Thermal Analysis of Double Pipe Heat Exchanger by Changing the Materials Using CFD

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Abstract – *Heat Exchanger is a device used to exchange the heat energy between the two fluids by which increases the operating efficiency? These Efficiencies plays a major role for cost effective Operations in the process industries. While the both Fluids flow through the heat exchanger, the temperature of both fluids will exchange.*

The main objective of this paper is deals with the performance rate of double pipe heat exchanger By changing the materials which uses the heat input From the waste recovery of steam in refinery process.

Double pipe heat exchangers are designed in CATIA and GAMBIT. CFD analysis is done by using ANSYS.Final Results are obtained with three different type of materials steel, aluminium and copper.

Keywords- *Heat transfer, operating efficiency, Thermal Analysis.*

I. INTRODUCTION

The objective of present work is based on design and thermal analysis of double pipe heat exchanger. The inner pipe is a suction pipe of the pump in which hot hydrocarbon flows and in outer annulus cold crude oil passes from opposite direction. The heat recovery from hot fluid is used to increase the temperature of cold fluid. Design was carried out based on the outlet temperature requirement of the cold fluid. With the help of computation fluid dynamics, the study and unsteady simulation was carried out for the designed heat exchanger and based on the simulation results, thermal analysis was carried out.

Typical applications involve heating or cooling of a fluid stream and evaporation or condensation of single- or multicomponent fluid streams. In other applications, the objective may be to recover or reject heat, or sterilize, pasteurize, fractionate, distil, concentrate, crystallize, or control a process fluid. In a few heat exchangers, the fluids exchanging heat are in direct contact.

Classifications of heat exchangers:

Based on Principles of Operation (Transfer process):

1. Regenerative type (Storage
2. Recuperative Type (Direct Transfer)
3. Fluidized Bed Type

Based on Fluid Flow Arrangement

1. Counter flow
2. Parallel flow
3. Single Pass Shell and Tube

Based on Method of Heat Transfer and Constructional Features

1. Shell and Tube Heat Exchanger
2. Single Tube Heat Exchanger
3. Parallel Plate Heat Exchanger

II. SYSTEM MODEL

Double pipe heat exchanger

This project work is based on design and thermal analysis of double pipe heat exchanger. Double pipe Heat exchangers (often also referred to as “double pipes”) are characterized by a construction form which imparts a U-shaped appearance to the heat exchanger. In its classical sense, the term double pipe refers to a heat exchanger consisting of a pipe within a pipe, usually of a straight-leg construction with no bends. However, due to the need for removable bundle construction and the ability to handle differential thermal expansion while avoiding the use of expansion joints (often the weak point of the exchanger), the current U-shaped configuration has become the standard in the industry. A further departure from the classical definition comes when more than one pipe or tube is used to make a tube bundle, complete with tube sheets and tube supports similar to the TEMA type exchanger.

In this section author should explain in little bit dept about his research or model he/she is working on. Author can be use suitable diagrams and images with the references mentioned [1] in square brackets from particular resource image or diagram author taken.

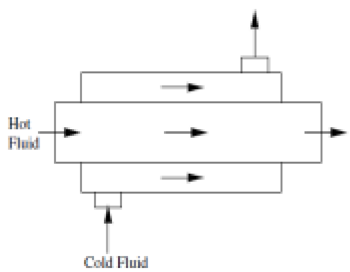


Fig: 1 Double pipe heat exchanger

III. PREVIOUS WORK

Behzadmehr et al., [1] have established numerically the critical Grashof numbers for transition from laminar to turbulent convection and relaminarization of fully developed mixed convection in a vertical pipe with uniform wall heat flux. A study of upward mixed convection of air in a long vertical tube with uniform wall heat flux has been conducted for two very low Reynolds numbers (*Re*=1000 and *Re*=1500) over a wide range of Grashof numbers ($G\,r \leqslant 10^8$) using a low Reynolds number k–ε model with proven capabilities of accurately simulating both laminar and turbulent flows. The results in the fully developed region define three critical Grashof numbers for each Reynolds number. The smallest critical value distinguishes the *Re*–*Gr* combinations that lead to a pressure decrease over the tube length from those leading to a pressure increase. The middle one corresponds to transition from laminar to turbulent conditions while the largest indicates the conditions for which relaminarization takes place.

Bergles et al., [2] reported an experimental investigation of enhanced tube side flow and heat transfer laminar flow conditions. The three test sections in this study included a plain tube, an internally finned tube, and a tube with a twisted-tape insert, all with a nominal diameter and a length. The heat transfer results were obtained in a horizontal test section with nearly constant wall temperature. Isothermal pressure drop, non-isothermal pressure drop, and heat transfer data were obtained over a wide range of the parameters.Laminar flow data were obtained using a viscous liquid, Polybutene 20, for both heating and cooling in a constant wall temperature test section.

IV. PROPOSED METHODOLOGY

Design Aspects of Present Heat Exchanger

In this project the heat exchanger is designed in CATIA. The materials used for the heat exchanger are Steel, Aluminium, and Copper. The properties of Material are mentioned in the below tables [2].Double pipe heat exchanger geometry is designed in GAMBIT Software and analysis id done in ANSYS.

Salient Features of Heat Exchanger

The heat exchanger considered for analysis here has the following parameters.

Shell side	**Tube side**
Type of fluid: crude oil.	Type of fluid: diesel oil.
Inlet temperature =313K	Inlet temperature =618K
Outlet temperature =553K.	Outlet temperature =?.
Mass flow rate=0.320kg/s.	Mass flow rate=145.6kg/s.
Diameter of shell=0.3m.	Specific gravity=0.874

Tube inside diameter =0.2027m.

Tube outside diameter=0.2191m

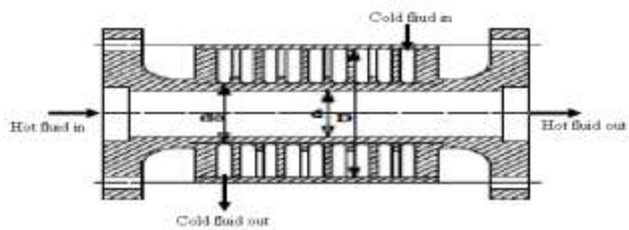
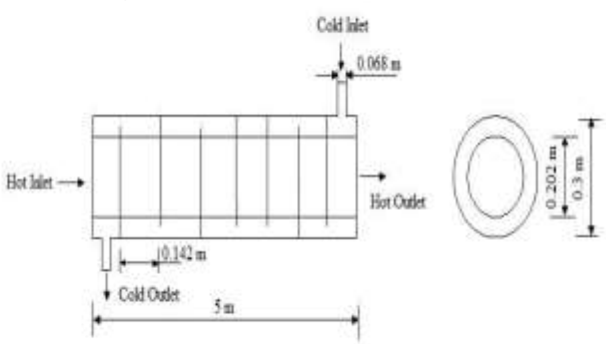


Fig.2 Heat exchanger

Geometry

The designed geometry under consideration in this thesis is a double pipe heat exchanger type or concentric tube heat exchanger with a circular fins or baffles the domain is sub divided in to two sections with a shell and tube channels. Figures 3.2 show schematic two-dimensional views of the heat exchanger to be analyzed. This type of heat exchanger has been designed to recovery of heat from hot source (hot fluid) which is flowing through the tube and the shell side fluid is cold the flow is counter flow. The heat exchanger is one shell pass and one tube pass based on



these conditions the heat exchanger is designed.

Fig.3 A schematic diagram of heat exchanger.

CFD ANALYSIS OF PLAIN TUBE

Fig.4 Heat exchanger without mesh

Fig.5 Heat Exchanger with mesh

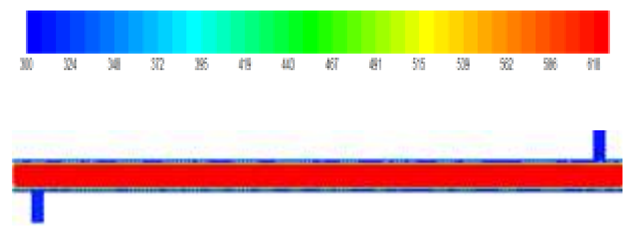


Fig.6 Temperature variation on plane along the heat exchanger.

The temperature contours with respective magnitudes are shown in fig.4.3 the temperature on the Plane shows a small gain in temperature nearly 11 K, along the heat exchanger. So from the above fig the targeted temperature is not reached due to that reason chosen the circular fin with different material as wells as different thickness the analysis has been carried out. And here circular fin will act as baffle to guide the flow.

V. SIMULATION/EXPERIMENTAL RESULTS

Numerical Simulation Procedure

Model of the heat exchanger in discussion is a double pipe heat exchanger with circular fins along the heat exchanger. The geometry was created in the GAMBIT. It also has the capability of handling direct CAD geometry inputs, geometry creation and editing, regions and zone definitions. The geometry in the study is complex and so is divided into two parts for simplification in geometrical modelling and mesh generation, the shell section, and tube section. The shell sections contains fins inside of the shell i.e. (it is on the tube section) two different sections in the present geometry. The dimensions of the heat exchanger were provided by the industry through drawings. The geometry creation in the GAMBIT is a very tedious procedure. The geometry in the GAMBIT builds up by first creating the vertices, edges, faces and then the volumes. All these volumes are joined by defining interfaces at the common faces.

Fig 7.1(a) Geometry of heat exchanger without mesh.

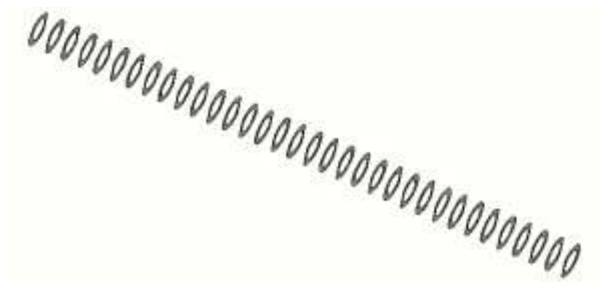


Fig 7.1(b) fin configuration

Fig 7.1 (c) Geometry of heat exchanger with mesh

Results and Discussion

The details of fin materials along with different thickness for comparison are presented in table 1.

Table 1 Details of Comparative Study

Material/fin thickness	Steel	Aluminium	Copper
t_1	0.002	0.002	0.002
t_2	0.003	0.003	0.003
t_3	0.004	0.004	0.004
t_4	0.005	0.005	0.005

Material Steel

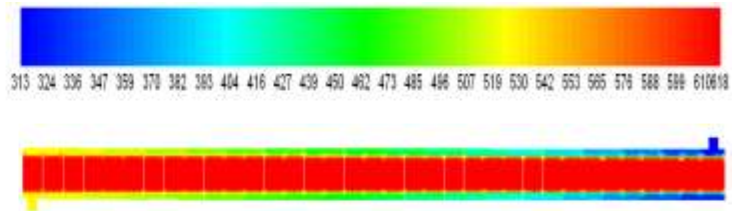


Fig 8 Temperature variation on plane along the heat exchanger.

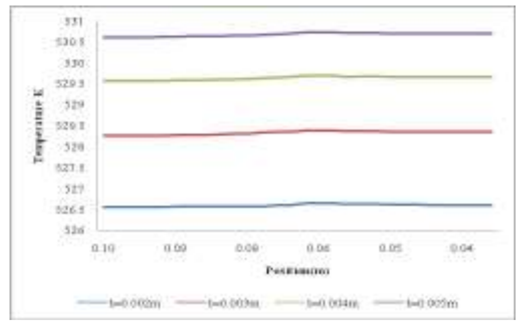
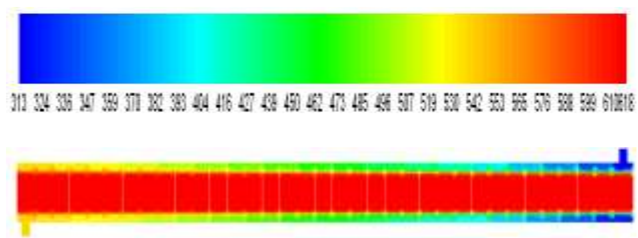


Fig 9 Temperature variation across Outlet for varying Fin thickness.

Material Aluminum

Fig 10 Temperature variations on plane along the heat exchanger



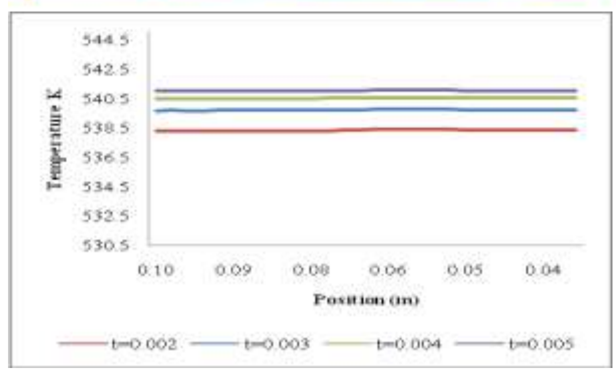


Fig 11 Temperature variation across Outlet for varying Fin thickness.

Material copper

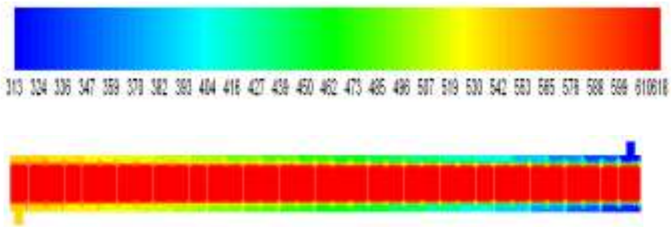


Fig 12 Temperature variations on plane along the heat exchanger.

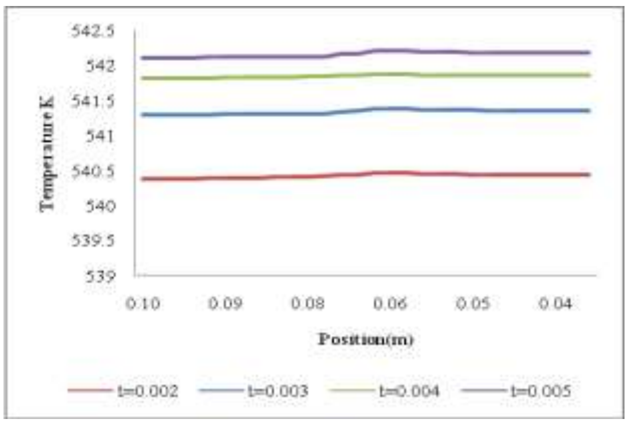
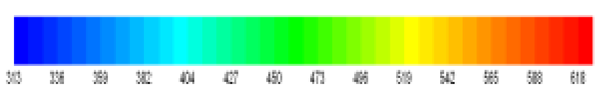


Fig 13 Temperature variation across Outlet for varying Fin thickness.

Comparison of materials



a

b

c

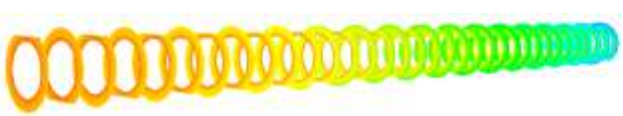


Fig 14 Temperature variation on fin along the heat exchanger.

(a) Steel, (b) Aluminum, (c) Copper.

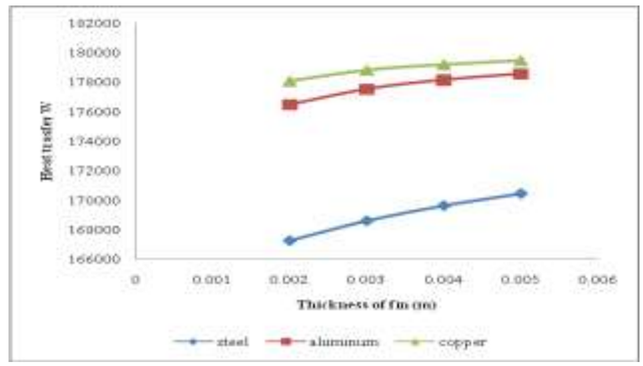
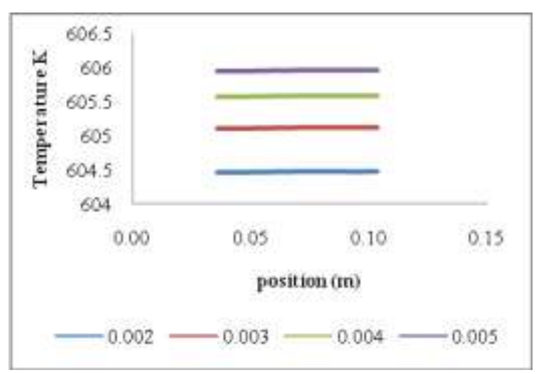


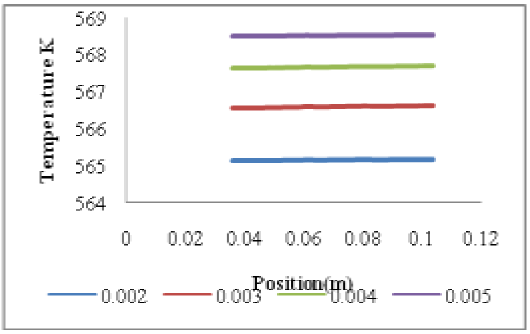
Fig 15 Variation of Heat Transfer with varying fin thickness.

The above graph shows the relation between the heat transfer and fin thickness with different materials. As the fin thickness increases the value of heat transfer is increasing. For copper heat transfer is maximum value when compared to other materials and steel is having the least value of heat transfer.

Comparison of temperature with massflow rates for steel material



(a)



(b)

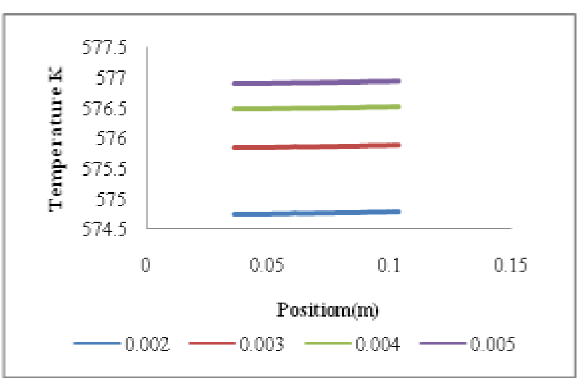
Fig 16 Temperature varition with different thickness

(a) massflow 0.120kg/s (b) massflow 0.220kg/s

Fig 16 (a) massflow 0.120kg/s and (b)0.220kg/s with temperature variation with different thickness. Above plots predicts that the temperature varition for different thickness with varing mass flow rates. In fig 16 (a) predicts that as the fin thickness increases the value of temperature increasing 1.5K, 1.20K and 1K for both the cases (a) and (b). But, comparing with mass flow rates there is 40K higher with (a) than with (b).

Comparison of temperature with massflow rates for Aluminum material

(a)



(b)

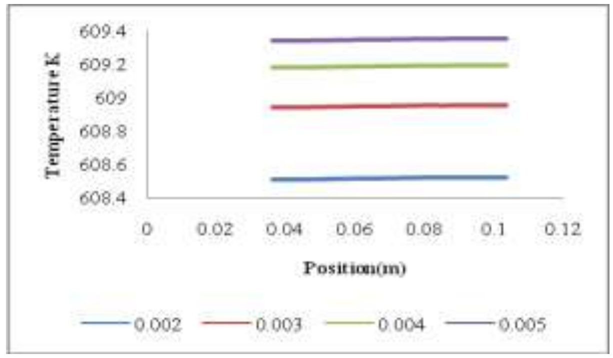
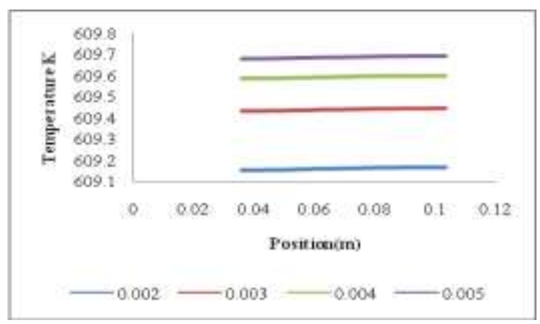


Fig 17 Temperature varition with different thickness

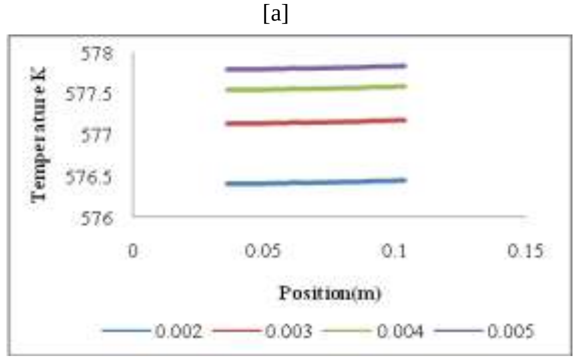
(a) massflow 0.120kg/s (b) massflow 0.220kg/s

Fig 17 (a) massflow0.120kg/s and (b)0.220kg/s with temperature varition with different thickness. Above plots predits that the temperature varition for different thickness with varing mass flow rates. In fig 17 (a) predits that as the fin thickness increases the value of temperature increasing 1K, 0.5K and 0.3K for both the cases (a) and (b). But as comparing with mass flow rate there is 32K with (a) than with (b).

Comparison of temperature with massflow rates for copper material



[a]



[b]

Fig 18 Temperature varition with different thickness
[a] massflow 0.120kg/s [b] massflow 0.220kg/s

Fig 18 (a) massflow0.120kg/s and (b)0.220kg/s with temperature varition with different thickness. Above plots predits that the temperature varition for different thickness with varing mass flow rates. In fig 6.12(a) predicts that as the fin thickness increases the value of temperature increasing 1K, 0.5K and 0.3K for both the cases (a) and (b) but as comparing with mass flow rate there is 33K higher than (b).

Mass flow rates 0.320kg/s

S no	Thickness of fin (m)	Temperature (k)	Pressure (Pascal)	Velocity(m/s)	Heat transfer (W)
1	0.002	526.65	37.65	0.14	167265.66
2	0.003	528.38	38	0.14	168600.
3	0.004	529.72	38	0.14	169622.3
4	0.005	530.72	38	0.14	170435.08

Sr no	Thickness of fin (m)	Temperature (k)	Pressure (Pascal)	Velocity(m/s)	Heat transfer (W)
1	0.002	538.39	37.7	0.14	176473.69
2	0.003	539.76	38	0.14	177524.04
3	0.004	540.55	38	0.14	178145.21
4	0.005	541.07	38	0.14	178549.9

[b]

Sr no	Thickness of fin (m)	Temperature (k)	Pressure (Pascal)	Velocity(m/s)	Heat transfer (W)
1	0.002	540.46	38	0.14	178074.16
2	0.003	541.39	37.8	0.14	178820.6
3	0.004	541.88	38	0.14	179189.36
4	0.005	542.21	37.8	0.14	179464.3

[C]

Table 3 Variation of properties with different thickness

[a] Steel [(b] Aluminium [c] Copper

VI. CONCLUSION

1. There is very minor changes occur in the pressure and velocity profile with increase of fin thickness as well as change of material that is pressure and velocity doesn't get much affected by thickness of fin and material of fin
2. The simulated outlet temperature is 532k which is very near to design outlet temperature 565k. There is less than 3% variation occurs than design value**.**
3. Design and heat transfer analysis on a double pipe heat exchanger is performed.
4. Heat transfer coefficients and friction coefficients for both hot and cold fluids, overall heat transfer coefficient and pressure drops both on port side and shell side as well as total pressure drop is determined.
5. We get high temperature profile at outlet in case of Aluminium and copper compared to steel material.
6. As we increase the fin thickness the temperature of the cold fluid at the outlet of the heat exchanger increases
7. By decreasing the mass flow rate for there is increasing the value of temperature up to 609k and 577k.

VII. FUTURE SCOPES

1. Optimization of fin thickness and material for a heat exchanger
2. Experimentation thermal analysis of double pipe heat exchanger.
3. Numerical analysis of double pipe heat exchanger using augmentation devices.

REFERENCES

[1]A.Behzadmehr, N. Galanis and A. Laneville, Low Reynolds number mixed convection in vertical tubes with uniform wall heat flux, International Journal of Heat and Mass Transfer **46** (2003), pp. 4823–4833.

[2] A. E. Bergles and W. J. Marner Augmentation of Highly Viscous Laminar Heat Transfer Inside Tubes with Constant Wall Temperature, Experimental Thermal and Fluid Science 1989; 2:252-267.

[3] A.E. Saad, A.E. Sayed, E.A. Mohamed, M.S. Mohamed, Experimental study of turbulent flow inside a circular tube with longitudinal interrupted fins in the stream wise direction, Experimental Thermal Fluid Science 15 (1) (1997) 1–15.

[4] Alam, P.S. Ghoshdastidar, A study of heat transfer effectiveness of circular tubes with internal longitudinal fins having tapered lateral profiles, International Journal of Heat and Mass Transfer 45 (6) (2002) 1371–1376.