CH 2015

Heat and Mass Transfer

Heat exchanger design

Group 1

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Introduction

Heat exchangers are crucial components of many industrial systems and processes, as well as usual applications. They are essential for the effective transfer of thermal energy between different substances or fluids while preserving their separation. A heat exchanger's main function is to enable the transfer of heat without direct contact between two fluids, usually one that is hot and the other that is cool. Depending on the exact design and application of the heat exchanger, several mechanisms, including conduction, convection, and radiation, may be used in this heat transfer process.

Here are some key factors to consider before designing a heat exchanger:

1. Heat transfer requirements:
   - Total heat transfer rate needed
   - Inlet and outlet temperatures of both fluids
   - Flow rates of both fluids
2. Fluid properties:
   - Viscosity, density, thermal conductivity
   - Phase changes
   - Corrosiveness or reactivity
3. Pressure considerations:
   - Operating pressures for both fluids
   - Allowable pressure drops
4. Space and weight constraints:
   - Available space for installation
   - Weight limitations
5. Material selection:
   - Compatibility with fluids

- Thermal conductivity
- Corrosion resistance
- Cost considerations

6. Fouling factors:
   - Expected fouling rates
   - Cleaning and maintenance requirements
7. Flow arrangement:
   - Parallel flow, counter flow, or cross flow
8. Type of heat exchanger:
   - Shell and tube, plate, finned tube, etc.
9. Environmental conditions:
   - Temperature, humidity, and other ambient factors
10. Economic factors (Initial cost)

Justification for the assumptions made in the design

Implementation of aluminum as the heat exchanger material

Aluminum has a higher amount of heat conductivity which would be a prominent factor that affects the effectiveness of the heat exchanger. When compared to other materials like copper and stainless steel the cost that would take by aluminum for overall process of manufacturing a heat exchanger might be a minimum value. Another key advantage of aluminum is its light weight that would be a positive factor in these weight-sensitive designs. [1]

BWG value

Since aluminum has been used as the manufacturing material, an average BWG value of 16 is being chosen. [2]

Viscosity

When compared to crude oil the viscosity of gasoline is generally low which would lead gasoline for having more heat transfer properties rather than crude oil. Meanwhile the elevated viscosity could be a negative impact on the heat exchanger design since it has the possibility to affect the pressure drop and the overall performance of the system. Even the viscosity of the mentioned fluids can vary with the change of temperature we have to assume that there are no changes of viscosity values with the temperature. [3]

Fluid Flow

Counter-current flow is chosen considering some of the main reasons for better heat transfer are consistent driving force, higher heat transfer rate, lower outlet temperature of hot fluid and reduced thermal stress. Therefore counter-current flow in heat exchangers has some advantages in the petroleum industry including lower LMTD, high efficiency. [4]

Number of passes

1-shell 2-pass heat exchanger is selected due to its advantages in heating the crude oil.

> **Compact Design**- 1-shell 2-pass design possesses a more compact and efficient use of space. This is very useful in petroleum industry where space is often limited. Also, lower installation costs.

Efficient heat transfer- the 2-pass design create more turbulence, which maximize the heat transfer between the shell-side and tube-side fluids.

Reduced pressure drop – compared to other designs the 1-shell 2-pass design has a lower pressure drop which is a huge advantage in petroleum industry.

[4]

Triangular pitch arrangement

The triangular pitch arrangement possesses many advantages, especially in the petroleum industry. It offers more heat transfer efficiency, less pressure drop, cleaning and maintenance and fluid distribution. [5]

Baffle cut percentage

35% of the baffle cut percentage is chosen as it is the most preferred in the industry

Dimensional Parameters

For best results, while building a shell and tube heat exchanger, choosing the right tubing sizes is essential. To choose the best tube dimensions, engineers and process managers must consider a number of variables, including application requirements, pressure drop, and flow characteristics.

Outer diameter = 1 inch (Suitable for medium to large-scale applications, including oil and gas, power generation, and desalination plants)

Tube length = 16ft

In shell and tube heat exchangers used in the petroleum sector, 16-foot tubes are a popular option. While the ideal tube length can change based on the demands of a particular application, 16-foot tubes have several benefits like

Effective heat transfer and reduced pressure drop.

[6]

Proposed heat exchanger summary

Number of tubes (N_t)	2793
Length of tube (L)	4.8768m
Inner diameter of tube (d_i)	0.022098m
Overall heat transfer coefficient(U)	45 W/m^2K
Tube pitch (p_t)	0.03175m
Bundle diameter (D_b)	1.7369119m
Bundle diameter clearance (BDC)	0.017128m
Shell Diameter (D_s)	1.7540399m
Baffle spacing (B_s)	0.701616m
Area for crossflow (A_s)	0.2461325m^2
Material selected	Aluminum

Further modification that can be

1. Designing Different Types of Floating Heads
    - We could explore variations in the floating head design to improve maintenance access and ease of cleaning.
    - For a shell and double tube heat exchanger, the floating head design is integral to its construction.
2. Using Alternative Materials for Heat transfer Enhancement
    - Material selection Should align with our specific application requirements.
    - Consider using material like copper, stainless steel or titanium instead of aluminum for the tubes to potentially improve heat transfer rates.

3. Counter Flow arrangement

    - We can experiment with different tube arrangement or consider finned tubes to enhance counterflow heat exchange.
    - A counter flow arrangement is a common configuration for shell and double tube heat exchanger.

4. Considering Corrosion Effects

    - Corrosion is a critical concern for heat exchangers, and We should select materials and coatings that resist corrosion, especially when we considering different materials.
    - Conduct corrosion studies to assess the impact on the heat exchanger's longevity.

5. Calculating Pressure Drop

    - We can use fluid dynamics and heat transfer software to estimate pressure drops and optimize the design.
    - Calculating the pressure drop inside a shell and double tube heat exchanger is important for assessing its performance

6. Designing Other Types of Heat Exchangers

    - While we currently using a shell and double tube heat exchanger, we could explore the possibility of designing other types of shell and tube heat exchangers with different tube configurations, such as multi pass or crossflow designs. [7] [8]

References

[1] P. Allumino, "https://www.profall.com/," 12 October 2018. [Online]. Available: https://www.profall.com/en/blog/why-use-aluminum-for-heat-exchangers.

[2] [Online]. Available: https://entech.rs/PDF-ENG/B2.4.3.pdf.

[3] "hyperphysics," [Online]. Available: http://hyperphysics.phy-astr.gsu.edu/hbase/Tables/viscosity.html#:~:text=Oil%20%28light%29%201.1,Oil%20%28heavy%29%206.6.

[4] J. H. L. I. a. J. H. L. V, Heat transfer.

[5] NPTEL, "Thermal Engineering".

[6] "enerquip," [Online]. Available: https://www.enerquip.com/selecting-tube-sizing-in-a-shell-and-tube-heat-exchanger/.

[7] K. M. LUNSFORD, "bre.com," [Online]. Available: https://www.bre.com/PDF/Increasing-Heat-Exchanger-Performance.pdf.

[8] "epj-conferences.org," [Online]. Available: https://www.epj-conferences.org/articles/epjconf/pdf/2015/11/epjconf_efm2014_02119.pdf.