PARAMETRIC STUDY OF DOUBLE PIPE HEAT EXCHANGERS WITH INTERNAL WAVY TAPE INSERTS

By

Mohamed Alaa Abdel Fatah Hassan

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfilment of the Requirements for the Degree of
MASTER OF SCIENCE
In
MECHANICAL POWER ENGINEERING

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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Title of Thesis: **Parametric Study of Double Pipe Heat Exchangers with Internal Wavy Tape Inserts**

Key Words: CFD; Heat Transfer; Thermal performance; Wavy tape; Double Pipe Heat Exchanger

Summary:

In the present study, Double pipe heat exchanger inserted with wavy tape turbulator is analysed numerically by solving the governing equations using ANSYS FLUENT 15.0 software. The thermal performance of the unit in the turbulent flow regime for Reynolds number range of 5000 – 25,000 is studied for different wavy tape geometries. Firstly, five different wavy tape angles of 45^o, 60^o, 90^o, 120^o and 150^o are considered.
Results showed that adding wavy tape increases the heat transfer rate up to 193% compared to plain tube coupled with a large value of the friction factor. It is seen that small wavy tape angles produce higher heat transfer enhancement and pressure drop.
Also, wavy tape amplitude is investigated and the results showed that increasing wavy tape amplitude increases the heat transfer rate and also the pressure drop. Eventually, it is concluded that the ideal tape amplitude is about 54% of the pipe inner diameter.
Finally, parametric model is developed in order to investigate the effect of the variation of different parameters on the performance of heat exchanging unit. Variations of inlet flow velocity of hot and cold streams are employed monitoring other performance parameters response. Results showed that variation of inlet velocity affects heat transfer rate and outlet temperatures of both streams. Also, effectiveness of heat exchanger is affected. Moreover, fouling of heat transfer surface is taken into consideration showing that fouling layer affects the response of performance parameters to velocity variations.

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NOMENCLATURE

Variables

Symbol	Quantity
k	Thermal conductivity, W/m.k
L	Length, m
Nu	Nusselt number
Nu_o	Nusselt number for plain tube
h	Heat transfer coefficient, $W/m^2.k$
Cp	Specific heat of fluid, J/kg.k
K	Kinetic energy of turbulence, m^2/s^2
U	Overall heat transfer coefficient $W/m^2.k$
A_s	Surface area of the pipe, m^2
Pr	Molecular Prandtl number, Pr = Cp μ / k
$\dot{q}$	Wall heat flux, W/m^2
T_i	Inlet temperature, ºC
T_w	Temperature at the wall, ºC
η_f	Fin efficiency
R_f	Fouling factor, m^2k/W
D	Pipe diameter, m
R	Total thermal resistance, m^2k/W
f	Friction factor for pipe with wavy tape
f_o	Friction factor of plain tube
Re	Reynolds number

Greek Letters

ρ	Density of the fluid, kg/m^3
μ	Fluid viscosity, kg /s.m
μ_t	Turbulent viscosity, kg.m/s
Є	Turbulence dissipation rate, m^2/s^3
θ	Wavy tape angle, degrees
θ_o	Dimensionless wavy tape angle
Ɛ	Effectiveness of heat exchanger

Subscripts

i	Inner side
o	Outer side
0	plain tube
in	Inlet of the tube
Out	Outlet of the tube
W	Tube wall

Abbreviations

BEV	Breakthrough energy venture
GDP	Gross domestic product
LMTD	Logarithmic mean temperature difference
CFD	Computational Fluid Dynamics
NTU	Number of transfer units
USP	Ultrasonic scale preventer
TEF	Thermal performance enhancement factor
PEC	Performance enhancement coefficient
DPHE	Double pipe heat exchanger

ABSTRACT

Heat transfer enhancement is one of the most interesting topics for researchers because of the energy problem worldwide and the need for optimizing energy processing equipment. Many researches have been performed on heat transfer augmentation for fluid flowing in pipes. Active, passive and compound methods are investigated resulting in number of recommendations and various types of techniques used for boosting heat transfer rate while keeping pressure drop as low as possible.

In the present study, Double pipe heat exchanger inserted with wavy tape turbulator is analyzed numerically by solving the governing equations using ANSYS FLUENT 15.0 software. The thermal performance of the unit in the turbulent flow regime for Reynolds number range of 5000 – 25,000 is studied for different wavy tape geometries. Firstly, five different wavy tape angles of 45^o, 60^o, 90^o, 120^o and 150^o are considered. Subsequently, effect of wavy tape amplitude on thermal behavior of the unit is also investigated.

Results showed that adding wavy tape increases the heat transfer rate up to 193% compared to plain tube coupled with a large value of the friction factor. It is seen that small wavy tape angles produce higher heat transfer enhancement and pressure drop.

Also, wavy tape amplitude is investigated and the results showed that increasing wavy tape amplitude increases the heat transfer rate and also the pressure drop. Eventually, it is concluded that the ideal tape amplitude is about 54% of the pipe inner diameter.

Finally, parametric model is developed in order to investigate the effect of the variation of different parameters on the performance of heat exchanging unit. Variations of inlet flow velocity of hot and cold streams are employed monitoring other performance parameters response. Results showed that variation of inlet velocity affects heat transfer rate and outlet temperatures of both streams. Also, effectiveness of heat exchanger is affected. Moreover, fouling of heat transfer surface is taken into consideration showing that fouling layer affects the response of performance parameters to velocity variations.

CHAPTER 1 : INTRODUCTION

1.1 Energy problem in the world

The world now, particularly developing countries, faces an increase in energy demand, as illustrated in Fig 1-1, due to modern technologies, enhanced living standards and population growth. This leads to more fossil fuel consumption as it is the most used energy source. However, fossil fuel is in decline production rate because it has been forming millions of years ago and since the past two hundred years massive amount of it are used. As a result, prices of non-renewable energy sources are increasing incredibly and supply shortage is now seen in many countries around the world. Furthermore, fossil fuel consumption results in the well-known global warming problem and many other problems (such as acid rains and climatic change) that demands immediate remedial actions.

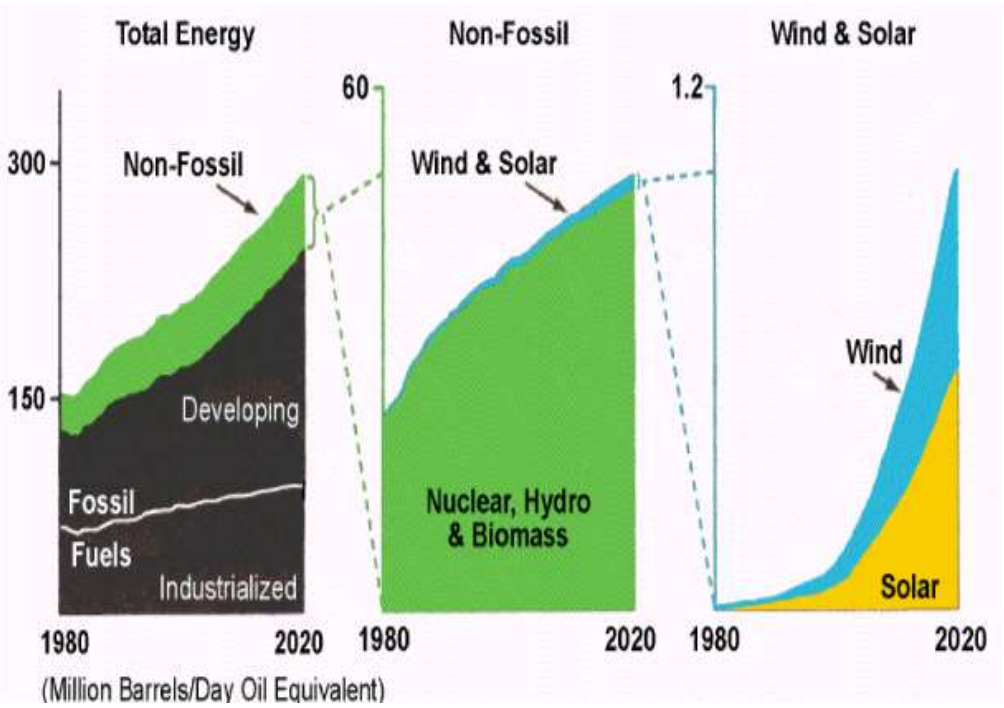

Figure 1-1-World energy demand for the past decades **[1]**

Thus, world now is concerned about utilizing non-fossil fuels with the maximum achievable efficiency and this would require so much effort to be exerted in the field of energy saving and heat transfer enhancement with regard to the challenging environmental considerations.

1.2 Energy problem in Egypt

Egypt is on the verge of an energy disaster. The rising demand together with reduced oil and gas productions (Refer to Fig 1-2) have recently transformed the country from exporter to importer of both, that in turn put a huge threat to its economy.