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CFD Analysis on the Design of Diffuser for Air Cooling of Low Concentrated Photovoltaic/Thermal (LCPV/T) Solar Collector

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Abstract: The CFD analysis on design of diffuser for air cooling of low concentrated photovoltaic (PV) solar collector is carried out. Basically a PV panel made of silicon, a semiconductor, have a capacity to convert dispersed as well as concentrated solar radiation into electricity directly. The problem encountered with silicon PV panel is overheating due to excessive solar radiation and high ambient temperature. Overheating drastically lowers the efficiency of solar panel. The proper cooling system is required to remove excessive heat and to increase the efficiency of PV panel. One method of cooling PV panel is the supply of uniformly distributed air along the panel. Diffuser is used for uniform distribution of air. Different shapes of diffusers with and without deflector plates are analysed for uniform distribution of air using commercial software ANSYS FLUENT. The CFD analysis revealed that the diffuser with curved side walls and deflector plates distribute the air more uniformly than the diffuser with straight side walls.

Keywords: Photovoltaic (PV), diffuser, deflector, distribution of air

1.Introduction

In the world of climate change, importance of renewable energy is crucial. In today's scenario not only fossil fuels are depleting but also due to pollution, the whole world is facing the effects of climate change. Solar energy is one of the promising ways to tackle this problem. Solar photovoltaic panel is the device which converts the solar energy into electrical energy.However, the use of PV cells is limited due to high cost. Scientists have been doing research on this since two decades and is still going on. Earlier research was carried on PV panels or thermal systems alone, but now emphasis is on PV/T systems [1]. The temperature of PV cells affects the power output of Photovoltaic/Thermal systems. The researcher focused on optimal thermal and electrical configuration of Photovoltaic/Thermal systems [2]. The various performance improvement techniques have been studied by some researchers such as geometrical modification of absorber plate, solar selective coatings and use of nanofluids [3]. The waste heat of solar PV cells can be utilized in integration with thermo electric generator for enhanced power output [4]. Based on various models it is found that PV panels yield highest output when the cooling of PV panel starts when the panels reaches maximum allowable temperature (MAT), that is 45 degrees. The MAT is the average temperature between the energy output and the cooling temperature required [5]. The innovative solution proposed to overcome the problem of overheating of PV panels is based on natural convection in which holes are drilled in PV panels to increase the natural convection which increases the heat transfer. This result in a better cooling of panels [6].
One way of improving efficiency of PV panel is the uniform distribution of air velocity along the panel. Diffusers are used for uniform distribution of air. In the present work, various shapes of diffuser and their effect on air velocity distribution is studied. The deflector plates are also used for uniform distribution of air. The various geometrical modifications of diffuser with and without deflector plates are simulated using commercial software ANSYS FLUENT.

2. System Description

2.1 Experimental setup

Figure 1 shows experimental set up by Amanlou et al. [7] for studying the air cooling of PV/T system. The solar collector has a wooden duct through which air is supplied. The fan of suitable capacity is used to supply air flow through the duct. The duct of collector is glazed by glass. The PV module used was single crystalline with standard electrical characteristics. The PV module was placed equidistance from glazing glass. The setup consist of two similar diffuser placed at upper and bottom side of the collector. The Fresnel reflector was used to direct solar radiations.

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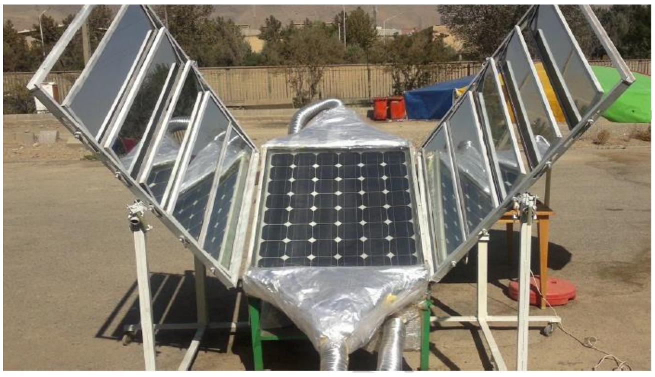
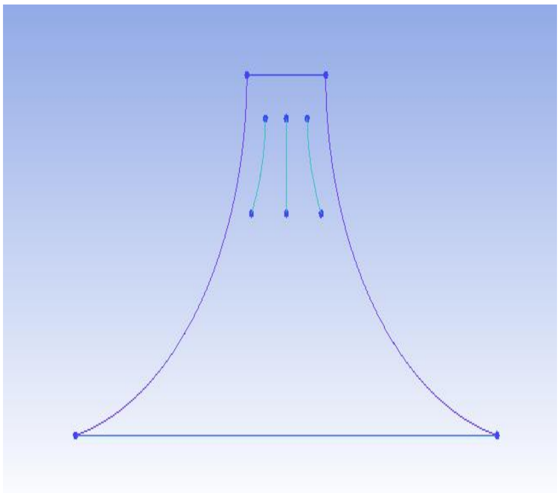


Fig.1 Experimental setup with PV/T collector [7]

2.2 Geometrical Modelling

2-dimensional geometrical model of diffuser is created to study the distribution of air velocity. Figure 2 shows one of the sketches of computational domain considered using ICEM CFD (circular side wall with three deflector plates). The dimensions of computational domain for the case considered are given in Table1. The diffuser dimensions are varied to obtain uniform distribution of air.



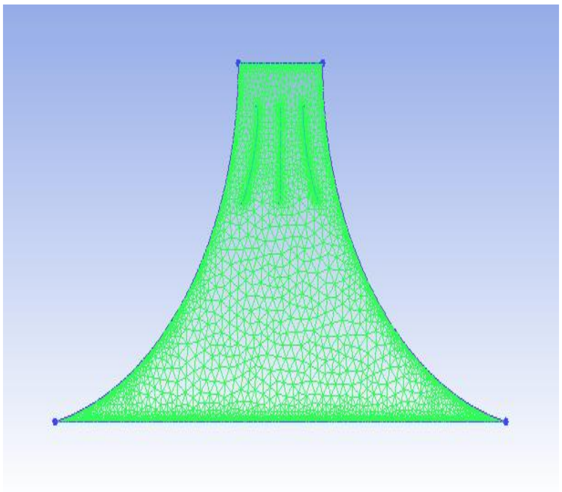


Fig.2 Computational domain of diffuser   Fig.3 Unstructured mesh generated for diffuser

Table.1. Dimensions of computational domain

Parameters	Dimensions
Panel dimension	0.655*0.455 m
Height of diffuser	0.2275 m
Radii of side walls	0.275 m
Diffuser outlet	0.455 m
Number of air deflectors	3,4

2.3 Mesh Generation

The computational domain has been discretized. The meshing of computational domain has been done using unstructured grids. Figure 3 shows unstructured mesh generated using ICEM CFD.

3. Result and discussion

Numerical analysis is carried out to study how the predicted flow field varies with the changes in the side walls of diffuser, height of diffuser and incorporating the deflector plates in the flow field. The analysis is carried out under the assumption of laminar flow. Equations that are used in the analysis is continuity, energy and Naiver-Stokes equations. The variation of fluid density was estimated by Boussinesq approximation. The inlet velocity of air is 0.5 m/s. Limited cases of diffusers are simulated computationally using the commercial software ANSYS FLUENT.

Figure 4 shows simple diffuser cases with the straight side walls and changes in the height of diffuser. This geometry does not distribute air velocity uniformly. When straight side walls of diffuser are replaced by curved side walls, air velocity get distributed to some extent. With increase in radius of curvature of side walls the air velocities tend to distribute more uniformly. Figure 5 shows distribution of air velocity with curved side walls. Figure 6 shows effect of use of deflector plates on distribution of air velocity. With three deflector plates, the air reaches to the corner of diffuser, but the centre of diffuser remains unaffected. Then the numbers of deflector plates are increased from 3 to 4. But it is observed that diffuser with three deflector plates is giving better distribution of air velocity compared to the diffuser with four deflector plates. Figure 7 shows the effect of curved side walls with four deflector plates on distribution of air velocity.

Figure 8 shows streamline contour for diffuser with curved side walls and three deflector plates. The velocity magnitude plot at the exit of this diffuser is shown in Figure 9. It shows that air velocity is uniformly distributed except at the centre of diffuser.

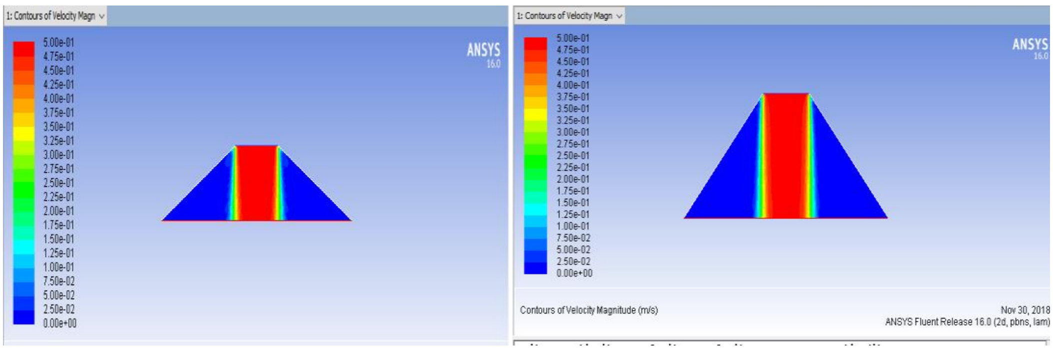


Fig.4 Effect of straight side walls and height of diffuser on distribution of air velocity

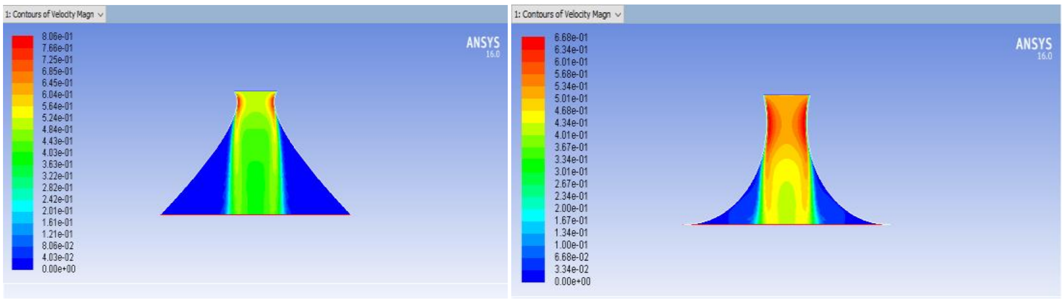


Fig.5 Effect of curved side walls of diffuser on distribution of air velocity

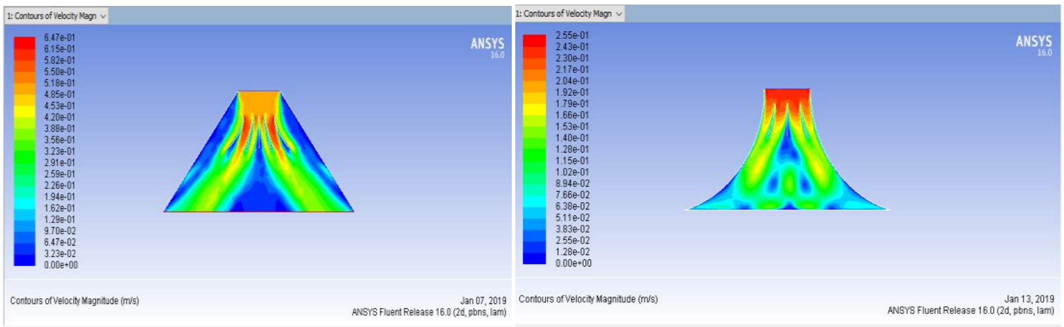


Fig.6 Effect of curved side walls of diffuser with deflector plates on distribution of air velocity

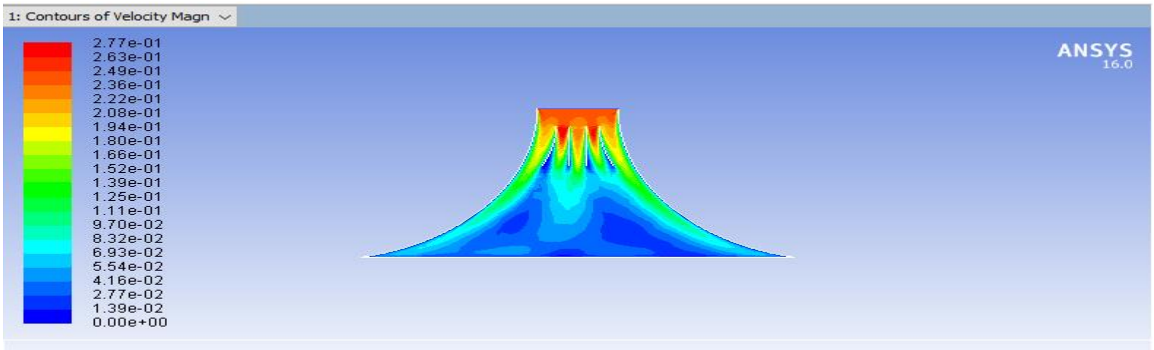


Fig.7 Effect of curved side walls of diffuser with four deflector plates on distribution of air velocity

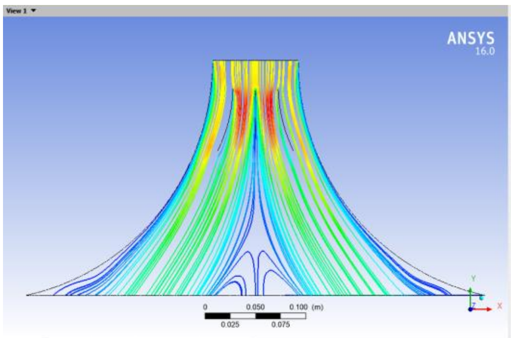


Fig.8 Stream line contour for diffuser with curved side walls and three deflector plates.

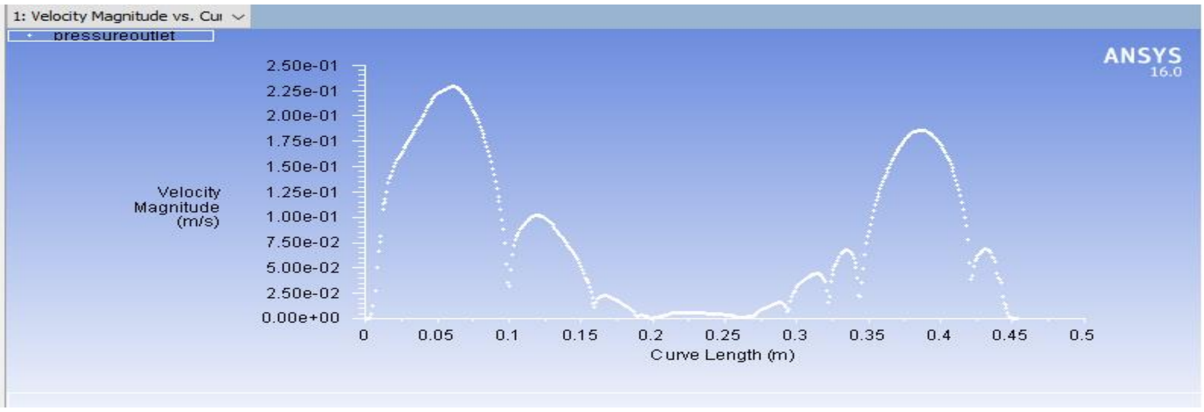


Fig.9 Magnitude of air velocity at the exit of diffuser for curved side walls with three deflector plates.

4.Conclusions

For designing suitable diffuser for uniform distribution of air velocity, different geometries of diffuser are simulated. The result of simulation shows that among all the geometries, diffuser with curved side walls and three deflector plates is the best geometry to be considered for uniform distribution of air velocity. It is also suggested that deflector plates should be close to the inlet of diffuser for uniform distribution of air velocity. It is also observed that height of diffuser has negligible effect on distribution of air velocity. The curvature of side walls and position of deflector plate significantly affect distribution of air velocity.

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