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# Thermal analysis of heat exchanger with and without baffles

**Nalivenkata Balakrishna[1], Dr. Mahesh Mallampati[2] , Dr. C.Govidarajulu[3],**
[1] PG scholar,Dept. of Mechanical Engineering, Guntur Engineering College, Guntur, AP
2Associate professor, Department of Mechanical Engineering, Guntur Engineering College, Guntur, AP
3professor &HOD, Department of Mechanical Engineering, Guntur Engineering College, Guntur, AP.

**ABSTRACT**

Heat exchangers have always been an important part to the lifecycle and operation of many systems. A heat exchanger is a device built for efficient heat transfer from one medium to another in order to carry and process energy. Typically one medium is cooled while the other is heated. They are widely used in petroleum refineries, chemical plants, and petrochemical plants. The purpose of this thesis work is to design an Oil Cooler, especially for shell and tube heat exchange which is the majority type of liquid to liquid heat exchanger with baffle for induced turbulence and higher heat transfer coefficient. Modeling is done by using solid works, and analysis carried out in Ansys software 15 General design consideration and design procedure are also illustrated in this thesis in design calculation;Within the project work the analysis are done for heat exchanger with baffle and without baffle also used four material for tubes (brass, monel-400, sae1020, steel 440c) and calculating results like Temperature distribution, heat flux and thermal gradient in heat transfer analysis. From these results we can calculate heat transfer rate is increased/ decreases for heat exchanger with baffle or without baffle usage.Also when we do structural analysis and calculate results like deformation, stress, and strain values too from all these which material or model is more optimum in real time boundary conditions

**Tools were used:**

**Cad tool**: solid works

**Cae tool**: Ansys workbench

## INTRODUCTION

### HEAT EXCHANGERS

A heat exchanger is a device that is used to transfer thermal energy (enthalpy) between two or more fluids, between a solid surface and a fluid, or between solid particulates and a fluid, at different temperatures and in thermal contact. In heat exchangers, there are usually no external heat and work interactions. Typical applications involve heating or cooling of a fluid stream of concern and evaporation or condensation of single-or multi component fluid streams. In other applications, the objective may be to recover or reject heat, or sterilize, pasteurize, fractionate, distill,

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concentrate, crystallize, or control a process fluid. In a few heat exchangers, the fluids exchanging heat are in direct contact. In most heat exchangers, heat transfer between fluids takes place through a separating wall or into and out of a wall in a transient manner. In many heat exchangers, the fluids are separated by a heat transfer surface, and ideally they do not mix or leak. Such exchangers are referred to as direct transfer type, or simply recuperate. In contrast, exchangers in which there is intermittent heat exchange between the hot and cold fluids—via thermal energy storage and release through the exchanger surface or matrix— are referred to as indirect transfer type, or simply regenerators. Such exchangers usually have fluid leakage from one fluid stream to the other, due to pressure divergences and matrix rotation/valve switching. Common examples of heat exchangers are shell-and-tube exchangers, automobile radiators, condensers, evaporators, air preheaters, and cooling towers. If no phase change occurs in any of the fluids in the exchanger, it is sometimes referred to as a sensible heat exchanger. There could be internal thermal energy sources in the exchangers, such as in electric heaters and nuclear fuel elements.Combustion and chemical reaction may take place within the exchanger, such as in boilers, fired heaters, and fluidized-bed exchangers. Mechanical devices may be used in some exchangers such as in scraped surface exchangers, agitated vessels, and stirred tank reactors. Heat transfer in the separating wall of a recuperate generally takes place by conduction.

**APPLICATIONS OF HEAT EXCHANGERS:**

- Heat exchangers are used in a wide variety of applications such as home heating, refrigeration, air conditioning, petrochemical plants, refineries as well as in natural gas processing.
- In many industrial processes a heat exchanger helps in using the wasted heat from one process to be utilized in another process which saves a lot of money while being efficient at the same time.
- Cooling of hydraulic fluid and oil in engines, transmissions and hydraulic power packs.
- Heat exchangers are used in many industries, including:

  -Waste water treatment

  -Refrigeration

  -Wine and beer making

  -Petroleum refining
- In commercial aircraft heat exchangers are used to take heat from the engine's oil system to heat cold fuel.

**Design developed by using cad tool**

(Create circles 323.80mm outer diameter 307mm inner diameter with reference dimensions

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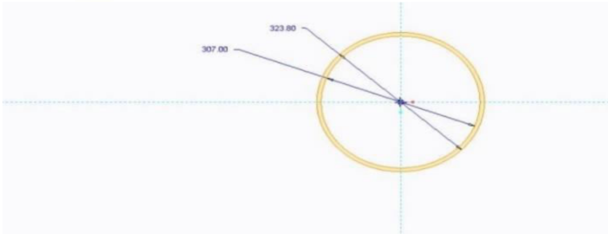
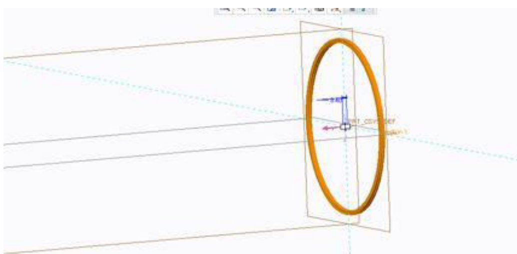
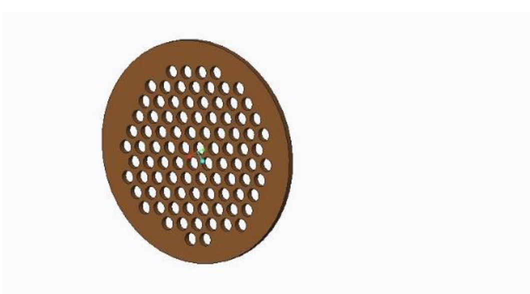


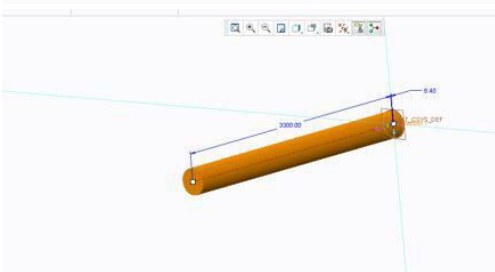

The above sketch should follow 3 conditions those are the sketcher should be closed and there should be no open end there should be no over lapping. By following these conditions we have to create our model. After completion of sketch click ok and we will get below model.

Then extrude it→8.40mm→ok



After creating extrude cut to repeat no of times here we used pattern option and in this we used fill option and the pattern model shown in below

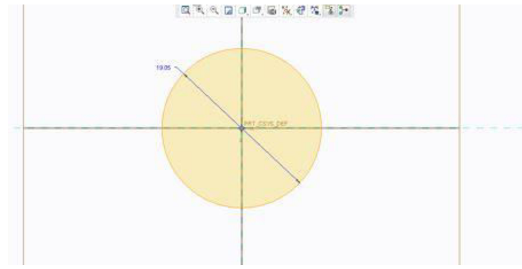




Heat exchanger →Extrude→3300mm→ok

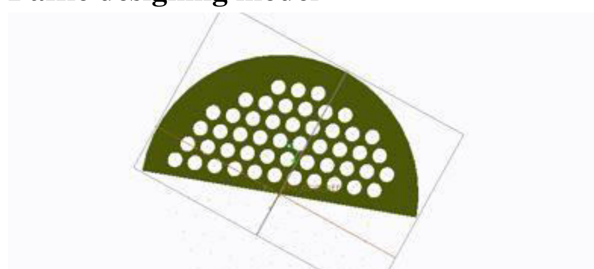
Shell→5mm thickness

**Tube designing**



The above sketch should follow 3 conditions those are the sketcher should be closed and there should be no open end there should be no over lapping. By following these conditions we have to create our model. After completion of sketch click ok and we will get below model.

**Baffle designing model**



**ASSEMBLING ALL MODELS**

Import heat exchanger shell first into assembly window then select default option this default option makes object planes coincide with assembly planes. Then import tube also and place it contact with plate hole. Here we are using only coincide constraint option for all these constraints To fill the object here we used reference pattern

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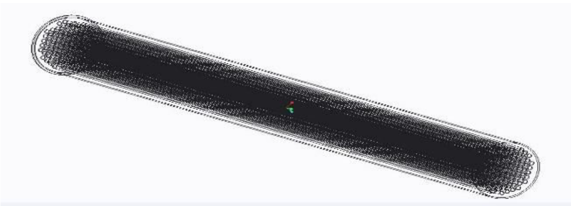
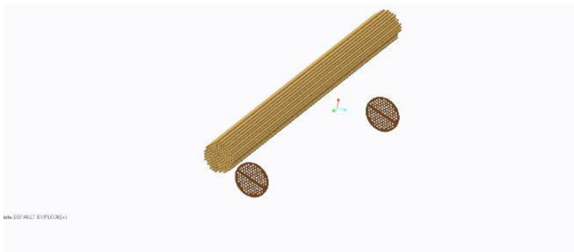
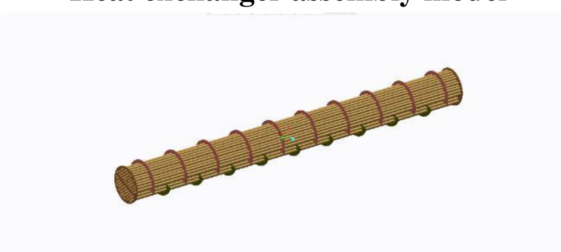


**Wireframe model**



**Explode view**

**Heat exchanger assembly model**



**Heat exchanger with baffles assembly model**

**ANSYS PROCESS**

**Material properties**

**Steel**

Young's modulus:- 2.0*10^11 Pa
Poison ratio: 0.3
Density: 7850Kg/m^3
Yield strength: 250 Mpa
Thermal conductivity: 60.5 w/m-k

**Brass**

Young's modulus:- 1.25*10^11 Pa
Poison ratio: 0.31
Density: 8490Kg/m^3
Yield strength: 310 Mpa
Thermal conductivity115 w/m-k

**Sae-1020**

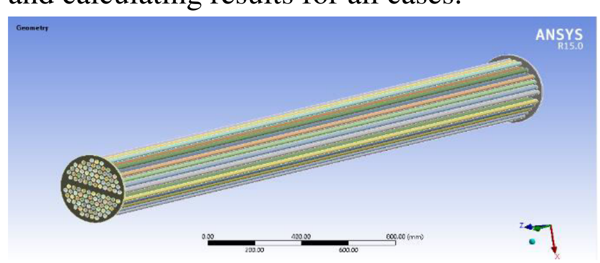
Young's modulus:- 2*10^11 Pa
Poison ratio: 0.29
Density: 7870Kg/m^3
Yield strength: 394.70 Mpa
Thermal conductivity: 51.9 w/m-k

**Steel - 440C**

Young's modulus:- 2.0*10^11 Pa
Poison ratio: 0.228
Density: 7800Kg/m^3
Yield strength: 450 Mpa
Thermal conductivity: 24.2 w/m-k

Geometry→ right click→ import geometry→ import iges format model

After importing model just click on geometry option then we will get selection of material. From engineering data here we already applied steel, sae1020, brass, steel440c material properties. Here we first took steel material for both fins and heat exchanger plate. Then we are changing fins material steel to sae 1020, brass, steel440c, and calculating results for all cases.




**Model imported from pro-e tool in IGES format.**

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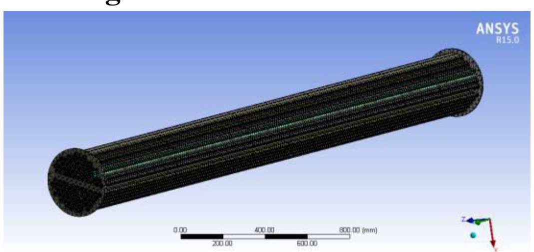
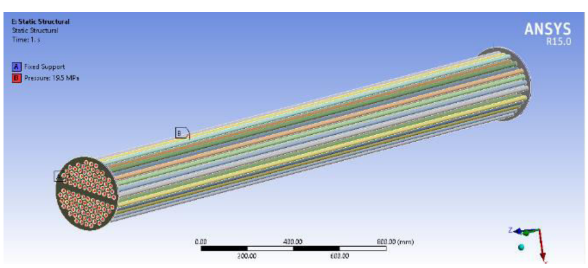
After completion of material selection here we have to create meshing for each object meshing means it is converting single part into no of parts. And this mesh will transfer applied loads for overall object. After completion meshing only we can solve our object. Without mesh we cannot solve our problem. And here we are using tetra meshing and the model shown in below.

**Meshing**




**Meshing**

After completion of meshing now we have to apply boundary conditions according to our requirement, in this process we fixed our model at two ends and applied pressure inside walls



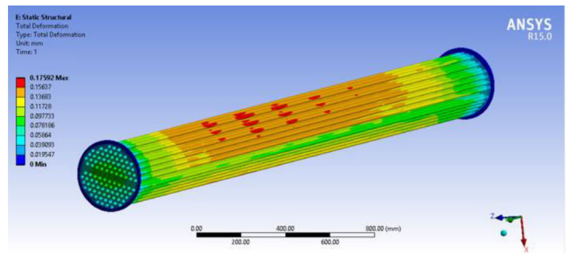

**Boundary conditions**

Static structural →supports→fixed support→select 2 side heat exchanger plates
Pressure→select in side fins area→19.5Mpa
Solution→solve→deformation, stress, and safety factor.

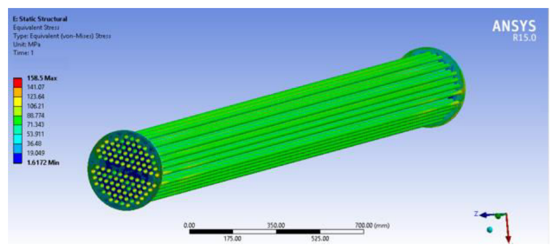
**HEAT EXCHANGER WITHOUT BAFFLE PLATES**

**Steel material for both fins and heat exchanger plate**

**Deformation**




**Stress**




**Safety factor**

From the results we have safety factor minimum 1.5773 for 19.5Mpa of pressure, it means our object is safe at this load. To increase efficiency values here we are changing fins material steel to brass and sae 1020, and steel 440c and applying same amount of boundary conditions on it calculating results

**Tables**

| | Deformation (mm) | Stress (Mpa) | Safety factor |
|---|---|---|---|
| Steel | 0.17592 | 158.5 | 1.5773 |
| Brass | 0.27128 | 171.83 | 1.4549 |
| Sae1020 | 0.17104 | 158.35 | 1.8166 |
| Steel-440c | 0.16618 | 158.2 | 1.8478 |

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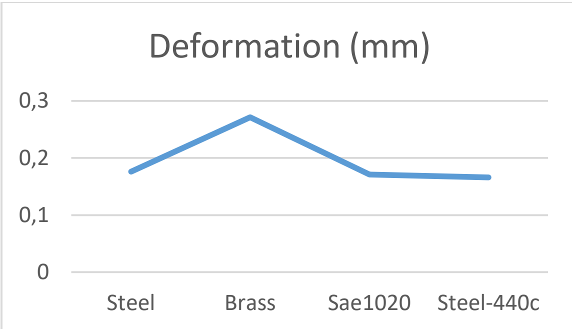
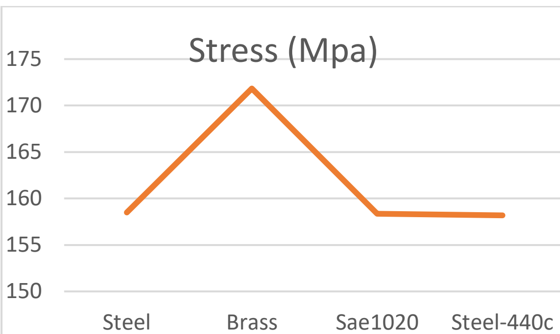
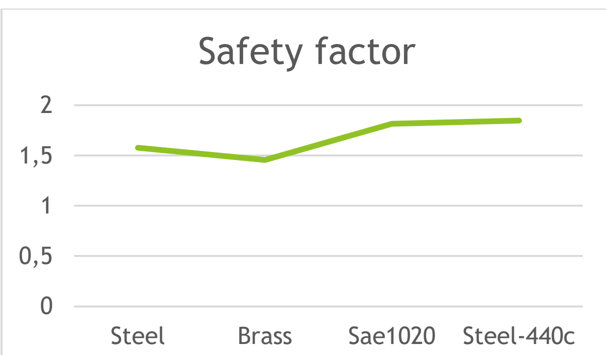
**Graphs**




From the results here we can say that by using steel fins we got 158.5Mpa of stress 1.5773 safety factor value, it means our model can use at this boundary condition, when we replace brass material the stress values increases to 171.83Mpa which is nearly 13Mpa higher than steel but safety factor value is not too decreases it is near to 1.5 only.

It means our brass even producing more stress values than steel material it is also under yield limit condition. Remaining sae1020, steel440c materials producing less stress values than steel and high strength values, so our 3 new materials all are safe to replace the steel material, by single analysis we cannot describe one material by comparing both static and thermal results we can conclude one material.

## HEAT EXCHANGER WITH BAFFLE PLATES

**Results**

| | Deformation (mm) | Stress (Mpa) | Safety factor |
|---|---|---|---|
| Steel | 0.058245 | 176.05 | 1.4201 |
| Brass | 0.0934555 | 176.19 | 1.4499 |
| Sae1020 | 0.058004 | 175.91 | 1.9063 |
| Steel-440c | 0.057743 | 175.78 | 1.9013 |

**THERMAL ANALYSIS**

After completion of meshing now we have to apply boundary conditions according to our requirement, in this process we gave conduction on heat exchanger plate and convection on fins

Select geometry assign material properties

Click on static thermal→ convectional→ select all fins inside areas→ 350*c ambient temperature→1.7035e-3 w/mm^2 film coefficient→ apply

→ Convectional→ select all fins outside areas→ 20*c ambient temperature→4.2587 e-3 w/mm^2 film coefficient→ apply

Temperature → select both heat exchanger plates→ 25*cc

. Solution→temperature→solve

**Boundary conditions**

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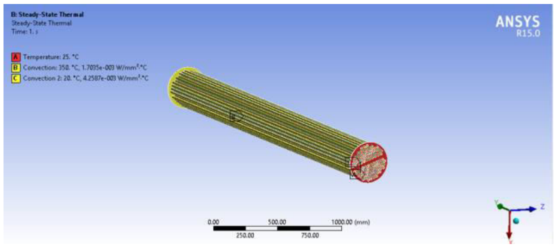


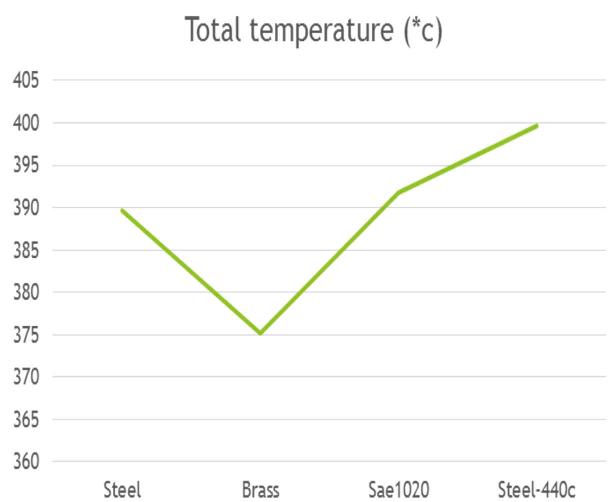

**Results**

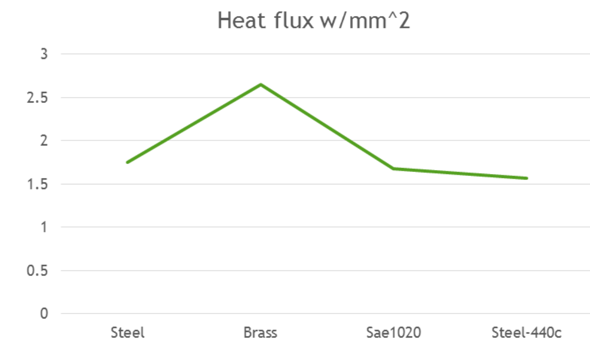
| | Total temperature (*c) | Heat flux w/mm^2 |
|---|---|---|
| Steel | 355.61 | 1.5056 |
| Brass | 326.73 | 2.0715 |
| Sae1020 | 360.85 | 1.4603 |
| Steel-440c | 377.84 | 1.4028 |

**HEAT EXCHANGER WITH BAFFLE PLATES**

| | Total temperature (*c) | Heat flux w/mm^2 |
|---|---|---|
| Steel | 389.72 | 1.7457 |
| Brass | 375.18 | 2.65 |
| Sae1020 | 391.83 | 1.6797 |
| Steel-440c | 399.59 | 1.5702 |

**Graphs**




By using baffle here heat transfer rate has been increased compare to without baffle and the total temperature distribution also increases compare to without baffle on each material

**CONCLUSION**

In this project we calculated stress and heat flux rate values on 2 different heat exchangers, to calculate those above results here we took 2 heat exchangers. one is completely fins and heat exchanger plate only, second is heat exchanger fins with baffle also.to create these models here we were used cad tool (solid works) and to calculate results we were used cae tool (Ansys workbench).

In this process we applied same boundary conditions on each model for both static and thermal cases. To get more efficient model here we also modifying fins existing material (steel) to (brass, sae1020, steel440) each time we calculated results and compare them with existing material

While analyzing our models here observe that without baffle model producing less stress values than with baffle, even with baffle heat exchanger producing more stress values but their safety factor results higher than without baffle. In this steel 440c, sae1020 material got less stress values and high strength values than two other materials, in each model.

Heat flow rate value is high in with baffle heat exchanger only compare to without baffle

Finally we can say by using with baffle heat exchanger we can get more heat transfer rate and high strength values. In this process we can also use sae1020, steel 440c fins instead of steel.

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