CFD ANALYSIS OF WIND PRESSURE OVER SOLAR PANELS AT DIFFERENT ORIENTATIONS OF PLACEMENT

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ABSTRACT

The problem of energy crises causes the solar energy gained a lot more important position in non-conventional energy. In the present study CFD methodology is used to figure out the pressure developed by the wind over the solar panels. Different angle of orientation of solar panels are studied at different speeds, so as to get optimum design for installation of the solar panels. The CFD model is developed with different speed under the steady state condition. In the present thesis the computational fluid dynamics (CFD) tool has been to simulate the solar collector for better understanding of pressure distribution. 3D model of collector involving the parts is modeled by CATIA V5 and the unstructured grid was created in HyperMesh. The results were obtained by using ANSYS FLUENT software. The maximum drag force is appeared for the 60^0 inclinations. The maximum lift force is appeared for the 45^0 inclinations. Depending on the speed of wind at various locations the pressure on the solar panel and its supports vary. The speed of wind is not same that means the materials required for the construction of solar panels can be changed for various speeds depending on the sunlight directions.

Keywords: Angle Of Inclination, CFD Analysis, Solar Panel, Lift And Drag Force;

I INTRODUCTION

Nowadays due to increasing in the demand for energy and depletion of fossil fuels and increase in population and change in life style of human beings the price of energy is increasing rapidly. There is a search for more reliable non-conventional energy sources. The major types of non-conventional energy sources are wind, solar, hydro powers etc. Out of which solar energy is better because, we can easily convert the solar energy into electricity compared to other non-conventional sources. The cost converting the wind and hydro energy is more but we get more power output and the operation cost of the conversion is much bigger. We can use solar energy conversion in the house itself with much lesser operating cost. The model is simple and it is easily operatable. The designing is also much simpler. We can use this conversion for various purposes like water heating, drying, cooking, power producing etc.

Solar energy is most considerable energy source in the world. Sun which is $1.495 x 10^{11}$m far from earth and has a diameter of $1.39 x 10^9$m and it would emit approximately 1353W/m^2 on to the surface perpendicular to rays if there was no atmospheric layer. The world receives 170 trillion kW of solar energy and 30% of this energy is reflected back to the space, 47% is transformed to low temperature heat energy, 23% is used for evaporation/rainfall cycle in the Biosphere and less than 0.5% is used in the kinetic energy of the wind, waves and photosynthesis of plants.

Solar energy conversion systems consist of many parts. The most important part of these systems is the solar panel, where the heat is transferred from sun to absorber plate. In order to affect the performance of these systems, generally modifications on solar panels are performed. The use of solar panel technology has recently increased in both domestic and industrial applications. This increased usage has been driven by the increasing financial cost of electric power, and the public desire to produce a greater proportion of energy from renewable resources and also to offset the power costs during pick periods. Based on their applications these panels are manufactured in different shapes and sizes. In industrial applications set of panels are considered in arrayed configuration.

For ease of maintenance and air ventilation purposes the panels are installed 2 to 5 feet above the ground. Given the large surface area the aerodynamic forces acting simultaneously on these modules could cause serious mechanical problems to the systems. Therefore, a good understanding of the wind flow and its interaction with the arrayed sets of panels is of interest to minimize the potential damages.

Fig1: Arrays of Flat Plate Panels

1.1. Destruction of solar panels

The effect of wind on the solar panel modules located in the space is as follows,

- **Wind speed:** On the earth there is a much difference in speed of wind from the region to another region. That means at the coastal regions the speed of wind is 60 to 90 km/hr. similarly at the normal region the speed is around 30 to 60 km/hr. at the situations of flood the speed may rises to maximum of 90 to 120 km/hr.
- **Wind direction**: The direction of wind is always changes. Because we place the solar panels at the top, wind may flow in either the direction. It may flow in the direction of inclination of panel, sometimes opposite to that.
- **Height of the building and the presence of the parapet**: The speed of wind is varied as the latitude increases that means more speed at the top. Parapet prevents the air to go into the backward position and to cause lift in the upward direction.
- **Building position in the build environment.**
- **Parallel or oblique arrangement of the solar panels to the sides of the building.**

- **Angle of inclination of the panels**: the orientations of solar panel is also important in wind effect. The solar panels may not be horizontal, it may be at the inclination of 30^0, 45^0, and 60^0 any of the required.
- **Position of the panels to the roof edges.**
- **Position of the panel in the panel field.**

1.2. Force exerted on solar panels due to fluid flow

There are mainly two forces that are acting on the solar panel due to wind flow, they are, Lift force, Drag force and Total force.

1. Lift force: The component of the total force in the direction perpendicular to the direction of motion. Lift is the force exerted by the fluid normal to the direction of motion. Lift is zero for symmetrical flow. Lift = Weight (in the case of an airplane in cruise). And it is denoted by FL

2. Drag force: The component of total force in the direction of motion is called as Drag (FD). Drag is the force exerted by the fluid on the body in the direction of motion. Drag resists motion of the body or fluid. For example, Wind resistance to a moving car, water resistance to torpedoes etc. Pressure is required to overcome drag and hence drag has to be reduced to a possible minimum. And it is denoted by FD

3. Total force: The summation of drag and lift force is the total force acting on the solar panel. And it is denoted by FR.

II METHODOLOGY

2.1 Geometric Model Creation

The Geometry of computational domain from the analysis point of view can be created top-down or bottom-up. Top-down refers to an approach where the computational domain is created by performing logical operations on primitive shapes such as cylinders, bricks, and spheres. Bottom-up refers to an approach where one first creates vertices (points), connects those to form edges (lines), connects the edges to create faces, and combines the faces to create volumes. Geometries can be created using the same pre-processor software that is used to create the grid, or created using other programs (e.g. CAD, CATIA, etc). Geometry files are imported to HM to create computational domain. Thus the Extracted fluid domain of computation is as shown. Here we first create the solar panel at an inclination of 30^0 with the dimensions of length 1000mm, breadth 700mm and the thickness of 30mm. In the second step create the support structures by taking the back supports at a length of 1300mm, and the other supports length can be varied according to the inclination. Lastly the computational domain is created by taking 20.8H as length, 11.5H as breadth and 5H as height and also the distance between the face of supports to the inlet region is of 6.254H is modeled using CATIA design software package. Then save the CATIA product model. And also save the model as iges to import to the HYPERMESH. The three models of different inclinations are prepared by CATIA and are as shown in the figure.

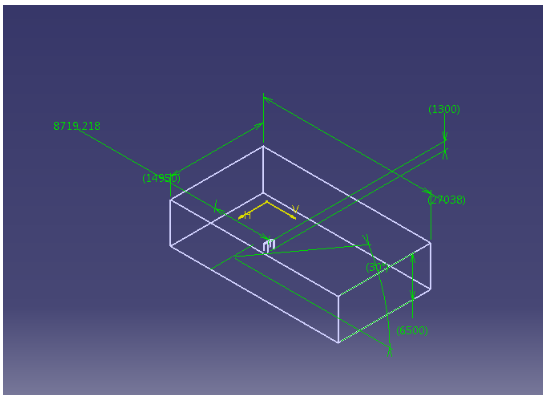

Fig 2: 30^0 inclined solar panel geometry

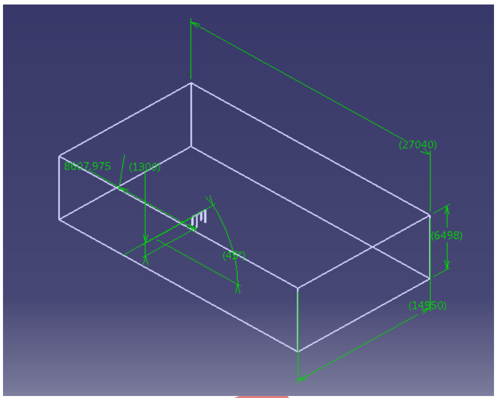

Fig3: 45^0 inclined solar panel geometry

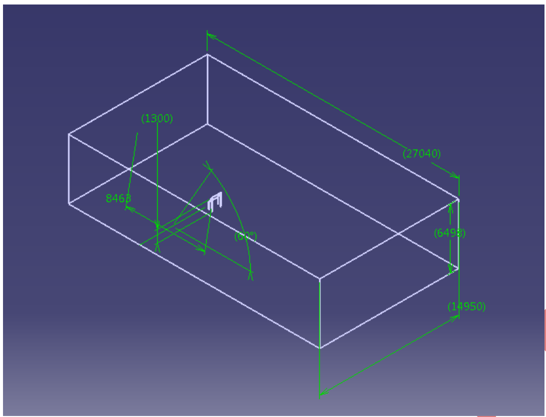

Fig4: 60^0 inclined solar panel geometry

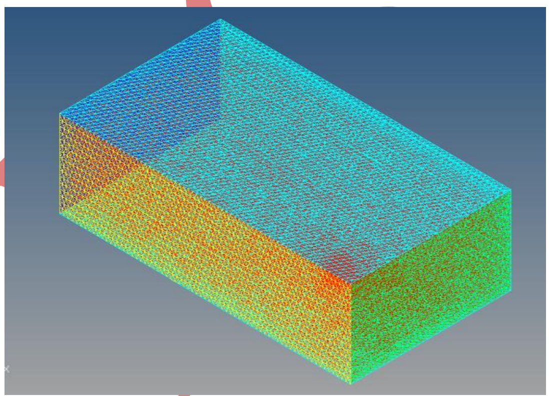

Fig5: Meshed model for 30^0 inclination

2.2 Mesh Generation

For the present work the meshing is done by using Hyper Mesh software. Many different cell/element and grid types are available. They are 2D (Triangle, Quadrilateral), 3D (Tetrahedron, Hexahedron, Pyramid, Wedge…) Choice depends on the problem and the solver capabilities. In boundary layers, quad, hex, and prism/wedge cells are preferred over tri's, tets, or pyramids. For the same cell count, hexahedral meshes will give more accurate solutions, especially if the grid lines are aligned with the flow. The mesh density should be high enough to capture all relevant flow features. The mesh adjacent to the wall should be fine enough to resolve the boundary layer flow. For this project take trias for 2D meshing and tetras for3D meshing. The meshed models contains around 62,000 nodes and 3, 10,000 elements. **Boundary conditions** used are, Fluid- air, wall – no slip, inlet – velocity inlet, and outlet – outflow.

III RESULTS AND DISCUSSION

3.1 For 30 km/hr

The below figures show that for the 30 km/hr wind speed and for different angle of inclination the variation of pressure in the center plane and on top plate. It shows that maximum pressure on the plate top for various inclinations. The pressure on solar plate top is maximum near the leading edge and decreases as we go towards the trailing edge. The drag force and lift force acting in each case is note down.

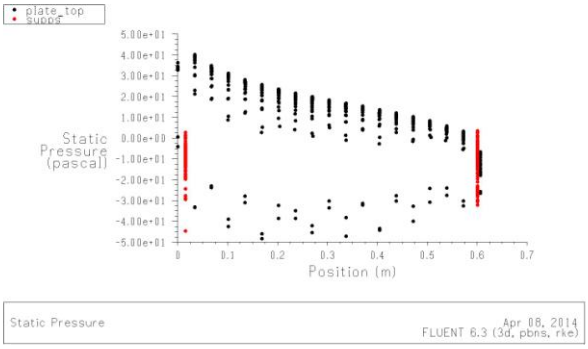

Fig6: XY plot of pressure for 30^0 inclinations

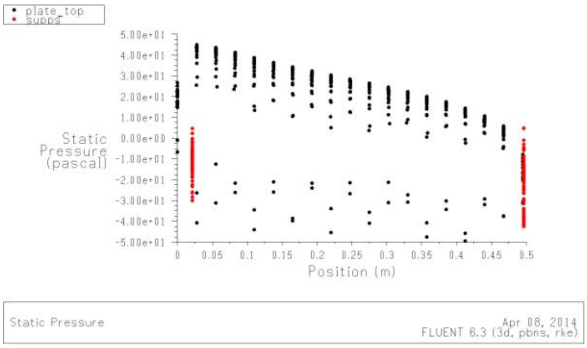

Fig7: XY plot of pressure for 45^0 inclinations

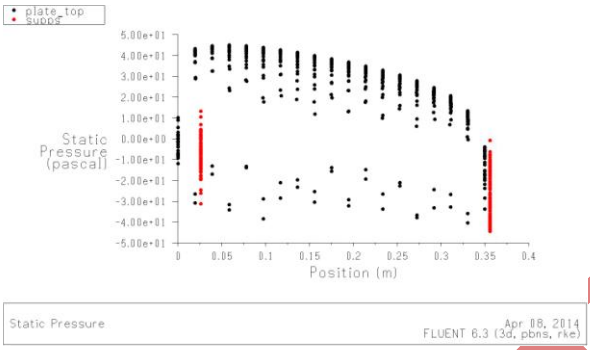

Fig8: XY plot of pressure for 60^0 inclinations

Fig9: Pressure contours for 30^0 inclination

3.2 For 60 km/hr

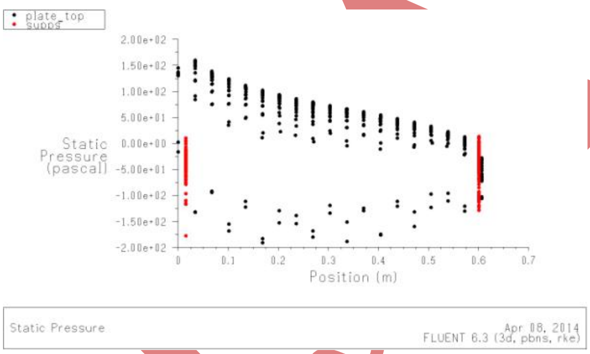

Fig10: XY plot of pressure for 30^0 inclinations

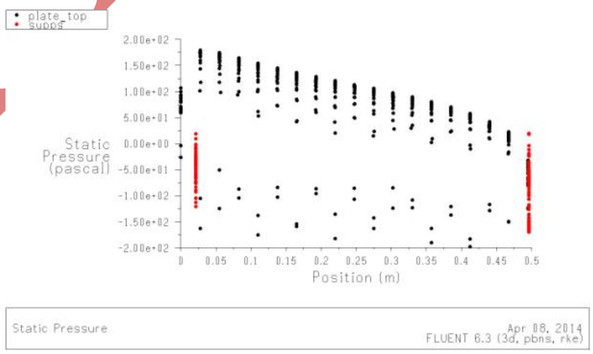

Fig11: XY plot of pressure for 45^0 inclination

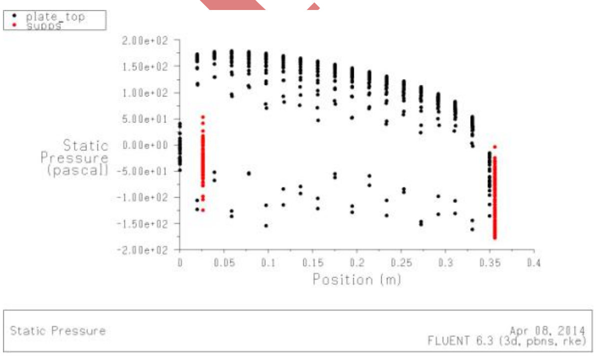

Fig12: XY plot of pressure for 30^0 inclinations

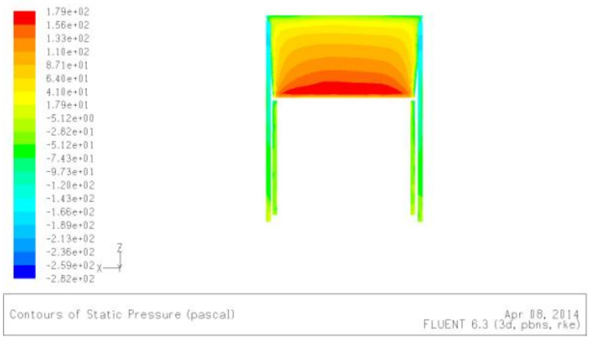

Fig13: Pressure contours for 45^0 inclination.

The above figures show that, for the 60 km/hr wind speed and for different angle of inclination the variation of pressure on the top plate and supports. It shows that maximum pressure on the plate top for various inclinations. The pressure on solar plate top is maximum near the leading edge and decreases as we go towards the trailing edge. The maximum pressure appeared area is more compared to 30 km/hr

3.3 For 90 km/hr

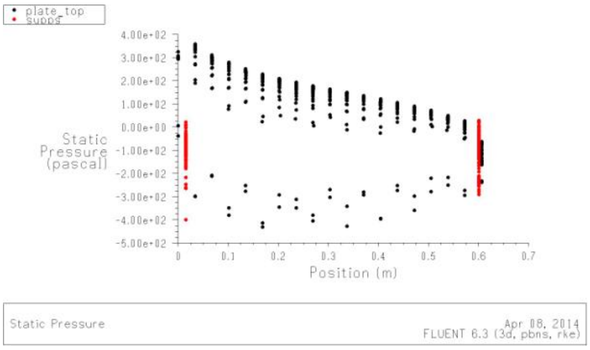

Fig14: XY plot of pressure for 30^0 inclination

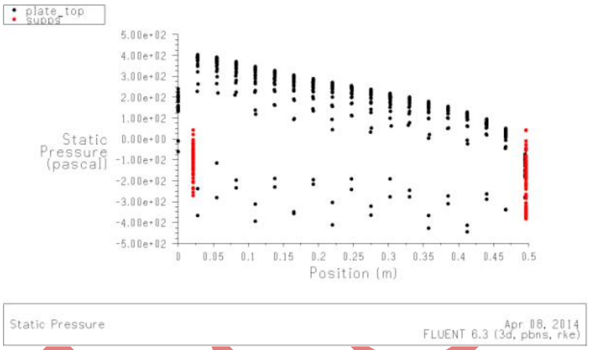

Fig15: XY plot of pressure for 45^0 inclination

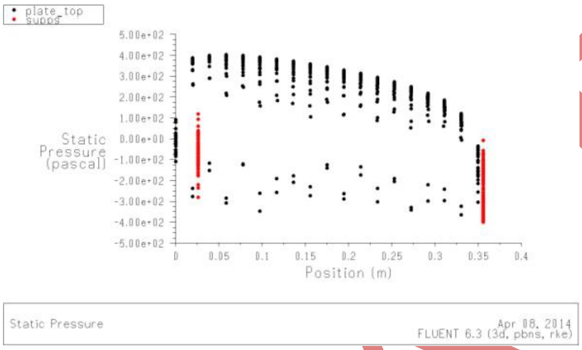

Fig16: XY plot of pressure for 60^0 inclinations

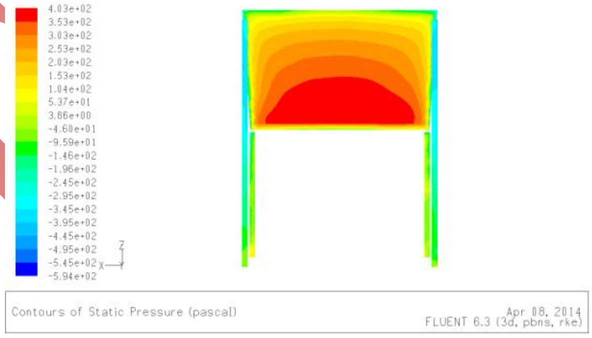

Fig17: Pressure contours for 60^0 inclination

The above figures show that for the 90 km/hr wind speed and for different angle of inclination the variation of pressure in the center plane and on top plate. It shows that maximum pressure on the plate top for various inclinations. The pressure on solar plate top is maximum near the leading edge and decreases as we go towards the trailing edge. The maximum pressure appeared area is more compared to 30 and 60km/hr. The drag and lift forces for various inclinations and for various speeds is tabulated in the table.

Table: Variation of Drag and lift forces inclinations and speeds

Inclination in degrees	Wind speed in km/hr	Drag force in N	Lift force in N
30^0 inclination	30	9.142	-9.755
	60	36.326	-38.702
	90	81.492	-86.757
	120	144.624	-153.895
45^0 inclination	30	13.535	-11.672
	60	53.876	-46.473
	90	120.917	-104.319

	120	214.611	-185.174
60^0 inclination	30	19.342	-10.653
	60	77.037	-42.450
	90	172.960	-95.334
	120	307.072	-169.275

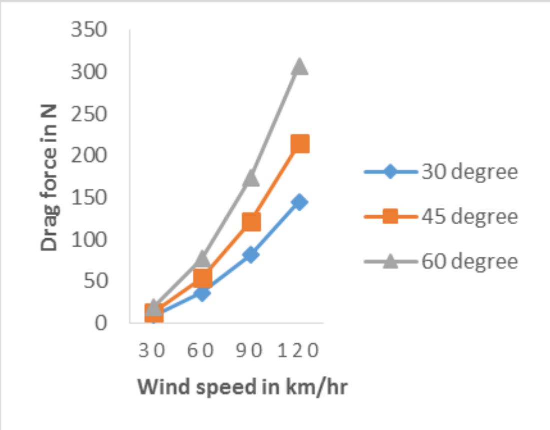

Fig18: Drag force V/s Wind speed

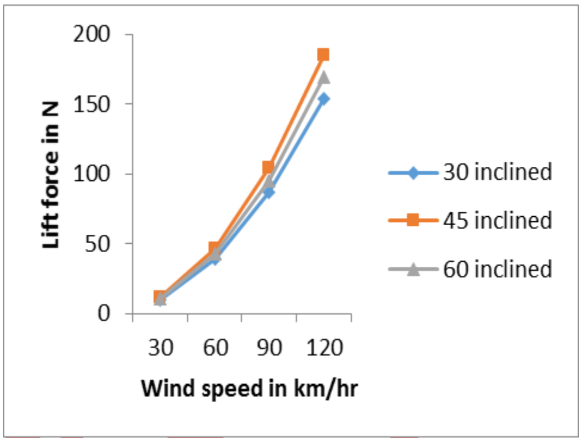

Fig19: Lift force V/s Wind speed

The above figure shows the variations of lift and drag forces for different angle of inclinations and also for different wind speeds. From the figure 5.17 it will conclude that the drag forces increases as the angle of inclination increases and also it increases with increasing the wind speed. From figure 5.18 it will conclude that the lift force increases as the angle of inclination increases and reaches the maximum and then decreases. Also the lift force increases with increasing the speed of wind.

IV CONCLUSION

- For 30^0 inclinations the lift force is higher than the drag force. As the wind speed increases the drag and lift forces increases rapidly. The average pressure on the supports is higher than that on solar plate.
- For 45^0 inclinations the drag force is higher than the lift force. As the wind speed increases the drag and lift forces increases with large slope. The average pressure on the solar plate is higher than that of supports.
- For 60^0 inclinations the drag force is higher than the lift force. As the wind speed increases the drag force increases with more slope, whereas the lift force increases with less slope compared to 45^0 inclinations. The lift force is lesser compared to lift forces for 45^0 inclinations. The average pressure on the solar panel is higher than that of supports.
- The maximum drag force is appeared for the 60^0 inclinations.
- The maximum lift force is appeared for the 45^0 inclinations.

From the above discussions it conclude that depending on the speed of wind at various locations the pressure on the solar panel and its supports vary. The speed of wind is not same in all the locations. That means the strength of materials required for the construction of solar panel can be changed for various speeds depending on the sunlight directions. And also the strength of support structures also it can calculate for various speeds. If the location needs go for more strength materials, otherwise use less strength materials.

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