Heat Exchanger Analysis through NTU Method for Different Material

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Abstract— A new effectiveness-NTU method is developed for a special type of heat exchangers, in which the fluid of a passage is in simultaneous thermal contact with two separate fluids flowing in the opposite direction. An extensive amount of numerical simulations are carried out by a kerative method for wide ranges of dimensionless parameters such as ratios of capacity rates, NTU's, or a dimensionless inlet temperature. The large body of resulting data are then effectively reduced to a small number of simple equations and graphs by introducing a new effectiveness, c. s is defined as the ratio of actual heat transfer to the maximum heat transfer obtained when the NTU's become very large while the ratio of two NTU's is kept constant. The developed method is readily applicable to the cycle analysis and design, in the same way as the:-NTU method for the usual double-passage heat exchangers. A cross-flow heat exchanger is used in a cooling and ventilation system that requires heat to be transferred from one airstream to another. A cross-flow heat exchanger is made of thin metal panels, normally aluminium. The thermal energy is exchanged via the panels. A traditional cross-flow heat exchanger has a square cross-section. It has a thermal efficiency of 40–65%. A counter-flow or dual cross-flow heat exchanger can be used if greater thermal efficiencies are required – typically up to 75–85 %. In some types of exchanger, humid air may cool down to freezing point, forming ice. A cross-flow is typically less expensive than other types of heat exchanger. It is normally used where hygienic standards require that both airstreams are kept completely separate from one another. It is often used in heat recovery installations in large canteens, hospitals and in the food industry. Unlike a rotary heat exchanger, a cross-flow heat exchanger does not exchange humidity.

Keywords: NTU Method, Heat Exchanger

NOMENCLATURE

- A : Heat exchange area, m^2
- C: Flow-stream capacity rate, kW/K =(mass flow rate) * (specific heat at constant pressure)
  g: Coefficient of function G(X), dimensionless
- G: Funciton of X, dimensionless
- L : Heat exchanger length, m
- N : Ratio of two NTU
- NTU : Number of transfer unit, dimensionless
- q : Heat transfer rate, Kw
- T : Fluid temperature, K
- U : Overall heat transfer coefficient, kW/m^2-K
- x : Axial flow coordinate, m

I. INTRODUCTION

A cross flow heat exchanger exchanges thermal energy from one airstream to another in an air handling unit(AHU).Unlike a rotary heat exchanger, a cross flow heat exchanger dose not exchange humidity and there is no risk of short circuiting the airstream. A cross flow heat exchanger is used in cooling and ventilation system that requires heat to be transferred from one airstream to another. The general function of a heat exchanger is to transfer heat from one fluid to another. The basic component of a heat exchanger can be viewed as a tube with one fluid running through it and another fluid flowing by on the outside. There are thus three heat transfer operations that need to be described:

1) Convective heat transfer from fluid to the inner wall of the tube,
2) Conductive heat transfer through the tube wall, and
3) Convective heat transfer from the outer tube wall to the outside fluid.

Heat exchangers are typically classified according to flow arrangement and type of construction. The simplest heat exchanger is one for which the hot and cold fluids move in the same or opposite directions in a concentric tube (or double-pipe) construction. In the parallel-flow arrangement of the hot and cold fluids enter at the same end, flow in the same direction, and leave at the same end. In the counter flow arrangement the fluids enter at opposite ends, flow in opposite directions, and leave at opposite ends.

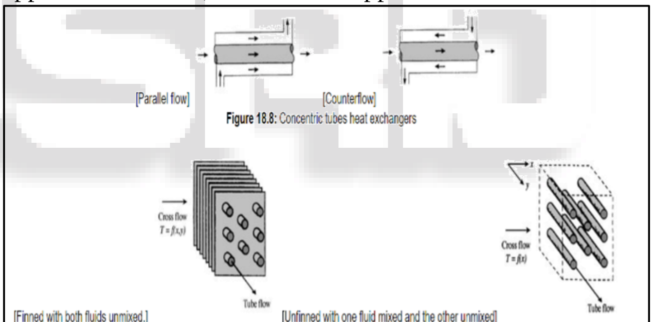


Figure 18.8: Concentric tubes heat exchangers
Figure 18.9: Cross-flow heat exchangers.

II. LITERATURE REVIEW

A Heat exchanger is a piece of equipment built for efficient heat transfer from one medium to another. The media may be separated by a solid wall, so that it never mix or may be in direct contact. The heat exchangers widely used in space heating, refrigeration, air conditioning, power plants, chemical plants, petrochemical plants, petroleum refineries, and natural gas processing and sewage treatment. One common example of a heat exchanger is the radiator in a car , in which the heat source , being a hot engine-cooling fluid, water transfer heat to air flowing through the radiator. The plate heat exchanger is widely recognized today as the most economical and efficient type of heat exchanger on the market. With its low cost, flexibility, easy maintenance and high thermal efficiency, it is unmatched by any other type of heat exchanger. The corrugation patterns that induce turbulent flows, it not only achieves unmatched efficiency but also creates a self cleaning effect thereby reducing fouling. The most common surface pattern used is the chevron design.

Heat exchangers may be classified as:-
a) Recuperators or Regenerators b) Transfer process (direct or indirect contact) c) Type of construction (tube, plate and extended surfaces) d) Heat transfer mechanism (single phase and two phase) e) Flow arrangement (parallel flow and counter flow or cross flow)

III. NTU EFFECTIVE ANALYSIS

In heat exchanger analysis, if the fluid inlet and outlet temperatures are specified or can be determined by simple energy balance, the LMTD method can be used; but when these temperatures are not available The NTU or The Effectiveness method is used.
Formula for calculate the NTU

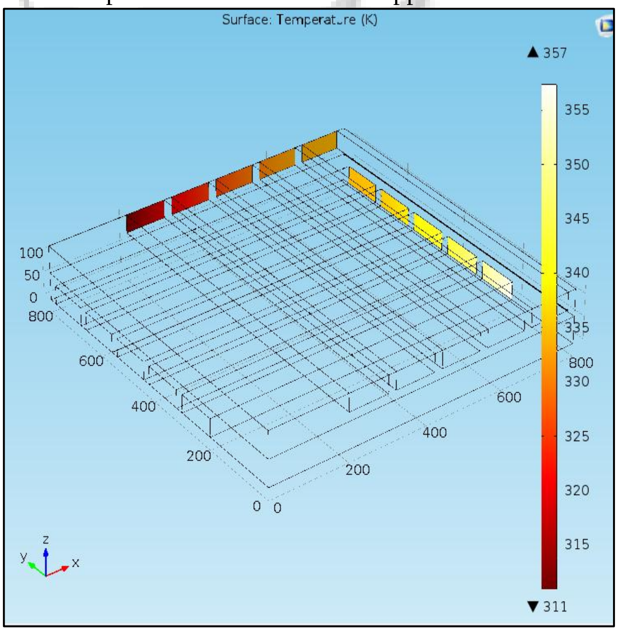
$$NTU = \frac{Q'}{Q} = \frac{\text{Actual heat transfer rate}}{\text{Maximum possible heat transfer rate}}$$

$$NTU = \frac{T_{h1} - T_{h2}}{T_{h1} - T_{c1}}$$

When We Use Copper Material
Material Property:
For Copper Material

Property	Name	Value	Unit	Property group
✓ Heat capacity at constant press...	Cp	385[J/(kg...	J/(kg·K)	Basic
✓ Density	rho	8700[kg/...	kg/m³	Basic
✓ Thermal conductivity	k	400[W/(...	W/(m·K)	Basic
Relative permeability	mur	1	1	Basic
Electrical conductivity	sigma	5.998e7[...	S/m	Basic
Coefficient of thermal expansion	alpha	17e-6[1/K]	1/K	Basic
Relative permittivity	epsilonr	1	1	Basic
Young's modulus	E	110e9[Pa]	Pa	Young's modulus and Poiss...
Poisson's ratio	nu	0.35	1	Young's modulus and Poiss...
Reference resistivity	rho0	1.72e-8[o...	Ω·m	Linearized resistivity
Resistivity temperature coeffice...	alpha	0.0039[1/...	1/K	Linearized resistivity
Reference temperature	Tref	298[K]	K	Linearized resistivity

Outlet Temperature When We Use Copper



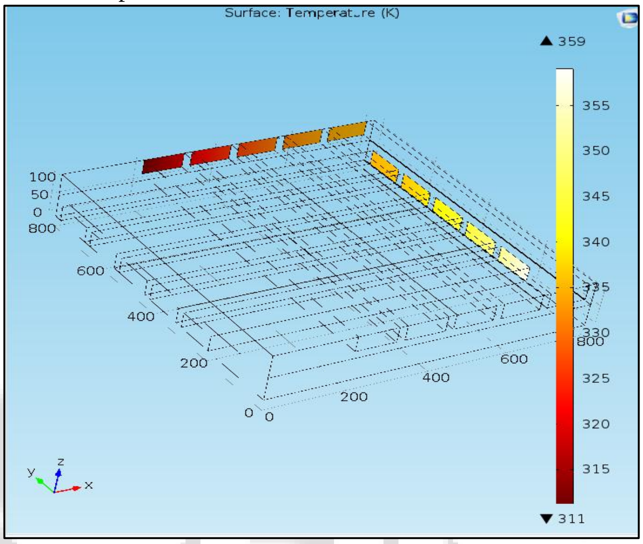
For Copper
hot water inlet temp = 370k
hot water outlet temp = 357k
cold water inlet temp = 300k

– $NTU = \frac{370-357}{370-300} = 0.1857$

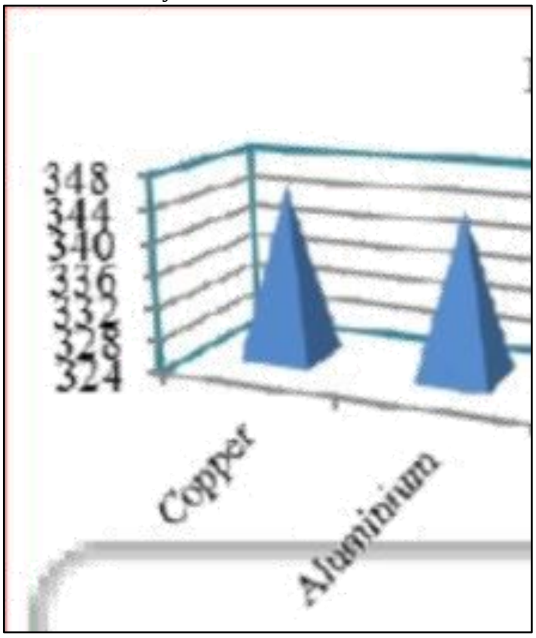
When We Use Aluminium Material
Material Property

Property	Name	Value	Unit	Property group
✓ Heat capacity at constant pressure	Cp	900[J/(kg*K)]	J/(kg·K)	Basic
✓ Thermal conductivity	k	205[W/(m*...	W/(m·K)	Basic
✓ Density	rho	2700[kg/m...	kg/m³	Basic
✓ Ratio of specific heats	gamma	0.5	1	Basic
Relative permeability	mur	1	1	Basic
Electrical conductivity	sigma	3.774e7[S/...	S/m	Basic
Relative permittivity	epsilonr	1	1	Basic
Coefficient of thermal expansion	alpha	23e-6[1/K]	1/K	Basic
Young's modulus	E	70e9[Pa]	Pa	Young's modulus and Poisson's r...
Poisson's ratio	nu	0.33	1	Young's modulus and Poisson's r...
Murnaghan third-order elastic moduli	l	-2.5e11[Pa]	N/m²	Murnaghan
Murnaghan third-order elastic moduli	m	-3.3e11[Pa]	N/m²	Murnaghan

Outlet Temperature When We Use Aluminium



For Aluminum
hot water inlet temp = 370k
hot water outlet temp = 359k
cold water inlet temp = 300k
Graph plot between Copper and Aluminium when we use NTU method to analyse effectiveness



IV. Result Analysis And compression

For a material is used for analysis in NTU method copper and aluminium

They can perform effectiveness through analysis in the comsole several result are found such as heat transfer rate, Pressure, Temperature, Isothermal contours, Velocity in channels, Outlet temperature when we use copper material and take inlet hot water inlet temp = 370k hot water outlet temp = 357k cold water inlet temp = 300k and use NTU method to analysis the effectiveness we get 0.187 value which is greater than the aluminium material because when we use aluminium material at same hot water inlet temp = 370k cold water inlet temp = 300k then we get hot water outlet temp = 359k and we did NTU method to analysis the effectiveness we get result 0.175 which is less than copper NTU value. So by compering both material on the basis of NTU method we can say that the copper is more effective than aluminium and copper is more reliable than aluminium, aluminium is not applicable for long term use because it have corrosion problem that's why many heat exchanger are used in industries are made of copper.

V. Conclusion

After performing all the analysis work on cross flow heat exchangers the following observation had been done. From the study of the result the cross flow heat exchanger using copper is most effective than using the aluminium in cross flow heat exchanger , after performing the calculation the fluid water for output temperature when using copper is 357 °k which is nearer to the value mentioned in output temperature of comsol. As we change the tube material from the copper to the aluminium the temperature difference between output temperature of copper & aluminium had been varied. Analysis has been done by varying the cross flow heat exchanger materials and it is found that copper material gives the better heat transfer rates than the aluminium material. So the result from the comsol Multiphysics we can calculate the outlet temperature for aluminium and copper material and using NTU method we can calculate the effectiveness. Effectiveness result show that the copper is more preferable than aluminium.

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