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Double Pipe Heat Exchanger - Design, Experimentation and Analysis

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Abstract: *Heat exchangers are devices designed for effectively transferring heat energy between hot and cold fluids. Heat exchangers are widely used in oil and gas industries, power generation, chemical processing, air conditioning systems etc., In this project, a Double pipe Heat Exchanger is designed & fabricated, experiments conducted upon it, with water and different concentrations of nano fluid. The results obtained are evaluated to study the effect of increase of heat transfer rate and overall heat transfer coefficient with the nano fluid. The results are tabulated and graphically depicted to facilitate comparisons and deducing conclusions.*

Keywords: *Heat flow rate, Logarithmic mean temperature difference (LMTD), Overall heat transfer coefficient, Nano fluid, Effectiveness, Number of transfer units (NTU)*

I. INTRODUCTION

Heat exchangers are devices that facilitate the exchange of heat between two fluids that are at different temperatures. Heat Exchangers present a wide scope for study because their applications are numerous and varied, involving hot and cold fluids. The primary objective in most heat exchanger experiments centers around the possibilities to effectively increase the rate of heat transfer between the hot & cold fluids. In order to effectively increase heat transfer between hot and cold fluids and to increase the rate of heat transfer, two major approaches to design are undertaken, the first, by making design enhancements such as attaching fins or baffles and second, by mixing small concentrations of nanoparticles to water. Numerous design combinations are made possible by fabricating the Heat Exchangers with different designs, performing experiments with different fluids, by varying the input parameters and analyzing the results. These studies provide valuable insight for different applications and typical requirements of the industry. One of the critical challenges that the industry is facing is to cope with the ever-increasing demand for energy conservation and to be able to effectively meet the needs of wide-ranging applications of the present day. Therefore, there remains a constant demand for research related to new designs of Heat Exchangers and the impact of their performance under varying input parameters and by using different fluids. Moreover, optimization of cost and time parameters on design and fabrication effort is crucial to meet stringent industrial requirements. Therefore, study on the design, fabrication, experimentation and analysis of Heat Exchangers continues to be enormously important.

1.1 Double-Pipe Heat Exchanger*:*

Heat exchanger types are classified depending on the applications. A Double pipe Heat exchanger is the simplest type, and usually consists of two concentric pipes. One of the fluids flows in the inner pipe and the other fluid flows in the annulus between the two pipes (Shell) as shown in Fig. 1 & Fig. 2.

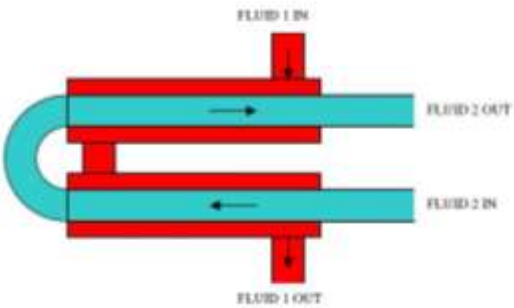


Fig. 1

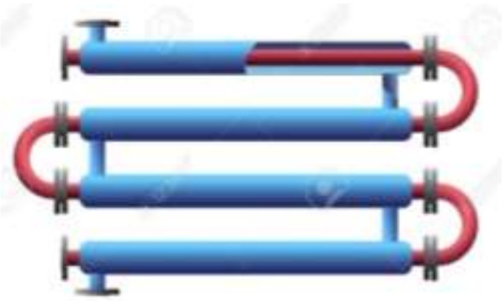


Fig. 2

1.2 Types of Flow Arrangements:

Two types of flow arrangements are possible in a double pipe heat exchanger.

Parallel-flow arrangement, in which the hot and cold fluids enter at the same end, flow in the same direction, and leave at the same end as shown in Fig. 3

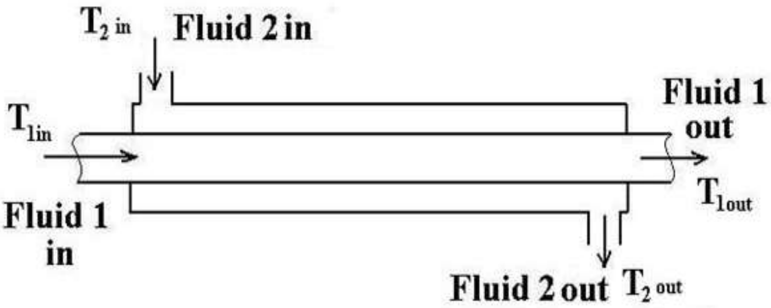


Fig. 2

Counter flow arrangement, in which the hot and cold fluids enter at the opposite ends, flow in opposite directions, and leave at the opposite ends as shown Fig 4.

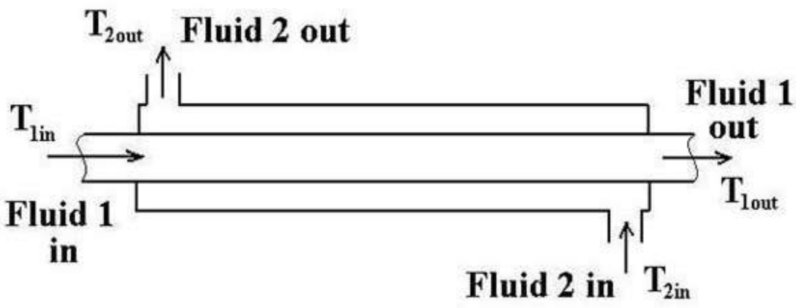


Fig. 4

1.3 DESIGN OF DOUBLE PIPE HEAT EXCHANGER

The Design of the Double pipe Heat Exchanger to be fabricated is shown in Fig.5

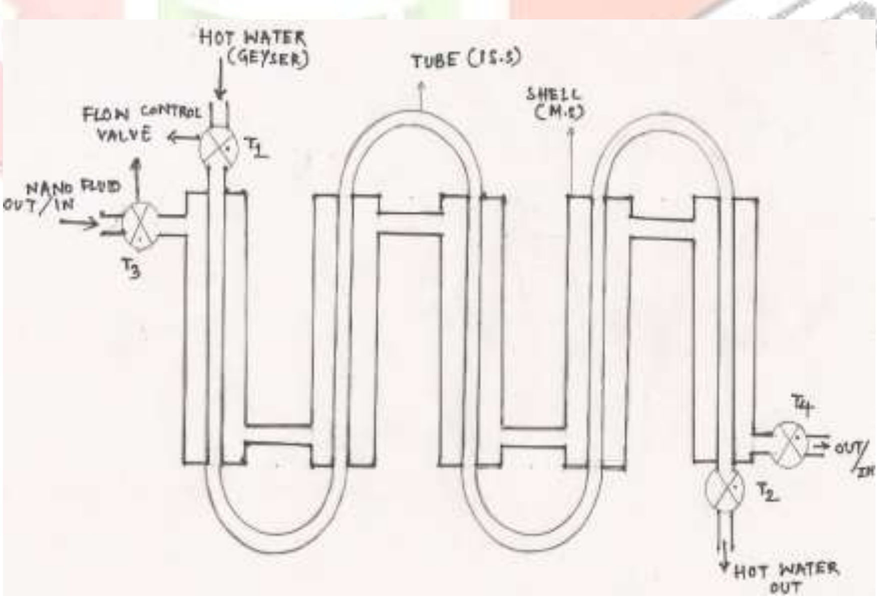


Fig. 5

1.4 SPECIFICATIONS OF DOUBLE PIPE HEAT EXCHANGER

SHELL

Material:	Mild steel
Outer diameter:	33 mm
Inner diameter:	24 mm
Shell length:	250 mm

TUBE

Material:	Stainless Steel
Outer diameter:	19 mm
Inner diameter:	16 mm
Tube length:	350 mm

T1: Hot water inlet temperature

T2: Hot water outlet temperature

T3: Nano fluid inlet/outlet temperature

T4: Nano fluid inlet/outlet temperature

DIGITAL THERMOMETER SPECIFICATIONS:

Temperature Range:	-50 to 1350°C
Power supply:	9V DC

Type k thermocouple inputs

Experimental set up of Double Pipe Heat Exchanger is shown in Fig 6.

Fig. 6

II.HEAT EXCHANGER TERMINOLOGY

LOGARITHMIC MEAN TEMPERATURE DIFFERENCE (LMTD)

LMTD is a logarithmic average of the temperature difference between the hot and cold fluids at each end of the double pipe heat exchanger
$LMTD = (\Delta T_A - \Delta T_B) / \ln (\Delta T_A / \Delta T_B)$
ΔT_A = Temperature difference between two streams at end A
ΔT_B = Temperature difference between two streams at end B

HEAT FLOW RATE (Q)

Q = Heat flow rate exchanged between hot & cold fluids in Watts

OVERALL HEAT TRANSFER COEFFICIENT (U)

U is the Overall Heat Transfer Coefficient
U_o = overall heat transfer coefficient based on the outer surface area (A_o)
U_i = overall heat transfer coefficient based on the inner surface area (A_i)
HEAT FLOW RATE EQUATION $Q = U_o A_o$ LMTD
The above equation can be applied to both parallel flow & counter flow arrangements.

EFFECTIVENESS (Ɛ)

Effectiveness of a heat exchanger is defined as the ratio of actual heat transfer rate to the theoretical maximum possible heat transfer rate.
$\varepsilon = Q / Q_{max}$
$Q = \dot{m}_h \times c_{ph} (T_{hi} - T_{ho}) = \dot{m}_c \times c_{pc} (T_{ci} - T_{co})$ W
$Q_{max} = C_{min} (T_{hi} - T_{ci})$ W

Where
$\dot{m}_h$ = mass flow rate of hot fluid, kg/s
c_{ph} = specific heat of hot fluid, kJ/kg K
$\dot{m}_c$ = mass flow rate of cold fluid, kg/s
c_{pc} = specific heat of cold fluid, kJ/kg K
C_{min} = minimum value of C_h & C_c
C_h = heat capacity rate of hot fluid, kW/K
C_c = heat capacity rate of cold fluid, kW/K
$C_h = \dot{m}_h \times c_{ph}$ & $C_c = \dot{m}_c \times c_{pc}$

NUMBER OF TRANSFER UNITS (NTU)

$NTU = (U_o \times A_o) / C_{min}$

III. EXPERIMENTATION

The arrangement of Heat Exchanger is done so that the hot fluid and cold fluids can flow in parallel and counter flow directions by setting the appropriate valves.

The inlet and outlet temperatures of hot and cold fluids are recorded by a Digital Thermometer. The mass flow rate of the fluid flowing through the Heat Exchanger is set to a certain value.

3.1 EXPERIMENT WITH WATER

Experiments were conducted using water as working fluid for two constant mass flow rates (slow & medium) in parallel & counter flow directions.

Slow flow rate:
Mass flow rate of hot fluid = 0.05 kg/s
Mass flow rate of cold fluid = 0.065 kg/s

Parallel flow:
Inlet temperature of hot fluid varied from 55ºC to 75ºC
Inlet temperature of cold fluid varied from 30ºC to 40ºC

Counter Flow:
Inlet temperature of hot fluid varied from 70º C to 75º C
Inlet temperature of cold fluid varied from 20º C to 30º C

Medium flow rate:
Mass flow rate of hot fluid = 0.16 kg/s
Mass flow rate of cold fluid = 0.2 kg/s

Parallel flow:
Inlet temperature of hot fluid varied from 60ºC to 70ºC
Inlet temperature of cold fluid varied from 35ºC to 45ºC

Counter Flow:
Inlet temperature of hot fluid varied from 65º C to 70º C
Inlet temperature of cold fluid varied from 25º C to 40º C

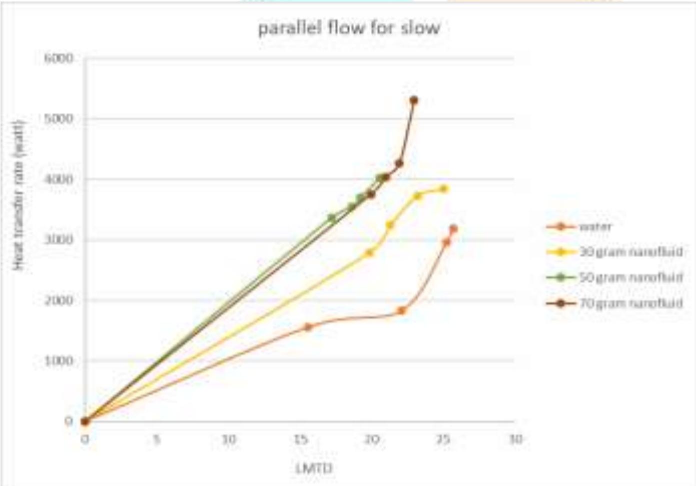
3.2 EXPERIMENT WITH IRON NANO FLUID

Experiments were conducted using iron nano fluid as working fluid for two constant mass flow rates (slow & medium) in parallel & counter flow directions.

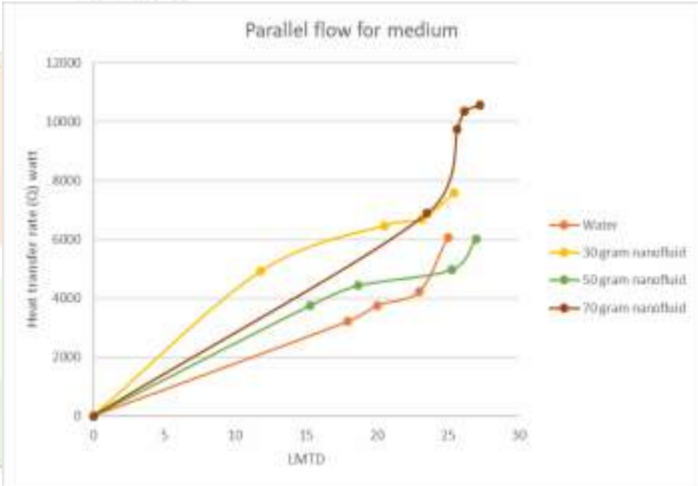
Inlet temperatures of hot & cold fluids were varied in parallel & counter flow directions for three different volume concentrations of nano fluid - 0.04%, 0.064%, & 0.085%.

The readings obtained from experiments were used to calculate the heat transfer parameters that affect the performance of the Heat Exchanger.

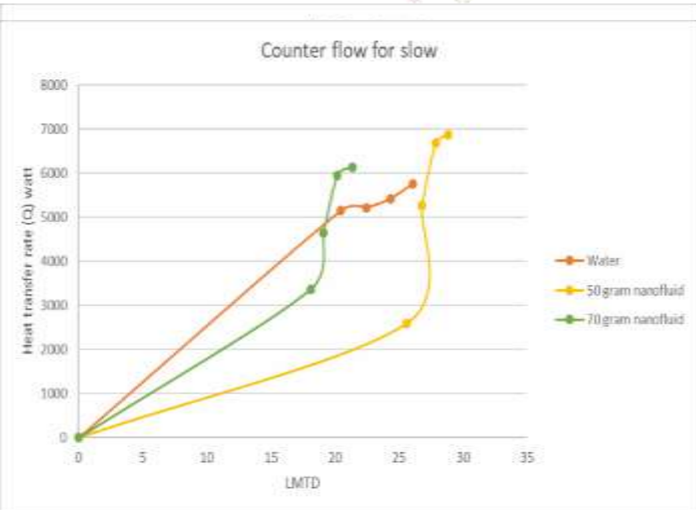
Heat Transfer Parameters in Graphical Form



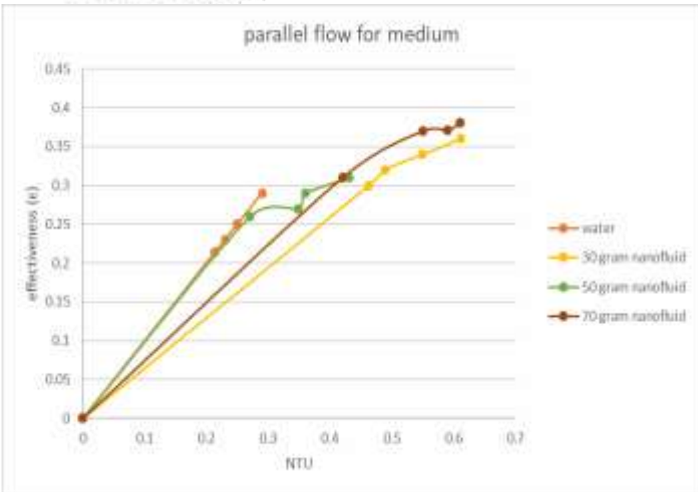
Graph 1



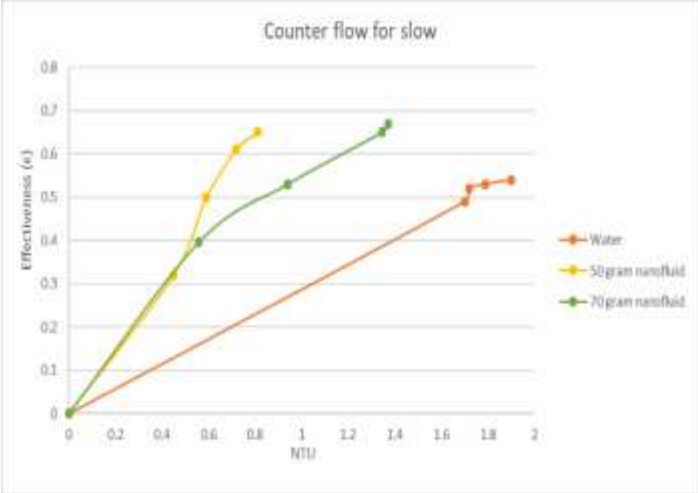
Graph 2



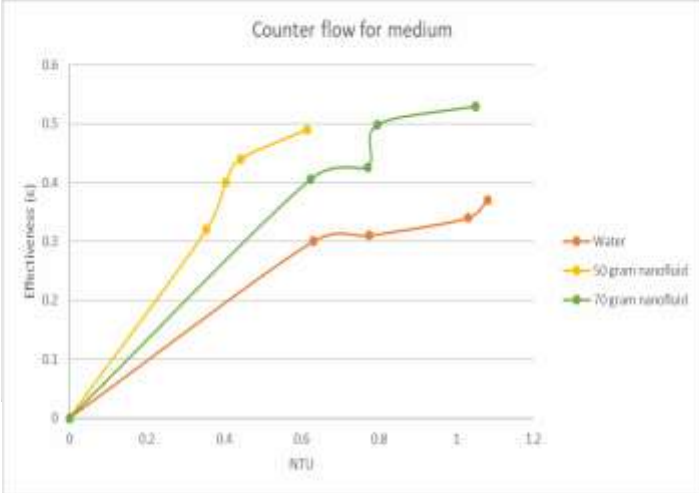
Graph 5



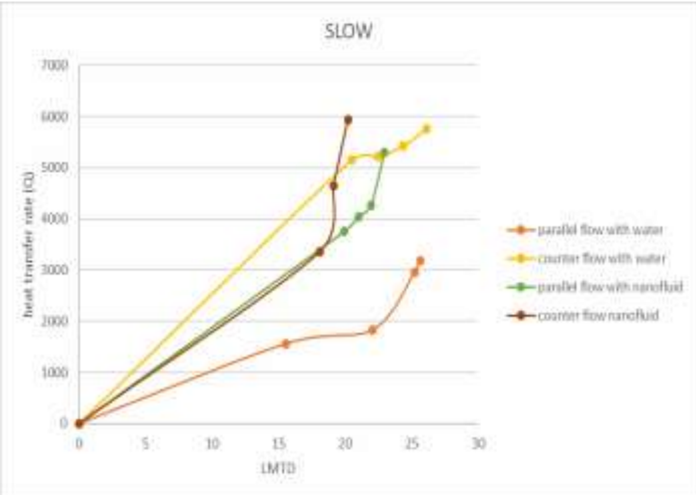
Graph 4



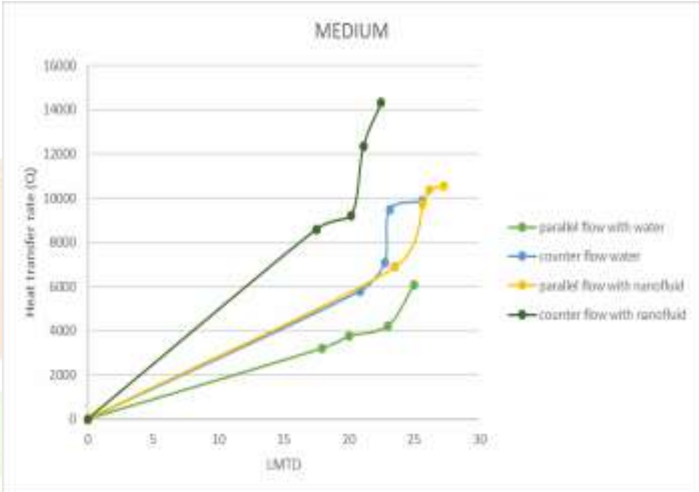
Graph 7



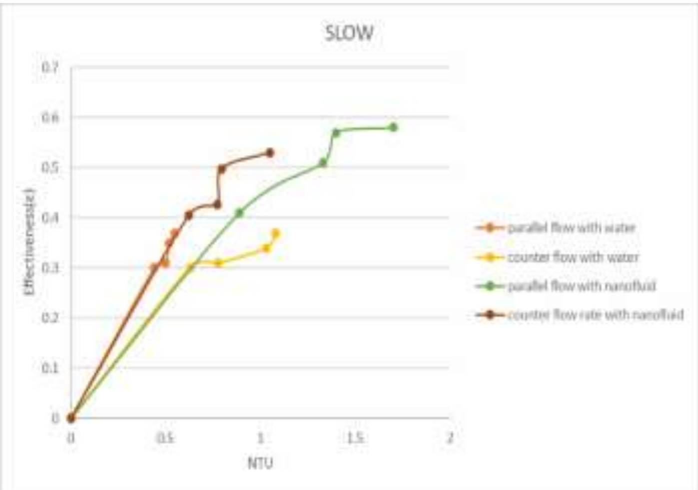
Graph 8



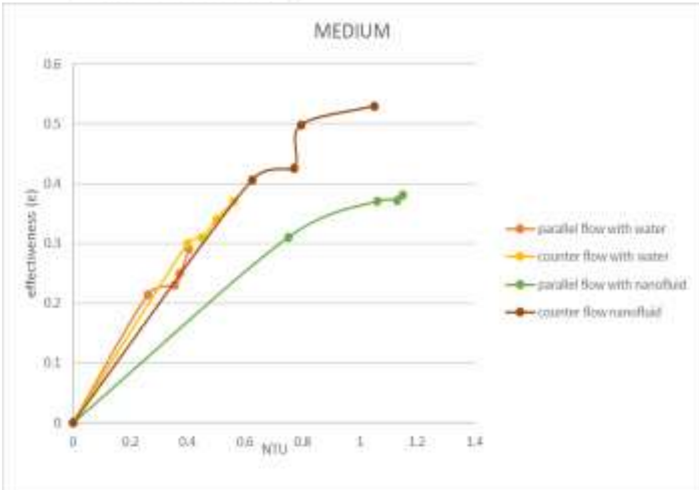
Graph 9



Graph 10



Graph 11



Graph 12

IV. CONCLUSIONS

1. The heat transfer rate Q increased for counter flow direction when compared to parallel flow direction.

   For slow flow rate and medium flow rate: the percentage increase in Q is around 60%
2. The heat transfer rate Q increased by significant value with nano fluid as working fluid when compared to water in both parallel and counter flow directions.

   For slow flow rate and medium flow rate: the percentage increase in Q is around 80%
3. The effectiveness of the Heat Exchanger increased with nano fluid as working fluid when compared to water in both parallel and counter flow directions.

4. The values of heat flow rate Q & Effectiveness ε are more for the highest volume concentration of nano fluid (0.0885%).

Therefore, it can be concluded that by increasing the volume concentration in the Heat Exchanger, the Heat transfer rate Q & Effectiveness ε can be significantly increased.

V. FUTURE SCOPE OF WORK

1. The experiments can be performed with increasing concentrations of nano fluid with an aim to arrive at optimum values of heat transfer Q and effectiveness.
2. Experiment can also be carried out with other Nano fluids, with different concentrations and different inlet temperatures of fluids.
3. The design specifications of heat exchanger can be varied to get varied results
4. Heat Exchanger with different design aimed at increasing the heat exchange parameters can be considered for experimentation.

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