Optimization of a Studied Shell and Tube Heat Exchanger

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Aim of the Project

- Investigate an existing shell and tube heat exchanger which was made in 2004.
- The design and efficiency of the heat exchanger were then improved to modern standards.

Background

- Heat Exchangers have become a popular piece of equipment in recent years in industry.
- Heat Exchangers are a versatile piece of equipment that can be used in a process to transfer heat between two or more fluids or gasses.

Case Study

Figure 1: Case Study Heat Exchanger

- The above figure shows an image of the heat exchanger unit studied as part of the case study.
- By gathering information such as flow rates, temperatures and pressures from surrounding probes, the efficiency could be calculated for the unit.
- The overall efficiency is shown in the figure below and was 13%. Overall, an extremely low values regarding todays standards.

Efficency Calculations	
Q Hot (kW)	492.51
Q Cold (kW)	503.28
Q Actual (kW)	**503.28**
C Hot (kW/K)	76.95
C Cold (kW/K)	29.26
C Min (kW/K)	**29.26**
Q Max (kW)	3844.764
Overall Efficency (0.00)	0.13
Overall Efficency (%)	13%

Figure 2: Original Heat Exchanger Efficiency

Efficiency Optimization

Efficency Calculations	
Q Hot (kW)	2691.22
Q Cold (kW)	2741.62
Q Actual (kW)	**2741.62**
C Hot (kW/K)	98.94
C Cold (kW/K)	108.79
C Min (kW/K)	**20.14**
Q Max (kW)	2924.328
Overall Efficency (0.00)	0.94
Overall Efficency (%)	94%

Figure 3: Optimized Heat Exchanger Efficiency

- The above image shows the improved efficiency value of 94%.
- An improvement of 81% was possible through adjustment of the flow rates and temperatures on both the hot and cold sides of the heat exchanger
- This resulted in estimates being made for its density and specific heat capacity.

Design Optimization

- As mentioned previously, the studied heat exchanger was both designed and made circa. 2004.
- Along with the poor efficiency in comparison with modern day standards, the design of the heat exchanger was also dated.
- The studied heat exchanger features a single pass design. Most modern heat exchangers benefit from the efficiency of the double pass design.

Tube Area Calculation			
Q Cold (kW)	2741.62	No. of Tubes	56
ΔT1 (°C)	120	Length (mm)	1289.32
ΔT2 (°C)	139	Diameter	19.05
LMTD (°C)	129.27	Area per Tube	1377.20
U (kW/m^2K)	0.4	Radius	9.53
Area (m^2)	77.12		
Area (mm^2)	77123.28		

Figure 4: Optimized Heat Exchanger Design

Bill of Materials / Pricing

- The figure to the right shows the bill of materials priced for the project.
- It includes every material required to build the shell and tube from start to finish priced from local retailers. The total price came to €6,574.
- There was initially an objective to make a physical model of the heat exchanger, however funding was an issue for this.

FEA (Thermal and Pressure)

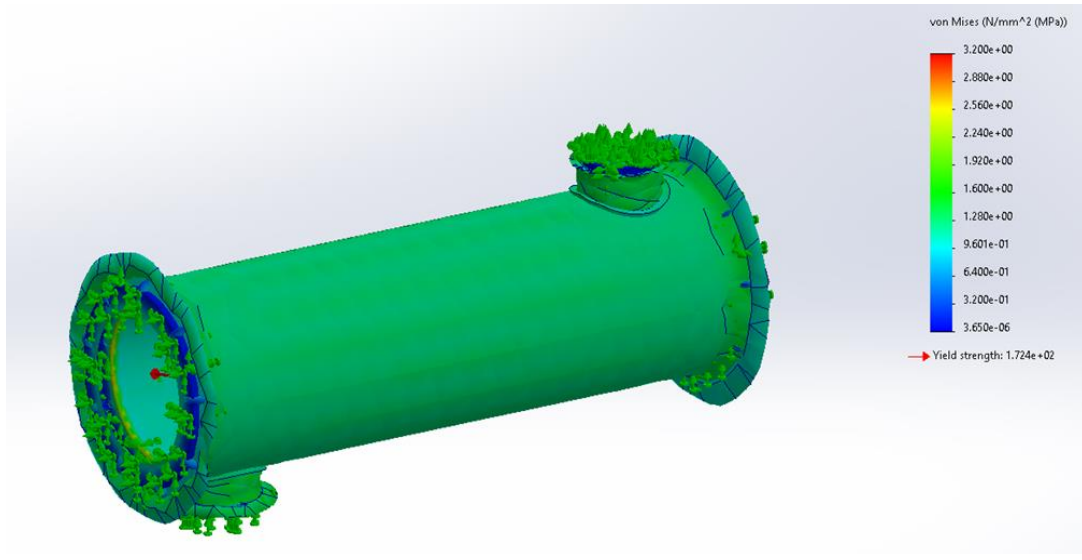

Figure 6: Shell and Tube FEA (Pressure)

- The above figure shows the FEA study for pressure on the inside of the shell. The shell is subdued to a 6bar or 0.6Mpa pressure whilst in operation.
- For good measure, a factor of safety of 3 was applied. The material used for the model was stainless steel 316L.
- With a total pressure of 1.8Mpa or 18bar, the stress was negligible.

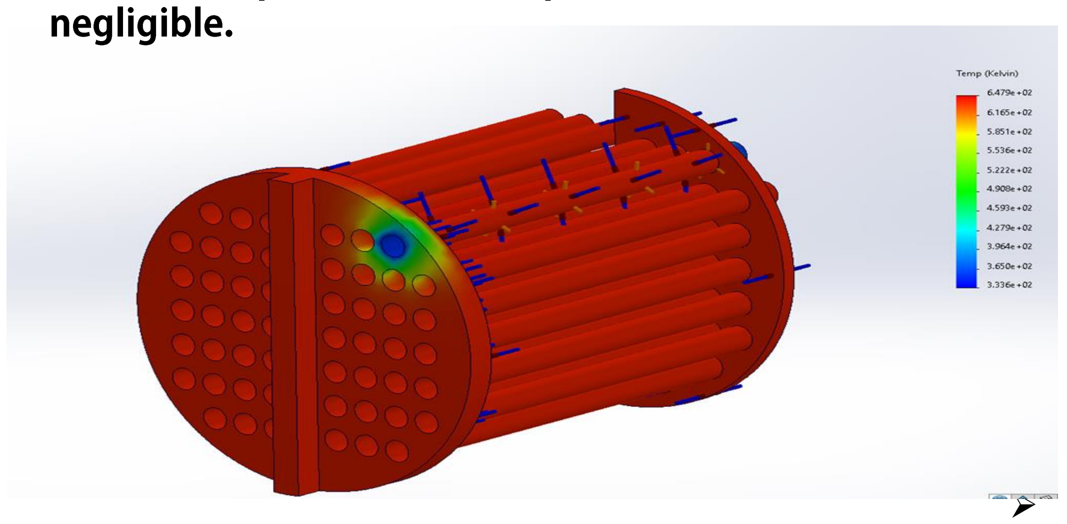

Figure 7: Shell and Tube FEA (Temperature)

- The above figure shows the FEA study for temperature. The study used the SolidWorks model of the tube bundle.
- Using the bundle, the effect on both the inside and outside of the tubes along with the baffles could be studied.

3D Printing

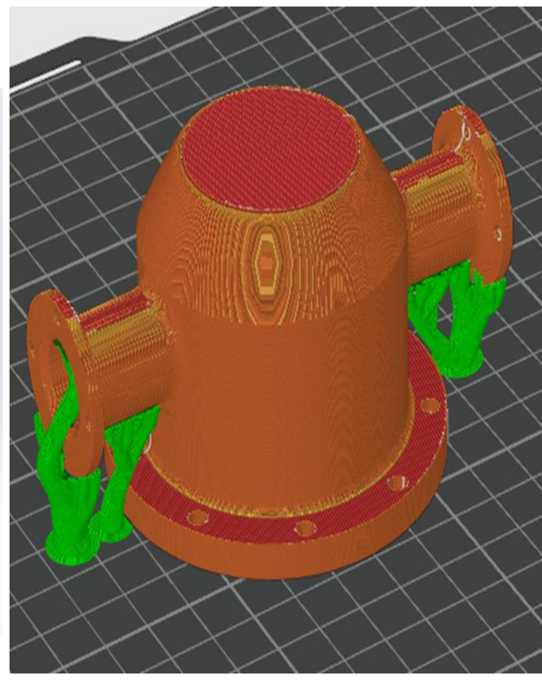

Figure 8: Inlet/Outlet End Cap in 3D Printing Slicer

Figure 9: Tube Bundle in 3D Printing Slicer

Conclusion

Figure 10: Optimized Shell and Tube Assembly

- The above image shows the final SolidWorks assembly. The assembly consisted of the main shell, tube bundle which contains the tubes and baffles, end cap blank and end cap inlet/outlet.
- The aim was creating a more efficient design using the improved values to create the improved heat exchanger using modern engineering to help reduce the disadvantages of the original heat exchanger and help maximize its efficiency

Materials (Stainless Steel Pipe and Fittings)					
Part	No.	Length (mm)	Supplier	Cost / Unit	Total Cost
12" Table-E Slip on 316L Flange	4	1	Nero S/S	€ 758.54	€ 3,034.16
12" Sch 40 316L Pipe	1	1650	Nero S/S	€ 0.22	€ 359.30
3" Sch 40 316L Pipe	1	800	Nero S/S	€ 27.14	€ 27.14
3" Table-E Slip on 316L Flange	4	1	Nero S/S	€ 67.96	€ 271.84
3/4" 316L Dairy Pipe	53	1250	Nero S/S	€ 0.00	€ 94.63
310x310x5 Stainless Steel 316L Plate	6	1	Rapid Metals	€ 56.03	€ 336.18
Laser Cutting Service	6	1	GF Laser	€ 40.00	€ 240.00
M24 Hex Bolt Flange Full Kit	2	1	Nero S/S	€ 133.16	€ 266.32
12" Sch 40 316L End Cap	2	1	Nero S/S	€ 737.14	€ 1,474.28
M16 Hex Bolt Flange Full Kit	4	1	Nero S/S	€ 30.32	€ 121.28
3/4" 316L Dairy 90 Degree Elbows	52	1	Buysteel.ie	€ 5.25	€ 273.00
12" EPDM Full-Face Flange Gasket	2	1	Nero S/S	€ 38.33	€ 76.66
Material Total			€		6,574.79

Figure 5: Bill of Materials