicon, i.e., To facilitate our conclusions further we can also see that the average temperature is also the lowest in case of crystalline silicon i.e., 173.68 degree Celsius and hence greater efficiency. Thermal analysis is a effective tool with which we can stimulate the models on various operating conditions without actually fabricating them and can compare their results. The best solution is then selected for fabrication so that we can save time and money. From thermal analysis results and practical test performance, it is concluded that-

- [1] Collector outlet temperature during day varies depending on solar intensity and it is directly proportional with it.
- [2] The best result is obtained on clear sunny days.



[3] Thermal analysis result values are higher than experimental values because there are some losses in actual practice. Also, locally available materials have slightly different properties than as given in thermal analysis stimulation.

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STRUCTURAL STEEL

Definition			
Type	Temperature	Total Heat Flux	Directional Heat Flux
By	Time		
Display Time	Last		
Separate Data by Entity	No		
Calculate Time History	Yes		
Identifier			
Suppressed	No		
Orientation			X Axis
Coordinate System			Global Coordinate System
Results			
Minimum	889.24 °C	2.2728e-006 W/m <sup>2</sup>	-68126 W/m <sup>2</sup>
Maximum	895.86 °C	1.6864e+005 W/m <sup>2</sup>	69583 W/m <sup>2</sup>
Average	890.47 °C	15088 W/m <sup>2</sup>	-89.128 W/m <sup>2</sup>
Minimum Occurs On	Part3-FreeParts PartBody		
Maximum Occurs On	Part3-FreeParts PartBody		

\



SILICON

Definition			
Type	Temperature	Total Heat Flux	Directional Heat Flux
By	Time		
Display Time	Last		
Separate Data by Entity	No		
Calculate Time History	Yes		
Identifier			
Suppressed	No		
Orientation			X Axis
Coordinate System			Global Coordinate System
Results			
Minimum	889.37 °C	2.7423e-006 W/m <sup>2</sup>	-68126 W/m <sup>2</sup>
Maximum	894.86 °C	1.6864e+005 W/m <sup>2</sup>	69583 W/m <sup>2</sup>

Average	890.39 °C	15088 W/m <sup>2</sup>	-89.128 W/m <sup>2</sup>
Minimum Occurs On	Part3-FreeParts PartBody		
Maximum Occurs On	Part3-FreeParts PartBody		

ALUMINUM ALLOY, WROUGHT, 6061, T6

Definition			
Type	Temperature	Total Heat Flux	Directional Heat Flux
By	Time		
Display Time	Last		
Separate Data by Entity	No		
Calculate Time History	Yes		
Identifier			
Suppressed	No		
Orientation			X Axis



Coordinate System			Global Coordinate System
<b>Results</b>			
Minimum	889.7 °C	2.9479e-006 W/m <sup>2</sup>	-68126 W/m <sup>2</sup>
Maximum	892.28 °C	1.6864e+005 W/m <sup>2</sup>	69583 W/m <sup>2</sup>
Average	890.18 °C	15088 W/m <sup>2</sup>	-89.128 W/m <sup>2</sup>
Minimum Occurs On	Part3-FreeParts PartBody		
Maximum Occurs On	Part3-FreeParts PartBody		



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