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ANALYTICAL INVESTIGATION OF SOLAR COLLECTORS BY USING FEA

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Abstract:
Solar energy currently represents the most abundant inexhaustible, nonpolluting, and free energy resources that could have a positive meaning in alleviating the global energy shortage and environmental pollution. However, the solar energy is intermittent in nature and that received on earth is of small flux density due to atmospheric scattering and abortion, making it necessary to use large surfaces to collect solar energy for drying cut tobacco process utilization. The major technologies used for solar energy conversion to heat are thermal processes comprising of solar collectors. In this thesis the fluid flow through solar collectors (flat plate and parabolic trough) is modeled using CREO design software. The thesis will focus on thermal and CFD analysis with different fluids air, water, R30 and R60 of the solar collectors. Thermal analysis done for the solar collectors by steel, aluminum & copper materials.In this thesis the CFD analysis to determine the heat transfer coefficient, heat transfer rate, mass flow rate, pressure drop at different fluids 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.

Keywords: Solar collectoer, FEA, CFD, ANSYS.

.I. INTRODUCTION

The operation of any solar thermal energy collector can be described as an energy balance between the solar energy absorbed by the collector and the thermal energy removed or lost from the collector. If no alternative mechanism is provided for removal of thermal energy, the collector receiver heat loss must equal the absorbed solar Energy. The temperature of the receiver increases until the convective and radiation heat loss from the receiver Equals the absorbed solar energy. The temperature at which this occurs is termed the collector stagnation Temperature. For control of the collector temperature at some point cooler than the stagnation temperature, active removal of heat must be employed. This heat will then available for use in a solar energy system. The rate at which Heat is actively removed from the collector determines the collector operating temperature. For removal of a large Fraction of the absorbed solar energy as useful heat, the amount of heat lost from the receiver must be kept small. Receiver heat loss can be reduced by operating the collector near the ambient temperature (such as with low-temperature flat-plate collectors) or by constructing the collector such that heat loss at elevated temperature is Reduced. The most common way of reducing receiver heat loss at elevated temperatures is to reduce the size of the hot surface (i.e., the receiver) since heat loss is directly proportional to area of the hot surface. Concentrating collectors reduce the area of the receiver by reflecting (or refracting) the light incident on a large area (the collector aperture) over an absorber of small area. With reduced heat loss, concentrating collectors can operate at elevated Temperatures and still provide significant quantities of useful thermal energy. A second reason for using concentration in the design of solar collectors is that, in general, reflective surfaces are usually less expensive than absorbing (receiver) surfaces. Therefore, large amounts of inexpensive reflecting surface area can be placed in a field, concentrating the incident solar energy on smaller absorbing surfaces. However, concentrating collectors must track the sun´s movement across the sky, adding significant cost to the construction of a concentrating collector system.

Fig.2.1.solar air heaters

II. LITERATURE REVIEW

A novel parabolic trough concentrating solar heating for cut tobacco drying system was established. The opening width effect of V type metal cavity absorber was investigated. A cut tobacco drying mathematical model calculated by fourth-order Runge-Kutta numerical solution method was used to simulate the cut tobacco drying process. And finally the orthogonal test method was used to optimize the parameters of cut tobacco drying process. The result shows that the heating rate, acquisition factor, and collector system efficiency increase with increasing the opening width of the absorber. The simulation results are in good agreement with experimental data for cut tobacco drying process. The relative errors between simulated and experimental values are less than 8% ,indicating that this mathematical model is accurate for the cut tobacco airflow drying process. The optimum preparation conditions are an inlet airflow velocity of 15 m/s, an initial cut tobacco moisture content of 26%,andan inlet airflow temperature of 200∘C.The thermal efficiency of the dryer and the final cut tobacco moisture content are 66.32% and 14.15%, respectively. The result shows that this parabolic trough concentrating solar heating will be one of the heat recourse candidates for cut tobacco drying system.

INTRODUCTION TO CAD

Computers are being used increasingly for both design and detailing of engineering components in the drawing office. Computer-aided design (CAD) is defined as the application of computers and graphics software to aid or enhance the product design from conceptualization to documentation. CAD is most commonly associated with the use of an interactive computer graphics system, referred to as a CAD system.

INTRODUCTION TO PRO/ENGINEER

Pro/ENGINEER, PTC's parametric, integrated 3D CAD/CAM/CAE solution, is used by discrete manufacturers for mechanical engineering, design and manufacturing. This powerful and rich design approach is used by companies whose product strategy is family-based or platform-driven, where a prescriptive design strategy is critical to the success of the design process by embedding engineering constraints and relationships to quickly optimize the design, or where the resulting geometry may be complex or based upon equations. Pro/ENGINEER provides a complete set of design, analysis and manufacturing capabilities on one, integral, scalable platform.

INTRODUCTION TO FEA

FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. A company is able to verify a proposed design will be able to perform to the client's specifications prior to manufacturing or construction. Modifying an existing product or structure is utilized to qualify the product or structure for a new service condition. In case of structural failure, FEA may be used to help determine the design modifications to meet the new condition.

INTRODUCTION TO ANSYS

ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements. The software implements equations that govern the behaviour of these elements and solves them all; creating a comprehensive explanation of how the system acts as a whole. These results then can be presented in tabulated, or graphical forms. This type of analysis is typically used for the design and optimization of a system far too complex to analyze by hand. Systems that may fit into this category are too complex due to their geometry, scale, or governing equations. ANSYS provides a cost-effective way to explore the performance of products or processes in a virtual environment. This type of product development is termed virtual prototyping.

INTRODUCTION TO CFD

Computational fluid dynamics, usually abbreviated as CFD, is a branch of fluid mechanics that uses numerical methods and algorithms to solve and analyze problems that involve fluid flows. Computers are used to perform the calculations required to simulate the interaction of liquids and gases with surfaces defined by boundary conditions. With high-speed supercomputers, better solutions can be achieved. Ongoing research yields software that improves the accuracy and speed of complex simulation scenarios such as transonic or turbulent flows. Initial experimental validation of such software is performed using a wind tunnel with the final

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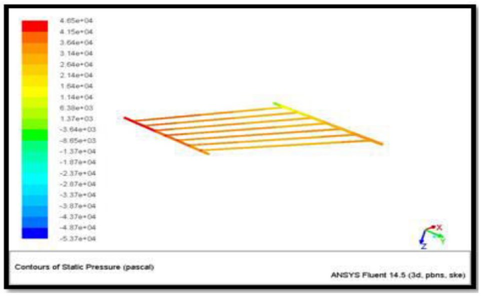
validation coming in full-scale testing, e.g. flight tests.

RESULTS & DISCUSSIONS

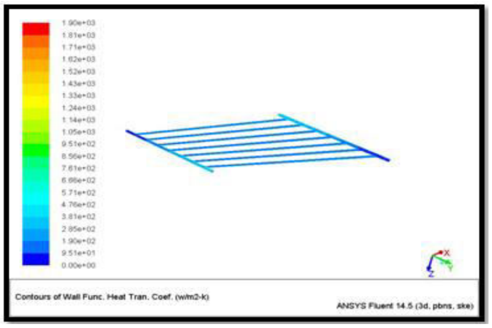
CFD ANALYSIS OF SOLAR FLATPLATE

FLUID-WATER

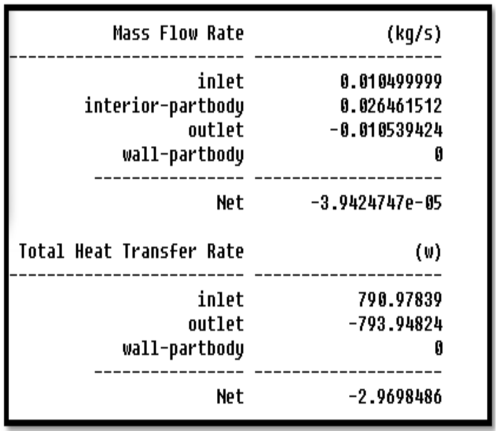
STATIC PRESSURE



HEAT TRANSFER COEFFICIENT



MASS FLOW RATE & HEAT TRANSFER RATE



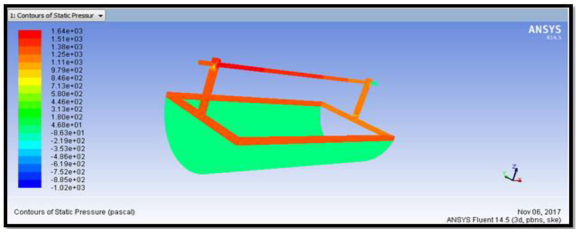
```
                 Mass Flow Rate                   (kg/s)
-------------------------------- --------------------
                          inlet              0.010499999
             interior-partbody              0.026461512
                         outlet             -0.010539424
                  wall-partbody                        0
                ---------------- --------------------
                            Net          -3.9424747e-05

        Total Heat Transfer Rate                      (w)
-------------------------------- --------------------
                          inlet                790.97839
                         outlet               -793.94824
                  wall-partbody                        0
                ---------------- --------------------
                            Net               -2.9698486
```

CFD ANALYSIS OF PARABOLIC SOLAR TROUGH

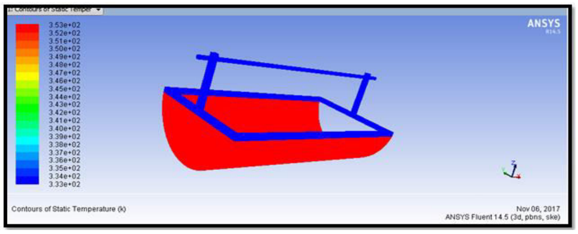
CASE 1-ORIGINAL MODEL

FLUID –WATER

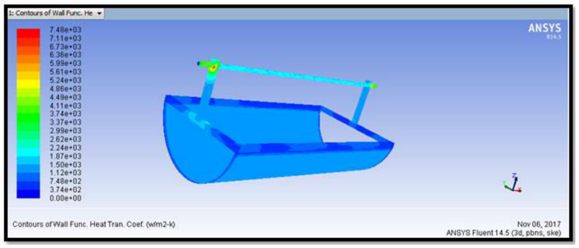
STATIC PRESSURE



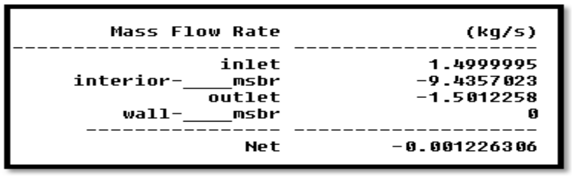
TEMPERATURE



HEAT TRANSFER CO-EFFICIENT

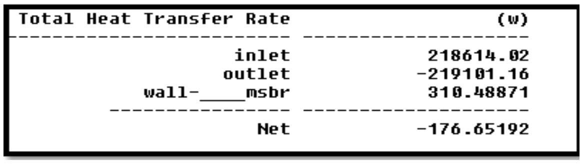


MASS FLOW RATE



```
                 Mass Flow Rate                   (kg/s)
-------------------------------- --------------------
                          inlet                1.4999995
             interior-_____msbr               -9.4357023
                         outlet               -1.5012258
                 wall-_____msbr                        0
                ---------------- --------------------
                            Net             -0.001226306
```

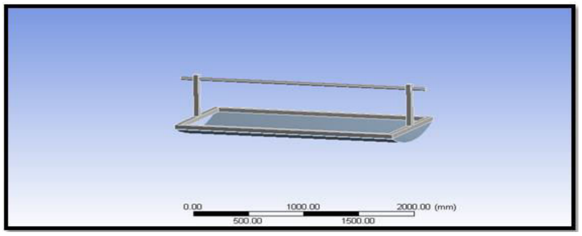
HEAT TRANSFER RATE



```
 Total Heat Transfer Rate                            (w)
-------------------------------- --------------------
                          inlet                218614.02
                         outlet               -219101.16
                 wall-_____msbr                310.48871
                ---------------- --------------------
                            Net               -176.65192
```

CASE 2-MODIFIED MODEL

IMPORTED MODEL



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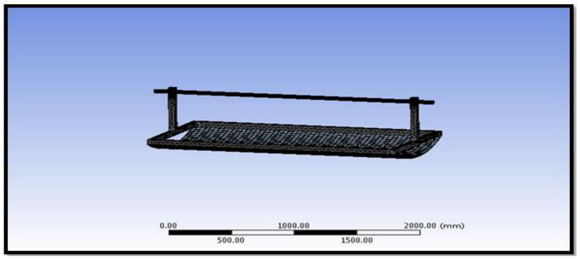
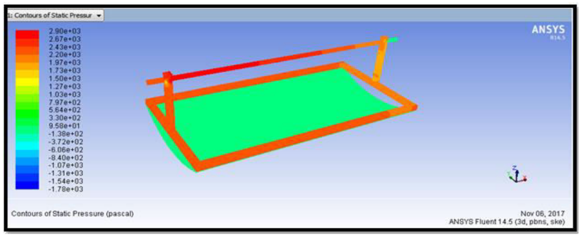
MESHED MODEL



FLUID –WATER

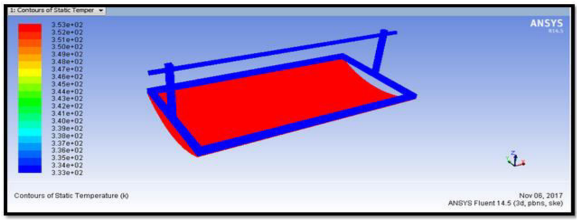
STATIC PRESSURE



Contours of Static Pressure (pascal)

Nov 06, 2017
ANSYS Fluent 14.5 (3d, pbns, ske)

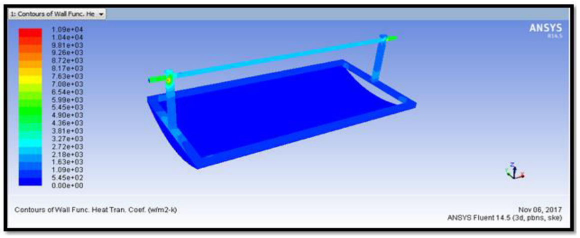
TEMPERATURE



Contours of Static Temperature (k)

Nov 06, 2017
ANSYS Fluent 14.5 (3d, pbns, ske)

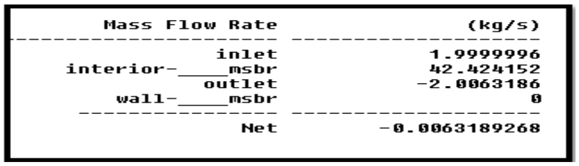
HEAT TRANSFER CO-EFFICIENT



Contours of Wall Func. Heat Tran. Coef. (w/m2-k)

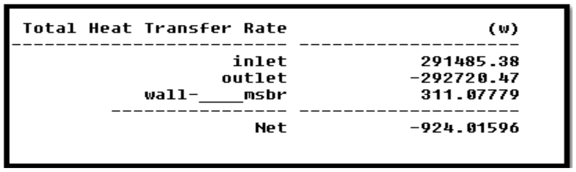
Nov 06, 2017
ANSYS Fluent 14.5 (3d, pbns, ske)

MASS FLOW RATE



```
                Mass Flow Rate                      (kg/s)
 -------------------------------- --------------------
                         inlet                   1.9999996
          interior-____msbr                  42.424152
                        outlet                  -2.0063186
                wall-_____msbr                           0
 -------------------------------- --------------------
                           Net              -0.0063189268
```

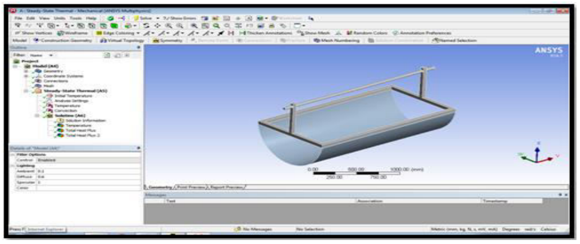
HEAT TRANSFER RATE



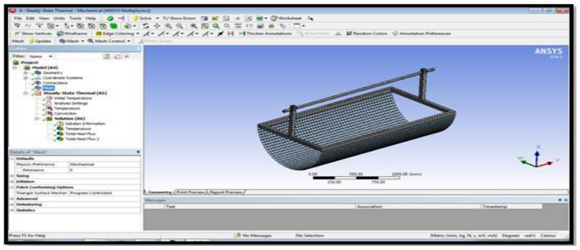
```
  Total Heat Transfer Rate                    (w)
 ---------------------------- --------------------
                     inlet              291485.38
                    outlet             -292720.47
             wall-____msbr              311.07779
 ---------------------------- --------------------
                       Net             -924.01596
```

THERMAL ANALYSIS OF SOLAR PARABOILC TROUGH

IMPORTED MODEL



MESHED MODEL

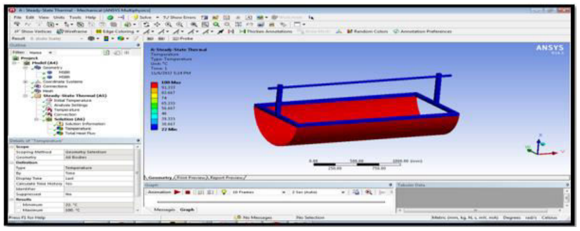


BOUNDARY CONDITIONS

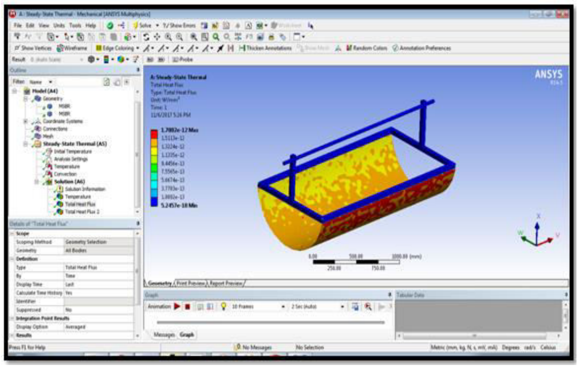
CASE -1 ORIGINAL MODEL

MATERIAL- STEEL

TEMPERATURE

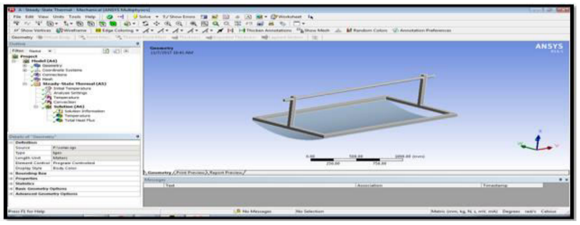


HEAT FLUX

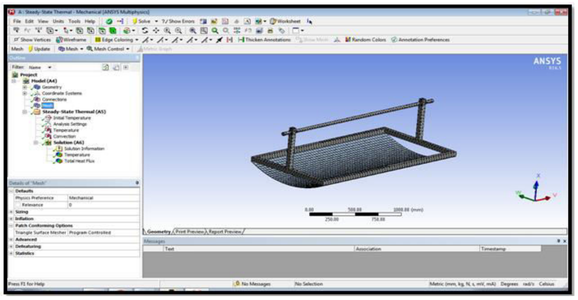


CASE -2 MODIFIED MODEL

IMPORTED MODEL

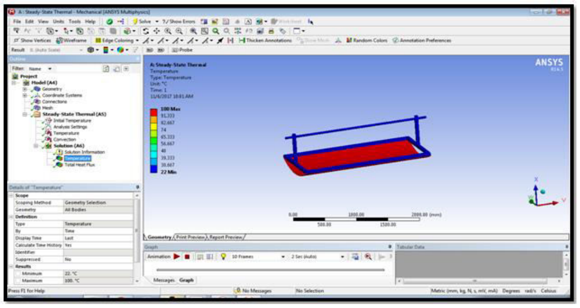


MESHED MODEL

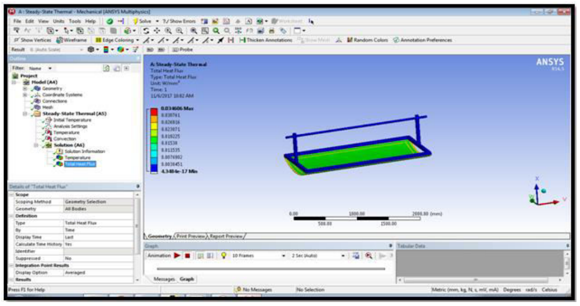


MATERIAL- STEEL

TEMPERATURE



HEAT FLUX



RESULTS TABELS

CFD ANALYSIS OF SOLAR FLAT PLATE

Fluids	Pressure (Pa)	Heat transfer coefficient (w/m^2-k)	Mass flow rate (kg/s)	Heat transfer rate(w)
AIR	3.55e+004	1.44e+03	1.0958e-05	0.82574
WATER	4.65e+04	1.90e+03	3.9424e-05	2.9698
R30	4.68e+04	1.64e+03	2.5503e-05	1.920105
R160	3.70e+04	1.22e+03	5.0231e-05	3.1235e-05

CFD ANALYSIS RESULTS

ORIGINAL MODEL

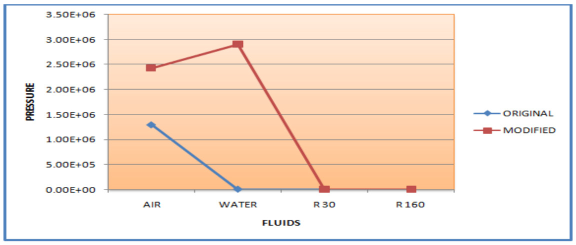
FLUID	PRESSURE (pa)	HEAT TRANSFER COFEEICENT	MASS FLOW RATE	HEAT TRANSFER RATE
AIR	1.30E+06	2.11E+03	0.00412	150.8656
WATER	1.64E+03	7.48E+03	0.0012263	176.651
R 30	1.24E+03	2.87E+02	0.001788	48.89
R 160	1.79E+03	9.84E+02	0.0013078	51.32959

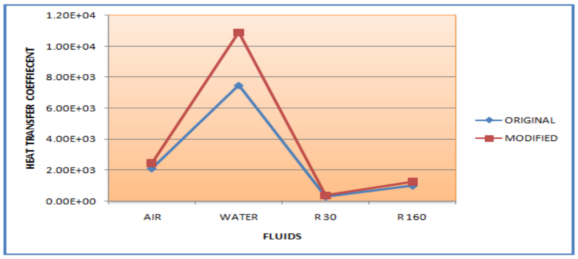
MODIFIED MODEL

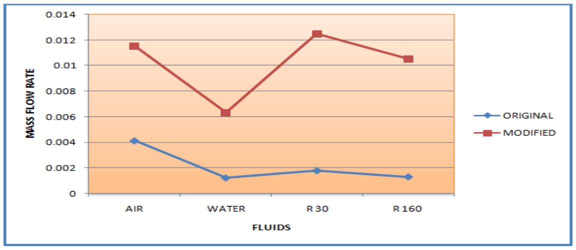
FLUID	PRESSURE (pa)	HEAT TRANSFER COFEEICENT	MASS FLOW RATE	HEAT TRANSFER RATE
AIR	2.43E+06	2.45E+03	0.011516	403.288
WATER	2.90E+06	1.09E+04	0.0063189	924.015
R 30	2.07E+03	3.60E+02	0.01248	449.7378
R 160	3.21E+03	1.25E+03	0.010541	371.2136

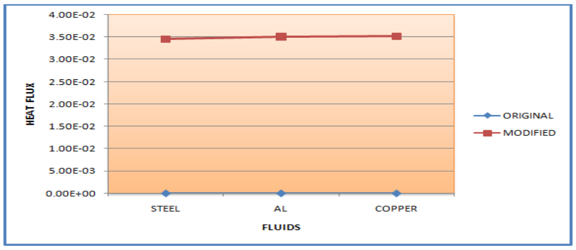
THERMAL ANALYSIS RESULTS

CASES	MATERIAL	HEAT FLUX
ORIGINAL MODEL	STEEL	1.7002E-12
	ALUMINUM ALLOY	4.5574E-12
	COPPER	1.237E-11
MODIFIED MODEL	STEEL	0.034606
	ALUMINUM ALLOY	0.035126
	COPPER	0.035206









CONCLUSION

In this thesis the fluid flow through solar collectors(flat plate and parabolic trough) is modeled using CREO design software. The thesis will focus on thermal and CFD analysis with different fluids air, water,R30 and R60 of the solar collectors. Thermal analysis done for the solar collectors by steel, aluminum & copper materials.By observing the CFD analysis the pressure drop & velocity values are more for water fluid at solar parabolic trough collectors compared with flat plate collector. The more heat transfer rate at fluid water.By observing the thermal analysis Heat flux value is less for steel material than aluminum and copper material at solar collectors and Heat flux value is more for copper material than aluminum and steel material at solar absorber So we can conclude the steel material is better for solar collectors, copper material is better for solar absorber and water is the best working fluid.

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