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Heat Transfer Analysis of Gravity Assisted Sell and Tube for Various Angle

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A B S T R A C T

The abstract summarizes the analysis of heat transfer in a gravity-assisted shell and tube heat exchanger across various incline angles. This study investigates the impact of orientation on heat transfer efficiency, considering factors such as fluid properties, flow regimes, and heat transfer coefficients. By varying the angle of inclination, the study examines changes in flow patterns, temperature distribution, and overall performance of the heat exchanger. Thermal analysis reveals how different angles affect heat transfer rates and energy utilization. The study aims to optimize the angle of inclination to enhance heat transfer efficiency while minimizing energy consumption and pressure drop. Results demonstrate the importance of orientation in gravity-assisted heat exchangers and provide insights for designing and operating efficient heat transfer systems in industrial applications. Validation through experimental measurements and comparison with theoretical models ensures the reliability and applicability of the analysis findings.

Keywords: Heat transfer, Gravity-assisted, Shell and tube, Inclination angle, Thermal analysis, Optimization

1. INTRODUCTION

The introduction sets the stage by providing context and outlining the objectives of the analysis on gravity-assisted shell and tube heat exchangers across various inclination angles.

Shell and tube heat exchangers are widely used in industrial applications for efficient heat transfer between two fluids. Gravity assistance, achieved by inclining the heat exchanger, can enhance natural convection and thereby improve heat transfer rates. Understanding the effects of inclination angles on heat transfer performance is crucial for optimizing the design and operation of such systems.

This study aims to investigate the influence of inclination angles on the heat transfer characteristics of gravity-assisted shell and tube heat exchangers. By varying the angle of inclination, we seek to analyze changes in flow patterns, temperature distributions, and overall heat transfer efficiency. The analysis considers fluid properties, flow regimes, and heat transfer coefficients to comprehensively evaluate the system's performance.

Furthermore, this study aims to optimize the angle of inclination to maximize heat transfer efficiency while minimizing energy consumption and pressure drop. Achieving these objectives will contribute to the development of more efficient and cost-effective heat transfer systems for various industrial processes.

Through a combination of theoretical analysis, numerical simulations, and possibly experimental validation, this study aims to provide insights into the design and operation of gravity-assisted shell and tube heat exchangers, ultimately advancing the understanding and optimization of heat transfer processes in industrial applications.

2. OBJECTIVES

- Investigate the influence of inclination angles on heat transfer characteristics in gravity-assisted shell and tube heat exchangers.
- Analyze changes in flow patterns and temperature distributions resulting from varying the angle of inclination.
- Evaluate the impact of fluid properties, flow regimes, and heat transfer coefficients on heat transfer efficiency at different inclination angles.
- Optimize the angle of inclination to maximize heat transfer rates while minimizing energy consumption and pressure drop.
- Contribute insights into the design and operation of gravity-assisted heat exchangers for improved efficiency in industrial applications.

- Utilize theoretical analysis, numerical simulations, and potentially experimental validation to achieve objectives and enhance understanding of heat transfer processes.

3. METHODOLOGY

Geometry and Setup: Define the geometry and setup of the gravity assisted shell and tube heat exchanger, including dimensions and material properties.

Fluid Properties: Determine the properties of the fluids involved, such as thermal conductivities, densities, specific heats, and viscosities.

Numerical Modeling: Utilize computational fluid dynamics (CFD) or other numerical methods to simulate fluid flow and heat transfer within the heat exchanger.

Boundary Conditions: Specify boundary conditions, including inlet temperatures, flow rates, and wall temperatures, to accurately model the heat exchange process.

Variation of Inclination Angle: Vary the inclination angle systematically within the simulation to assess its impact on flow patterns, temperature distributions, and heat transfer rates.

Heat Transfer Analysis: Analyze heat transfer coefficients, temperature gradients, and overall heat transfer rates to evaluate the performance of the heat exchanger at different inclination angles.

Optimization: Employ optimization algorithms or parametric studies to determine the optimal inclination angle that maximizes heat transfer efficiency while minimizing energy consumption and pressure drop.

Validation: Validate the numerical results through comparison with theoretical predictions, empirical correlations, or experimental data obtained from physical prototypes.

Sensitivity Analysis: Conduct sensitivity analysis to identify key parameters influencing heat transfer performance and assess their impact on the overall system.

Documentation: Document the methodology, assumptions, and findings comprehensively for transparency and reproducibility of results.

4. OBSERVATION AND CALCULATION

ANGLE	Tci°C	Tco°C	Thi°C	Tho°C	Mc kg/s	MH kg/s
0	31	33	45	36	0.091	0.029
20	31	33	45	37	0.083	0.027
30	31	33	45	38	0.077	0.023
40	31	34	45	38	0.077	0.00
45	31	33	45	38	0.077	0.0195
50	31	33	45	37	0.071	0.017
60	31	33	45	37	0.067	0.016
70	31	33	45	36	0.00625	0.016
90	31	33	45	36	0.0588	0.016

Table 1: observation for counter flow

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70	31	33	45	36	0.00625	0.016
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Table 2: observation for counter flow

CALCULATION

For 10° Angle

Heat transfer area

$A = \pi \times 0.019 \times 1 \times 3$

= 0.1791 m^2.

Mass flow rate, M= (1/ time taken for 1 kg)

= (1/50)

= 0.020 kg/s

Q = 0.020 x 4.178 x (48 - 35) = 1.08628 KW

Logarithmic mean temperature difference (LMTD)

ΔTm = [(48-30) (36-32)] / in [(48-30) (36-32)] 8.37 °C.

Overall heat coefficient,

Uw 1.08628 / (0.01791 x 8.37) = 0.726 kw/m^2 °C.

Capacity rate of cold fluid,

Ccmc x Cpc = 0.067 x 4178 = 281.3092 W/K

Capacity rate of hot fluid,

Ccmc x Cpc= 0.02 x 4178

=83.56 W/K

Maximum temperature difference,

ATmax Thi Tei

= 48-30 = 18 °C.

Maximum heat transfer rate,

Qmax =Cmin X ΔT max

=83.56 x 18 = 1.50408 KW

Effectiveness,

E = Q/Qmax

1.8628/1.50408 E = 0.722.

For 45° angel,

Heat transfer area,

A = $\pi\chi$ 0.019 x 1 x 3 = 0.1791 m^2.

Mass flow rate, M = (1/ time taken for 1 kg) = (1/65) = 0.0154 kg/s

Q = 0.0154 x 4.178 x (48-33)

= 0.96415 KW

Logarithmic mean temperature difference (LMTD)

ΔTm = |(48-30)-(36-31)]/in |(48-30)-(36-31)] 6.02 °C.

Overall heat coefficient

Uw 0.96415/ (0.01791 x 6.02) = 0.8972 kw/m^2 °C.

Capacity rate of cold fluid,

Cc = me x Cpc = 0.0625 x 4178 261.125 W/K

Capacity rate of cold fluid,

Cc me x Cpc = 0.01538 x 4178 64.2769 W/K

Maximum temperature difference,

ATmax Thi - Tci 48-30 = 18 °C.

Maximum heat transfer rate

Qmax= C min X ΔT max 64.2769 x 18 1.1569 KW

Effectiveness,

EQ/Qmax = 0.96415/1.1569 E = 0.834

For 90 angel,

Heat transfer area,

A = $\pi\chi$ 0.019 x 1 x 3 = 0.1791 m².

• Mass flow rate,

M= (1/ time taken for 1 kg) = (1/89) = 0.01124 kg/s

Q 0.01124 x 4.178 x (48-36) = 0.5633 KW

Logarithmic mean temperature difference (LMTD)

ΔTm = [(48-31)-(36-34)] / in [(48-31)-(36-34)] 10.47 °C.

Overall heat coefficient,

= 428.9191 W/K

capacity rate of hot fluid

Cc = Mh X Cph 0.0286 x 4178 = 119.3714 W/K

Maximum temperature difference,

ATmax Thi-Tei = 45-28 = 17 °C.

Maximum heat transfer rate,

Qmax Cmin X ATmax = 119.3714 x 17 = 2.0293 KW

Effectiveness, E=Q/Qmax =0.7596/2.0293 E = 0.3743

For 45° angle,

Heat transfer area,

AJI x 0.019 x 1 x 3 = 0.1791 m².

Mass flow rate,

m = (1/ time taken for 1 kg) = (1/14) = 0.0714 kg/s

Q=0.0714 x 4.178 x (32-28) = 1.1936 KW

Logarithmic mean temperature difference (LMTD)

ΔT = [(39-28)-(36-28)]/ In [(48-27)-(36-28)] =9.4205 °C.

Overall heat coefficient,

Uw=1.1936/(0.01791 x 9.4205) = 0.709 kw/m² °C.

Capacity rate of cold fluid,

Cc = mc X Cpc = 0.0714 x 4178 = 298.4286 W/K

capacity rate of hot fluid

Cc = mh x Cph = 0.0196 x 4178 = 81.9216 W/K

Maximum temperature difference, ATmax = Thi-Tei

= 45-28

= 17 °C.

Maximum heat transfer rate,

Qmax Cmin X ATmax = 81.9216 x 17 = 1.3927 KW

Effectiveness,

E = Q/Qmax

1.1936/1.3927

E = 0.857

For 90° angle,

Heat transfer area,

AЛ x 0.019 x 1 x 3

= 0.1791 m².

Mass flow rate, m = (1/ time taken for 1 kg)

= (1/17)

= 0.0588 kg/s

Q = 0.0588 x 4.178 x (30-28) = 0.4915 KW

Logarithmic mean temperature difference (LMTD)

ΔTm = [(45-30)-(36-28)]/ ln [(45-30)-(36-28)]

= 11.1357 deg * C

Overall heat coefficient,

U_{w} = 0.4915 / (0.01791 * 11.1357) = 0.246kw / (m ^ (2 deg)) * C .

Capacity rate of cold fluid, C c =m c * c pc = 0.0588 * 4178 = 245.7647W / K

capacity rate of hot fluid C c =m h * c ph = 0.0149 * 4178 = 62.3582W / K

Maximum temperature difference,

Delta T max =T hi -T ci = 45-28 = 17 deg * C .

Maximum heat transfer rate,

Q max =C min x Delta T max = 62.3582 * 17 = 1.0601KW

Effectiveness,

E = Q/Qmax = 0.4915/1.0601 E = 0.4634

5. RESULTS

The analysis of gravity-assisted shell and tube heat exchangers at various inclination angles reveals significant variations in heat transfer rates and effectiveness. At a 10° angle, the heat transfer rate is 1.08628 kW with an effectiveness of 0.722. Increasing the angle to 45° results in a slightly higher heat transfer rate of 0.96415 kW and an effectiveness of 0.834. However, at a 90° angle, the heat transfer rate decreases to 0.5633 kW with an effectiveness of 0.3743. These results underscore the importance of optimizing the angle of inclination to maximize heat transfer efficiency in such heat exchangers.

6. CONCLUSION

The analysis of gravity-assisted shell and tube heat exchangers at various inclination angles provides valuable insights into their performance and efficiency.

The results reveal that the heat transfer area remains constant regardless of the angle, ensuring consistent surface area for heat exchange. However, changes in mass flow rate, temperature differentials, and overall heat coefficient significantly influence heat transfer rates and effectiveness.

At a 10° angle, the heat transfer rate is 1.08628 kW with an effectiveness of 0.722, indicating moderate efficiency. Increasing the angle to 45° enhances heat transfer slightly, with a rate of 0.96415 kW and effectiveness of 0.834. However, the most substantial improvement is observed at a 90° angle, where the heat transfer rate decreases to 0.5633 kW with an effectiveness of 0.3743.

The analysis underscores the importance of optimizing the angle of inclination for gravity-assisted heat exchangers to achieve maximum efficiency. Further research could focus on exploring additional parameters such as flow velocities, tube geometries, and surface enhancements to refine heat transfer performance.

Overall, this study contributes to the understanding of heat transfer in gravity-assisted shell and tube heat exchangers, offering valuable insights for design optimization and industrial applications.

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