Influence of Pressure Drop, Reynolds Number and Temperature in the Design of Double Pipe Heat Exchanger on Hot Fluid Side in Inner Pipe

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Abstract

A feature of heat exchanger design is the process of specifying a design, Heat transfer area, pressure drop, Reynolds number and Temperature are checking whether the assumed design satisfies all requirement or not. The idea of this paper is how to design the double pipe heat exchanger which is the majority type of liquid –to- liquid heat exchanger. General design consideration and design processes are also illustrated in this paper. Also the main components of heat exchanger are shown in drawing and its detail discussion is given. Heat exchanger is a heat transfer device that is used for transfer of internal thermal energy between two or more fluids available at different temperatures. Heat exchanger is one of the important devices in cooling and heating process in the process, power, petroleum, transportation, air-conditioning, refrigeration, cryogenic, heat recovery, building, and others.

Keywords — *Coefficient of heat transfer, Double pipe Heat Exchanger, length and diameter, overall heat transfer coefficient*

I. INTRODUCTION

Heat exchanger is a special equipment type because when heat exchanger indirectly fired by a combustion process, it becomes furnace, boiler, heater, tube-still heater and engine. Vice versa, when heat exchanger make a change in phase in one of flowing fluid such as condensation of steam to water, it becomes a chiller, evaporator, boiler, condenser etc. Heat exchanger may be designed for chemical reactions or energy-generation processes which become an integral part of reaction system such as a nuclear reactor, catalytic reactor or polymer. Normally, heat exchanger is used only for the transfer and useful elimination or recovery of heat without changing in phase. The fluids on either side of the barrier usually liquids but they can be gasses such as steam, air and hydrocarbon vapor or can be liquid metals such as sodium or mercury. In some application, heat exchanger fluids may use fused salts.

Horizontal double pipe heat exchanger uses various inserts inside tube so as to enhance heat transfer and hence increase heat transfer coefficient. These types of heat exchangers found their applications in heat recovery processes, air conditioning and refrigeration systems, chemical reactors, and food and dairy processes. The double pipe heat exchanger would normally be used for many continuous systems having small to medium duties. This double pipe heat exchanger is a device which transferred the heat from hot medium to cold medium without mixed both of medium since both mediums are separated with a solid wall generally. There are many types of heat exchanger that used based on the application. For example, double pipe heat exchanger is used in chemical process like condensing the vapor to the liquid. For this type of heat exchanger, the outlet temperature for both hot and cold fluids that produced is estimated by using the best design.

Fig1: Double pipe Heat Exchanger

P.K. Swamee et al [1] Formulated optimal design of the exchanger as a geometric programming with a single degree of difficulty. For yield problem the optimum values of inner/ outer pipe diameter and utility flow rate used for a double pipe heat exchanger of a given length, when a specified flow rate of process stream is to be treated for a given inlet to outlet temperature. They observed outlet temperature of the process stream is around 323 K which is well below the approachable temperature indicating the practicality of the solution. They found efficiency of the exchanger is around 63.6% which is reasonably high.

Shou-Shing HSIEH et Al [2] worked for single-phase forced convection in double pipe heat exchangers containing a two-dimensional helical fin roughness on the outer surface of the inner tube. From This Study, with a helical angle (α: 65°), a pitch to height ratio (p/e = 1.45), and three aspect ratios (shell side to tube side dia.) of Do/Di- 2.68, 3.48 and 5.1.Three corresponding ratios are taken of roughness height to hydraulic dia. (e/Ds) of 0.192, 0.13 and 0.08, respectively. They found heat transfer performance is to be depended upon both the mass flow rate and the ratio of roughness height to hydraulic dia. (e/DH).They observed that the Nusselt numbers of the ratios of roughness height to hydraulic dia. of 0,192 and 0.13 are found nearly 60 and 40%, respectively, higher than that of the ratio of roughness height to hydraulic dia. of 0.08 for all the flow rates investigated.

Timothy J. Rennie et al [3] performed an experimental study of double pipe helical heat exchanger with parallel and counter flow configuration. Overall heat transfer coefficients were calculated and heat transfer coefficients in the inner tube and the annulus were determined using Wilson plots. They calculated a Nusselt numbers for the inner tube and the annulus. Heat transfer rates, however, are much higher in the counter flow configuration, due the increased log mean temperature difference.

H. A. Mohammed et al [4] studied an effect of louvered strip inserts placed in a circular double pipe heat exchanger on the thermal and flow fields utilizing with various types of nano-fluids. The continuity, momentum and energy equations are solved by means of a finite volume method (FVM). Reynolds number range of 10,000 to 50,000.

Paisarn Naphon, Et al [5] investigated a heat transfer characteristics and the pressure drop in the horizontal double pipes with twisted tape insert. The twisted tape is made from the aluminium strip with thickness of 1 mm and the length of 2000 mm.R22 is used as the refrigerant for chilling the water. They compared tube with twisted insert to without twisted tape. The twisted tape insert has significant effect on enhancing heat transfer rate. However, the pressure drop also increases. The heat transfer rate increases with increasing tube-side Reynolds number.

Smith Eiamsa-Ard, et al [6] carried out an Experimental work on turbulent heat transfer and flow friction characteristics in a circular tube equipped with two types of twisted tapes: (1) typical twisted tapes (2) alternate clockwise and counterclockwise twisted tapes (C–CC twisted tapes). They included the tapes with three twist ratios, y/w = 3.0, 4.0 and 5.0 and each with three twist angles, h = 30°, 60° and 90°.The maximum heat transfer enhancement indexes of the C–CC twisted tapes with h = 90° for y/w = 3.0, 4.0 and 5.0, are 1.4, 1.34 and 1.3, respectively.

Hamed Sadighi Dizaji, et al [7] worked to increase the number of thermal units (NTU) and performance in a vertical shell and coiled tube heat exchanger via air bubble injection into the shell side of heat exchanger. In this Experiment Air bubbles were injected inside the heat exchanger via a special method and at new different conditions.

Ali Hasan [8] several models were created with varying; geometry, flue gas entry temperature, and flow rates. The analysis should provide designers and manufacturers a judgment on the expected level of accuracy when using mathematical modelling methodology.

Patel et al [9] double pipe heat exchanger is one of simplest type of heat exchanger, generally used for the purpose of sensible heating or cooling. In this paper it describes the different techniques which may help to enhance the heat transfer rate. Heat exchangers are modified in space of annular, also using Nano particle in water and compared with the conventional heat exchanger. Double pipe heat exchanger is practically investigated and results are validated with Ansys CFD software. Results shows that heat transfer rate of modified heat exchanger are higher than the conventional heat exchanger.

Antony et al [10] Flow Analysis and Characteristics Comparison of Double Pipe Heat Exchanger Using Enhanced Tubes In this investigation, augmented surface has been achieved with dimples strategically located in a pattern along the tube of a concentric tube heat exchanger with the increased area on the tube side. Augmented surfaces to increasing the heat transfer coefficient with a consequent increase in the friction factor. In this analysis to modify the inner tube of double pipe heat exchanger using dimpled tube.

Kukulka et al [11] Development and evaluation of enhanced heat transfer tubes, Enhancement tube and smooth tubes are compared and material is enhanced 304 L stainless steel tube and steel. This experiment under performed by Turbulent flow in the range of Reynolds Numbers near 2900, Water as working fluid. Increases in heat transfer for most Enhancement tubes are in excess of 120% over smooth tubes and minimize the fouling rate. Inlet water flow was a constant rate of 6 L/min. After the prescribed time, the tubes were drained, samples dried and measurements made. Rate of fouling for the smooth stainless steel tubes were compared to the average values of the four dimpled tubes. Dimpled tubes minimize the fouling rate and also provide heat transfer performance gains in excess of 100%.

Juin et al [12] Heat transfer enhancement in dimpled tubes, Coaxial-pipe heat exchanger using Six dimpled copper tubes of varying geometries were used for comparison with a standard smooth tube. This experiment under performed by turbulent flow. Water as test fluid and experimental method. Best dimpled tube was tube 6, which had the largest dimple depth-to-tube inside diameter ratio, dimple depth to-pitch ratio, dimple depth-to-dimple diameter ratio, and number of dimple columns. Tube 6 have high heat transfer coefficient are significantly larger (between 1.25 and 2.37times) than those for the smooth tube. Friction factor for all the dimpled tubes are 1.08 to 2.3 times higher than the value for the smooth tube.

Saleh et al [13] Flow and Heat Transfer Performance of a Dimpled-Inter Surface Heat Exchanger-an Experimental /Numerical Study. This paper presents and discusses the flow and heat transfer performance of a parallel/ counter flow heat exchanger, when the heat transfer surface is provided with dimples on one or both sides (cold fluid side and hot fluid side). Evaluation of the performance is based here on experimental and numerical data obtained for a typical such exchanger. It is found that the overall heat transfer rates that are 2.5 times greater for the dimpled surface compared to plain tube.

Sai et al [14] Heat transfer in a conjugate heat exchanger with a wavy fin surface. A three dimensional computational study on conjugate heat exchangers was conducted Attention was specially directed towards studying extended surfaces used to increase heat transfer The strategy adopted in the present investigation of forced convection in a flow passage was to use the finite volume method Our implementation incorporated a simple based semi implicit solution algorithm which was applied to working equations formulated within the single phase catalo. The analysis allowed for marked changes in thermodynamic and flow properties. To better illuminate the flow and heat transfer characteristics in a flow passage bounded by two fins having wavy geometries we have plotted solutions in a three dimensions.

Kim et al [15] Numerical study on characteristics of flow and heat transfer in a cooling passage with protrusion-in-dimple surface, Four different protrusion heights were considered and protrusion height to channel height (h/H) of 0.05, 0.10, 0.15, and 0.20. This experiment under performed by turbulent flow, Water as test fluid. CFD analysis and Experimental method and 40% negligible pressure drop, 24% increase heat transfer, increase friction factor up to 5-6% and volume goodness factor slightly increases by approximately 4%.

REQUIREMENTS OF HEAT EXCHANGERS:

Heat exchangers have to fulfill the following requirements:

1. High thermal effectiveness
2. High-quality product
3. Pressure drop as low as possible
4. Safe in operation
5. Reliability and life expectancy.
6. Material compatibility
7. Convenient size, easy for installation, reliable in use
8. Easy for maintenance and servicing
9. Light in weight
10. Must have good strength to withstand the operational pressures and temperature as well vibrations.
11. Simplicity in manufacture
12. Low initial cost
13. Low maintenance and easy to handle and repair.

II. SELECTION OF PARAMETERS

A. Outer Pipe

It is made of copper which has a length of 2m and 24mm diameter and is insulated with asbestos lining to avoid heat transfer into atmosphere. In this pipe cold water is send from water tank through a pipe.

B. Inner Pipe

It is made of copper surrounded by outer pipe which has inner diameter of 8mm and outer diameter with 10mm. It contains hot lubricating oil send from tank in which geyser is placed.

C. Valves

These are of 6 in number which are utilized for control/regulate the flow of liquids at various locations as shown in figure.

D. Geyser

Arrangement of geyser is present over the heat exchanger for heating fluid before entering into heat exchanger. It is has a capacity of 3 liter.

E. Thermocouples

A thermocouple consists of two dissimilar conductors in contact, which produces a voltage when heated. The size of the voltage is dependent on the difference of temperature of the junction to the parts of the circuit. Thermocouples are widely used type of temperature sensor for measurement and control and can also be used to convert a temperature gradient into electricity. Commercial thermocouples are inexpensive, interchangeable, are supplied with standard connectors, and can measure a wide range of temperatures.

F. Electric Pumps

Pumps are used for lifting water and lubricant from their tank to circulate in concentric tube heat exchanger.

Let,

D_i= pipe inner diameter in m
m_{hot}=hot fluid flow rate in LPM
m_{cold}=cold fluid flow rate in LPM
L = length of the inner pipe in m
Vfluid =volume of fluid in ml
U= overall heat transfer coefficient in kW/m^2C
C_{pc} = specific heat of cold fluid in KJ/kg K
C_{ph} =specific heat of hot fluid in KJ/kg K
Th,in= hot fluid inlet temperature in °C
Tc,in= cold fluid inlet temperature in °C
m_c =cold fluid in kg/sec
m_h=hot fluid in kg/sec
As = Surface Area in m^2
Cc =Heat capacity of cold fluid in kW
Ch =Heat capacity of hot fluid in kW
Cmin= Minimum heat capacity in kW
Cmax= Maximum heat capacity in kW
C =Capacity Ratio = Cmin/Cmax
Qmax = maximum heat transfer in kW
Q actual= actual heat transfer in kW
NTU= number of transfer units
ε = Effectiveness
Th,out= hot fluid outlet temperature in °C
Tc,out= cold fluid outlet temperature in °C
Thi-Tho= hot fluid temperature difference in °C
Tco-Tci= cold fluid temperature difference in °C
LMTD= log mean temperature difference
ρ=density of oil, kg/m3
ν=kinematic viscosity, m2/s
Q= discharge, m3/s
A_c=cross sectional area, m2
V=velocity, m/s
Re=reynolds number
f=friction factor
h_f=pressure drop due to friction, ba

III. EXPERIMENTAL SET UP:

Fig 2: Experimental Set up

The important parts of experimental set-up are the test section containing horizontal concentric copper pipes, hot lubricating oil tank and cold water tank, Rota meters, pumps, sensors etc. All these instruments are selected as per the requirements depending upon their measuring range, accuracy and availability in the market. The test section is made up of copper tubes as it has higher thermal conductivity. The important parts of the setup are:

1= fluid tanks:

Hot fluid tank & cold fluid tank --- a cylindrical tanks of 3 liter capacity each, insulated outside, heater of capacity 1000W (immersion type) and thermocouple is provided to read temperature

2= pumps: Crompton greaves MINI MASTER IV **(size** 13 X 13, 0.125 HP)
3= control valves
4=flow meters
5= suitable pipings
6= copper pipe diameter 8mm and 2m length
7= copper pipe diameter 24mm and 2m length, with insulation
8= drains

9= Y-type filters
10= Mano meters are preferable to measure pressure

IV.CALCULATIONS TO SELECT SUITABLE PARAMETERS:

s.no	Constant parameters	values
1	m_{cold}	2
2	m_{hot}	3
3	U	0.2
4	Cpc	4.178
5	Cph	2.219
6	Th,in	100
7	Tc,in	30
8	mc	0.0333
9	mh	0.042
10	Cc	0.1393
11	Ch	0.0932
12	Cmin	0.0932
13	Cmax	0.1393
14	C	0.6692
15	Qmax	6.5239

s.no	parameter	1	2	3	4
	D_i	0.008			
1	L	1	1.5	2	2.5
2	V_{fluid}	50.2400	75.3600	100.4800	125.6000
3	As	0.0251	0.0377	0.0502	0.0628
4	Q actual	0.3365	0.4941	0.6452	0.7902
5	NTU	0.0539	0.0809	0.1078	0.1348
6	ε	0.0516	0.0757	0.0989	0.1211
7	Th,out	96.3891	94.6979	93.0768	91.5214
8	Tc,out	32.4164	33.5482	34.6331	35.6739
9	Re	398.0891			
10	h_f	0.0836	0.1254	0.1672	0.2090

s.no	parameter	1	2	3	4
	D_i	0.018			
1	L	1	1.5	2	2.5
2	V_{fluid}	254.3400	381.5100	508.6800	635.8500
3	As	0.0565	0.0848	0.1130	0.1413
4	Q actual	0.7185	1.0302	1.3155	1.5776
5	NTU	0.1213	0.1819	0.2426	0.3032
6	ε	0.1101	0.1579	0.2016	0.2418
7	Th,out	92.2911	88.9463	85.8847	83.0723
8	Tc,out	35.1588	37.3972	39.4460	41.3281
9	Re	176.9285			
10	h_f	0.0033	0.0049	0.0065	0.0082

s.no	parameter	1	2	3	4
	D_i	0.012			
1	L	1	1.5	2	2.5

2	V_{fluid}	113.0400	169.5600	226.0800	282.6000
3	As	0.0377	0.0565	0.0754	0.0942
4	Q actual	0.4941	0.7185	0.9294	1.1281
5	NTU	0.0809	0.1213	0.1617	0.2022
6	ε	0.0757	0.1101	0.1425	0.1729
7	Th,out	94.6979	92.2911	90.0279	87.8961
8	Tc,out	33.5482	35.1588	36.6734	38.1000
9	Re	265.3927			
10	h_f	0.0165	0.0248	0.0330	0.0413

s.no	parameter	1	2	3	4
	D_i	0.024			
1	L	1	1.5	2	2.5
2	V_{fluid}	452.1600	678.2400	904.3200	1130.4000
3	As	0.0754	0.1130	0.1507	0.1884
4	Q actual	0.9294	1.3155	1.6603	1.9699
5	NTU	0.1617	0.2426	0.3234	0.4043
6	ε	0.1425	0.2016	0.2545	0.3020
7	Th,out	90.0279	85.8847	82.1852	78.8628
8	Tc,out	36.6734	39.4460	41.9218	44.1451
9	Re	132.6963			
10	h_f	0.0010	0.0015	0.0021	0.0026

V. RESULTS AND DISCUSSION

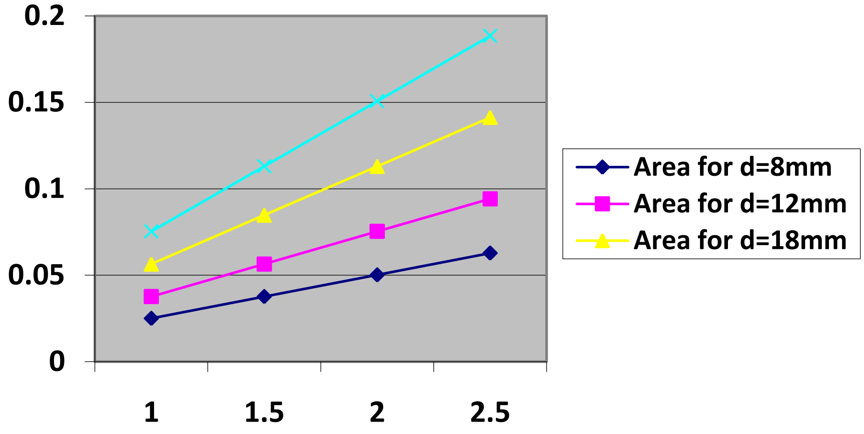

Fig:Variation of As along the length

From the above diagram, we can observe that as the diameter of pipe increses the area also because of proporationality, but there is much deviation in this area as the length of pipe increases, thus at 2.5m length the deviation of areas is much higher compared to the length of 1m.

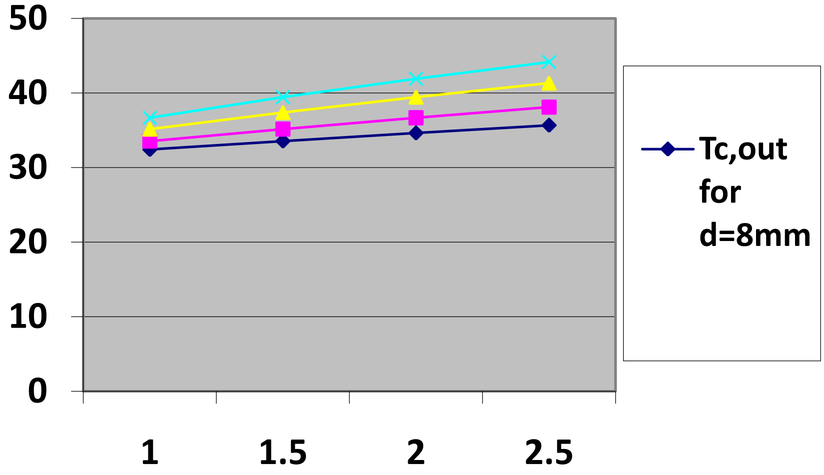

Fig:Variation of $Tc_{,out}$ along the length

The above diagram shows that as the diameter increases with respect to length, their will be more temperature change in the cold fluid of the pipe. Hence, it is advisable to have large diameter for better temperature distribution, to increase heat transfer rate. In above selection it is preferrable to have diameter 24mm for hot fluid pipe.

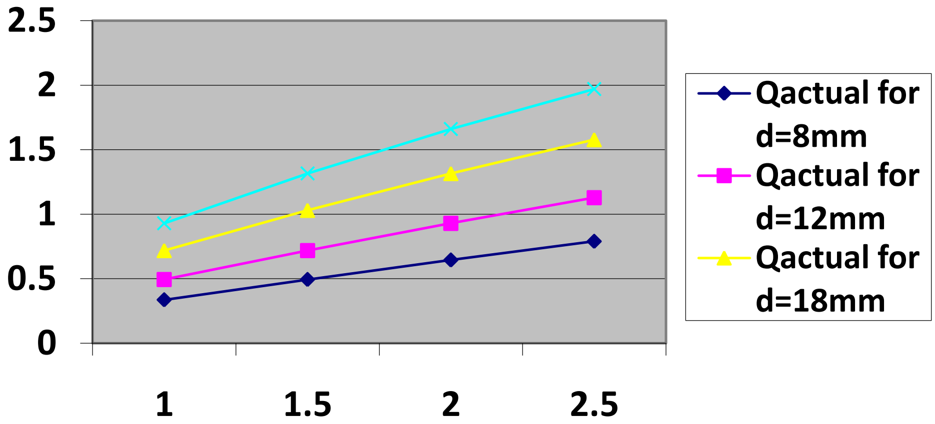

Fig:Variation of Qactual along the length

from above diagram we can understand that as the diameter increases with respect to length, their will be more heat transfer in the cold fluid of the pipe. Hence, it is advisable to have large diameter for better heat exchange, to increase heat transfer rate. from above diagram it is preferrable to have diameter 24mm for cold fluid pipe.

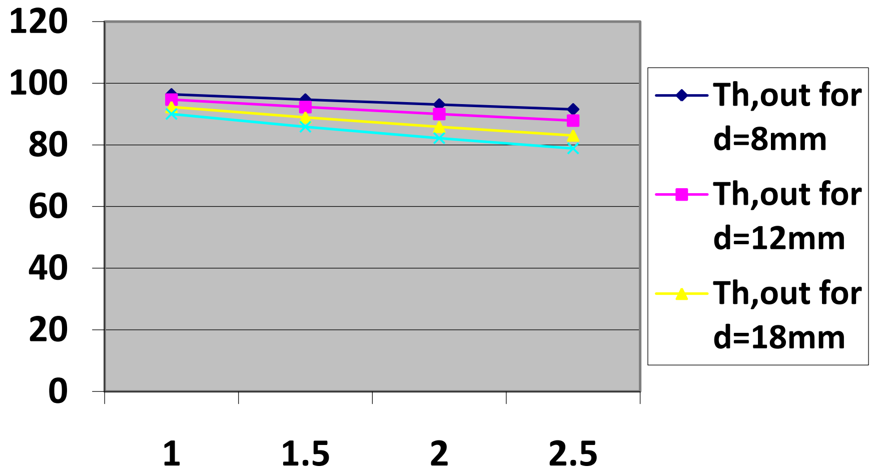

Fig:Variation of Th,out along the length

from above diagram we can observe that as the diameter increases with respect to length, their will be less heat transfer in the hot fluid of the pipe. Hence, it is advisable to have less diameter for better heat exchange, to increase the temperature rate. from above diagram it is preferrable to have diameter 8mm for hot fluid pipe.

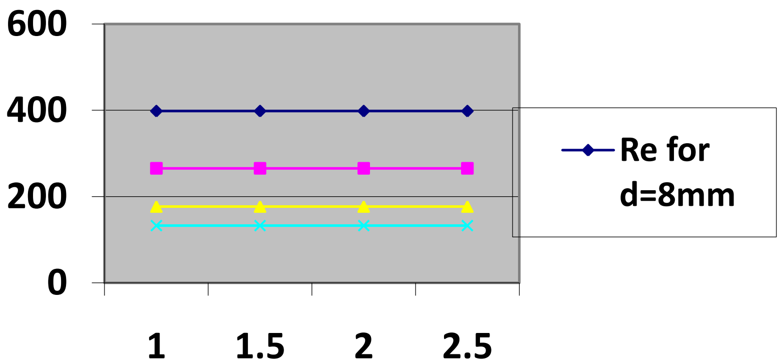

Fig:Variation of Re along the length

The above figure shows that as the diameter increases there will be low reynolds number, causes the flow lower laminar side. If the diameter is more and more, the flow is moving much into laminar low side, may be at point the obstruction of flow may occur. And it will be serious problem, for more viscous fluids. Hence, from the observations it is prefferble to have low diameter of pipe.

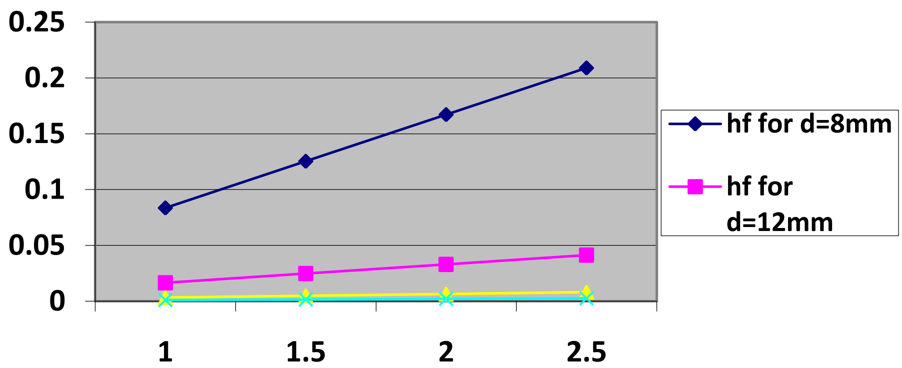

Fig:Variation of hf along the length

The above figure shows that as the diameter increases there will be less friction. If the diameter is more and more, friction will be less. So, it is better is have more diameter for the pipe.

VI. CONCLUSION

From above diagrams and discussion, it was concluded that the length of the pipe is 2m, diameter of the pipe is 8mm, m_{hot}=3 LPM, m_{cold}=2 LPM.

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