INTERNATIONAL JOURNAL OF TECHNO-ENGINEERING
IJTE

ISSN: 2057-5688

DESIGN AND FE ANALYSIS OF SOLAR FLAT PLATE COLLECTOR

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A B S T R A C T

Flat-plate collectors, developed by Hottel and Whillier in the 1950s, are the most common type. They consist of (1) a dark flat-plate absorber, (2) a transparent cover that reduces heat losses, (3) a heat-transport fluid (air, antifreeze or water) to remove heat from the absorber, and (4) a heat insulating backing.In this thesis the air flow throughsolar flat plates is modeled using PRO-E design software. The thesis will focus on thermal and CFD analysis with different fluid air, water and different angles (90^0,30^0,45^0&60^0) of the solar flat plates. Thermal analysis done for the solar flat plates by, aluminum &copper at different heat transfer coefficient values. These values are taken from CFD analysis.In this thesis the CFD analysis to determine the heat transfer coefficient, heat transfer rate, mass flow rate, pressure drop and thermal analysis to determine the temperature distribution, heat flux with different materials.3D modeled in parametric software Pro-Engineer and analysis done in ANSYS.

Key words: Solar collector, CREO Software. Ansys software

I INTRODUCTION

INTRODUCTION TO FLAT PLATE COLLECTORS

Flat-plate collectors, developed by Hottel and Whillier in the 1950s, are the most common type. They consist of (1) a dark flat-plate absorber, (2) a transparent cover that reduces heat losses, (3) a heat-transport fluid (air, antifreeze or water) to remove heat from the absorber, and (4) a heat insulating backing. The absorber consists of a thin absorber sheet (of thermally stable polymers, aluminum, steel or copper, to which a matte black or selective coating is applied) often backed by a grid or coil of fluid tubing placed in an insulated casing with a glass or polycarbonate cover. In water heat panels, fluid is usually circulated through tubing to transfer heat from the absorber to an insulated water tank. This may be achieved directly or through a heat exchanger.

Most air heat fabricators and some water heat manufacturers have a completely flooded absorber consisting of two sheets of metal which the fluid passes between. Because the heat exchange area is greater they may be marginally more efficient than traditional absorbers.[3] Sunlight passes through the glazing and strikes the absorber plate, which heats up, changing solar energy into heat energy. The heat is transferred to liquid passing through pipes attached to the absorber plate. Absorber plates are commonly painted with "selective coatings", which absorb and retain heat better than ordinary black paint. Absorber plates are usually made of metal—typically copper or aluminum—because the metal is a good heat conductor. Copper is more expensive, but is a better conductor and less prone to corrosion than aluminum.

Applications

The main use of this technology is in residential buildings where the demand for hot water has a large impact on energy bills. This generally means a situation with a large family, or a situation in which the hot water demand is excessive due to frequent laundry washing. Commercial applications include Laundromats, car washes, military laundry facilities and eating establishments. The technology can also be used for space heating if the building is located off-grid or if utility power is subject to frequent outages. Solar water heating systems

ISSN: 2057-5688

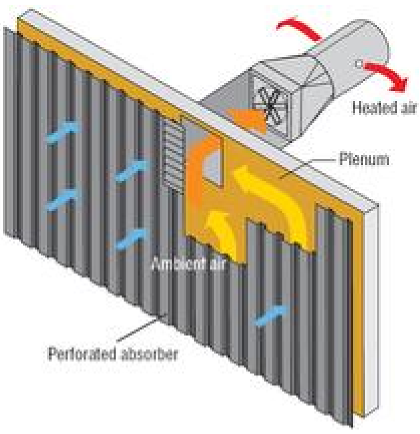
are most likely to be cost effective for facilities with water heating systems that are expensive to operate, or with operations such as laundries or kitchens that require large quantities of hot water. Unglazed liquid collectors are commonly used to heat water for swimming pools but can also be applied to large scale water pre-heating. When loads are large relative to available collector area the bulk of the water heating can be done at low temperature, lower than at swimming pool temperatures where unglazed collectors are well established in the marketplace as the right choice.

Glazed systems

Glazed systems usually have a transparent top sheet and insulated side and back panels to minimize heat loss to ambient air. The absorber plates in modern panels can have absorptivity of more than 93%. Glazed Solar Collectors (recirculating types that are usually used for space heating). Air typically passes along the front or back of the absorber plate while scrubbing heat directly from it. Heated air can then be distributed directly for applications such as space heating and drying or may be stored for later use. Payback for glazed solar air heating panels can be less than 9–15 years depending on the fuel being replaced.

Unglazed systems

Unglazed systems, or transpired air systems have been used to heat make-up or ventilation air in commercial, industrial, agriculture and process applications. They consist of an absorber plate which air passes across or through as it scrubs heat from the absorber. Non-tranparent glazing materials are less expensive, and decrease expected payback periods. Transpired collectors are considered "unglazed" because their collector surfaces are exposed to the elements, are often not transparent and not hermetically sealed.



LITERATURE REVIEW

Flat Plate Collector (FPC) is widely used for domestic hot-water, space heating/drying and for applications requiring fluid temperature less than 100oC. Three main components associated with FPC namely, absorber plate, top covers and heating pipes. The absorber plate is selective coated to have high absorptivity. It receives heat by solar radiation and by conduction; heat is transferred to the flowing liquid through the heating pipes. The fluid flow through the collector pipes is by natural (thermosyphon effect) or by forced circulation (pump flow). For small water heating systems natural circulation is used for fluid flow. Conventionally, absorbers of all flat plate collectors are straight copper/aluminum sheets however, which limits on the heat collection surface transfer area. Thus, higher heat collection surface area is optimized by changing its geometry with the same space of conventional FPC. The objective of present study is to evaluate the performance of FPC with different geometric absorber configuration. It is expected that with the same collector space higher thermal efficiency or higher water temperature can be obtained. Thus, cost of the FPC can be further bringing down by enhancing the collector efficiency.

Chapter -3

Problem description & methodology

Air flow through solar flat plates is modeled using PRO-E design software. The thesis will focus on thermal and CFD analysis with different fluids air, water and different angles (90^0,30^0,45^0&60^0) of the solar flat plates. Thermal analysis done for the solar flat plates by aluminum & copper at different heat transfer coefficient values.

• **Fluids**	• **Angle of plate**	• **material**
• air	• • **0^0,30^0,45^0&60^0**	• **Copper**
• water		• **aluminum** •

ADVANTAGES OF CREO PARAMETRIC SOFTWARE

1. Optimized for model-based enterprises
2. Increased engineer productivity
3. Better enabled concept design
4. Increased engineering capabilities
5. Increased manufacturing capabilities
6. Better simulation
7. Design capabilities for additive manufacturing

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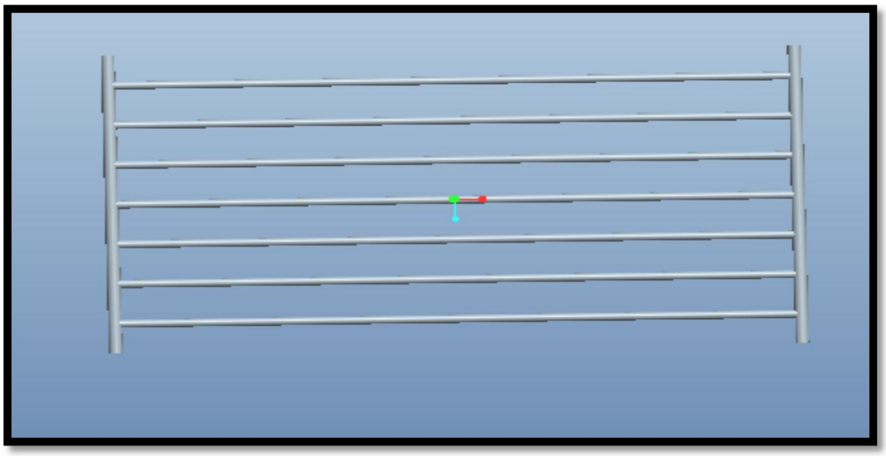
CREO parametric modules:

- Sketcher
- Part modeling
- Assembly
- Drafting



CFD ANALYSIS OF SOLAR FLAT PLATES

SOLAR FLAT PLATE ANGLES 90^0,60^0,45^0& 30^0

FLUID –AIR & WATER

MATERIAL PROPERTIES OF AIR

Thermal conductivity = 0.024w/m-k

Density = 1.225kg/m^3

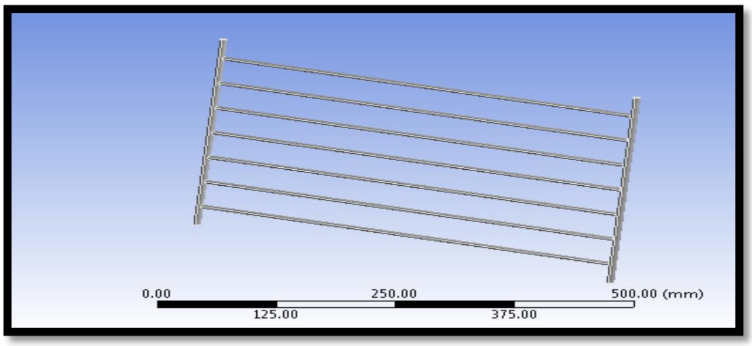
Viscosity = 1.98×10^{-5} kg/m-s

MATERIAL PROPERTIES OF WATER

Thermal conductivity = 0.024w/m-k

Density = 1.225kg/m^3

Viscosity = 1.98×10^{-5} kg/m-s



Meshing

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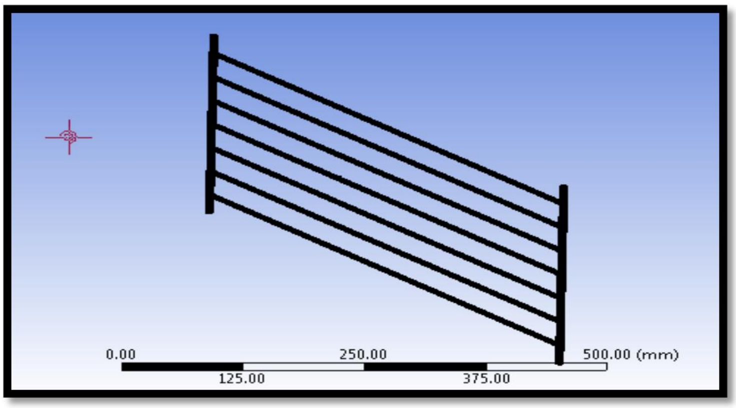
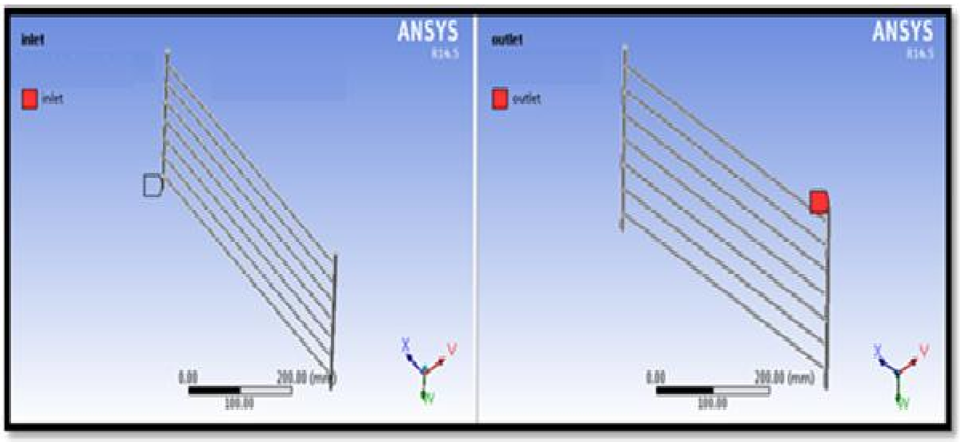
IJTE
ISSN: 2057-5688

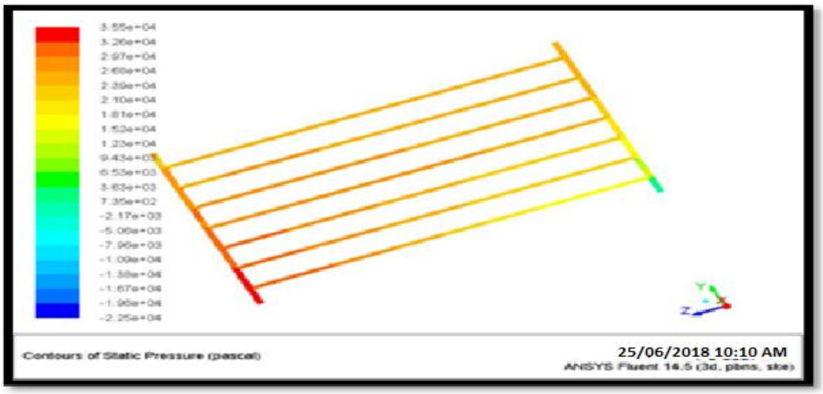




SOLAR FLATPLATE AT 90^0

FLUID-AIR

STATIC PRESSURE



Static pressure

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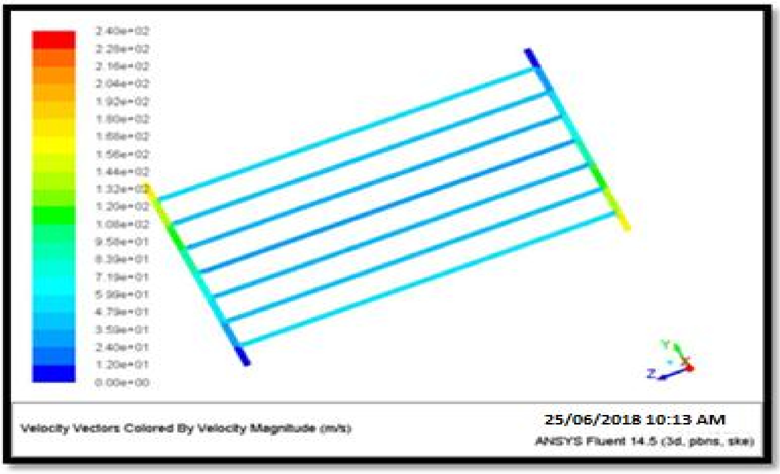
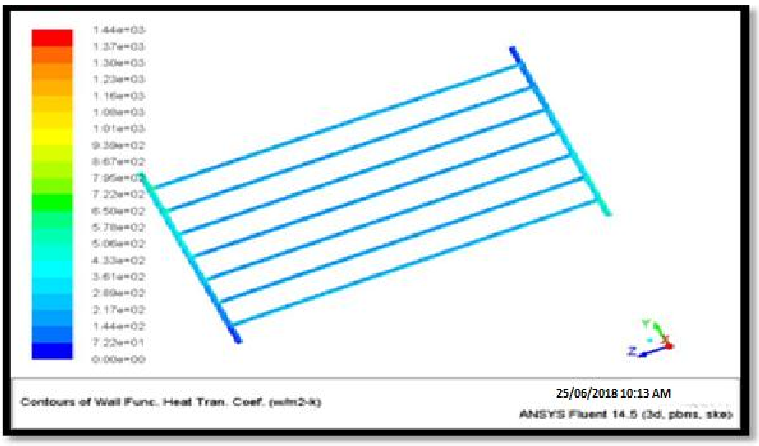
ISSN: 2057-5688



HEAT TRANSFER COEFFICIENT



Mass flow rate

```
                  Mass Flow Rate                  (kg/s)
-------------------------------- --------------------
                           inlet           0.010499999
               interior-partbody            0.03278254
                          outlet          -0.010510959
                   wall-partbody                     0
                ---------------- --------------------
                             Net        -1.0959804e-05

         Total Heat Transfer Rate                   (w)
-------------------------------- --------------------
                           inlet             790.97839
                          outlet            -791.80414
                   wall-partbody                     0
                ---------------- --------------------
                             Net           -0.82574463
```

CFD ANALYSIS RESULTS TABLE

Angle (^{0})	Fluids	Pressure (Pa)	Velocity (m/s)	Heat transfer coefficient (w/m^2-k)	Mass flow rate (kg/s)	Heat transfer rate(w)
	Air	3.55e+004	2.40e+02	1.44e+03	1.0958e-05	0.82574

ISSN: 2057-5688

90^0	Water	1.5e+02	2.95e-01	7.91e+03	3.23e-05	10.122314
60^0	Air	4.65e+04	3.40e+02	1.90e+03	3.9424e-05	2.9698
	Water	1.66e+02	4.68e-01	1.33e+04	0.0001913	59.8955
45^0	Air	4.68e+04	2.85e+02	1.64e+03	2.5503e-05	1.920105
	Water	1.40e+02	3.14e-01	9.36e+03	7.77e-05	24.3361
30^0	Air	3.70e+04	2.39e+02	1.22e+03	5.0231e-05	3.1235e-05
	Water	1.30e+02	2.90e-01	6.78e+03	3.7843628	9.75878

CONCLUSION

In this thesis the air flow through solar flat plates is modeled using PRO-E design software. The thesis will focus on thermal and CFD analysis with different fluids air, water and different angles (90^0,30^0,45^0&60^0) of the solar flat plates. Thermal analysis done for the solar flat plates by aluminum & copper at different heat transfer coefficient values. These values are taken from CFD analysis at different Reynolds numbers.By observing the CFD analysis the pressure drop & velocity values are more for water fluid at 60^0 solar flat plate collectors. The more heat transfer rate at 60^0 angles by fluid water.By observing the thermal analysis, the taken different heat transfer coefficient values are fromCFD analysis. Heat flux value is more for copper material than aluminum at 60^0 solar flat plate collectorsSo we can conclude the copper material is better for solar flat plates.

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