International Journal of Mechanical Engineering (IJME)
ISSN(P): 2319-2240; ISSN(E): 2319-2259
Vol. 4, Issue 3, Apr - May 2015, 85-92

International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations
IASET

PRESSURE DROP ANALYSIS OF INLET PIPE WITH REDUCER AND WITHOUT REDUCER USING CFD ANALYSIS

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ABSTRACT

A plate heat exchanger uses metal plates to transfer heat between two fluids. The metal plates are made up of stainless steel because of its ability to withstand high temperatures, its strength and its corrosion resistance. PHE is use in industries such as chemical, food and pharmaceutical process and refrigeration. The attempt made in this paper is to study the pressure drop in accessories of plate heat exchanger and to observe which geometry of inlet pipe gives the best results. Using simulation. Computational Fluid Dynamic (CFD) is a tool used in this simulation which consists of ICEM CFD and FLUENT. Volume meshing in ICEM is an important part to be considered before doing simulation in FLUENT as a solver.

The velocity for water were calculated using flow rate of 1680m^3/hour. Inlet dimension of pipe is 500mm and material of pipe is steel. Water is fluid which is passed through pipe. The temperature of water is 25degree Celsius.

Thus, this paper presents the simulation of pressure drop at inlet of reducer and without reducer of pipe of plate heat exchanger model.

KEYWORDS: Plate Heat Exchanger (PHE), CFD, ICEM, Pressure Drop Analysis

INTRODUCTION

Over the past quarter century, the importance of plate heat exchanger(PHE) in industries all over world has increased rapidly. Heat exchanger is a device in which the flow of thermal energy between two or more fluids at different temperatures.

Now-a-days PHE widely used in different industries such as chemical, food and pharmaceutical process and refrigeration due to a many of advantages such as compactness, flexibility, ease maintenance and ability to recover heat at extremely small temperature differences. However, the growth of the process industries include mainly reliable operation and high combination of temperature levels, pressure drop, fouling resistance, hence plate heat exchangers become the fastest growing member of the heat exchanger family.

Inlet pipe of Plate heat exchanger is made up of steel. Inlet of pipe is connected to the 2.4 bar motor and outlet of inlet pipe is connected to the PHE. In between inlet and outlet of pipe reducer is installed.

Pressure drop is important parameter in pipe flow. Pressure drop generally occurs due to friction, pipe elevation, change in kinetic energy. The pressure drop caused by friction of fluid flow i.e. turbulent flow depends on roughness of pipe.

The pressure drop between inlet pipe is calculated by analytical as well as by simulation method. This paper makes a contribution to the overall effort to increase understanding of the behaviour fluid flow in PHE inlet pipe.

PROBLEM STATEMENT

The Plate Heat Exchanger (PHE) with constant flow rate of $1680 m^3/hr$. Water is use as cooling fluid which is at room temperature. Reducer and without reducer inlet pipe of standard dimensions are fitted to heat exchanger. “To calculate and analyse of pressure drop occurs between cross-section of pipe by using CFD and Mathematical equations.”

Case 1: Pressure drop using reducer.

Case 2: Pressure drop without using reducer (i.e. sudden contraction)

THERMAL PROPERTIES OF STAINLESS STEEL

Thermal Conductivity = 17 W/m.K

Density = $7.93 Mg/m^3$

Specific Heat =490J/kg.k

THERMAL PROPERTIES OF FRESH WATER

Thermal Conductivity= 0.604 W/m.k

Density =$997.4\ kg/m^3$

Specific Heat= 4181 J/Kg.K

MODELLING OF INLET PIPE

Modelling is a pre-processor tool, modelling of inlet pipe is done in Creo and meshing of inlet pipe is created using the ICEM CFD software. Meshing can be defined as the process of splitting a physical domain into smaller sub domain in order to facilitate the numerical solution of a partial differential equation.

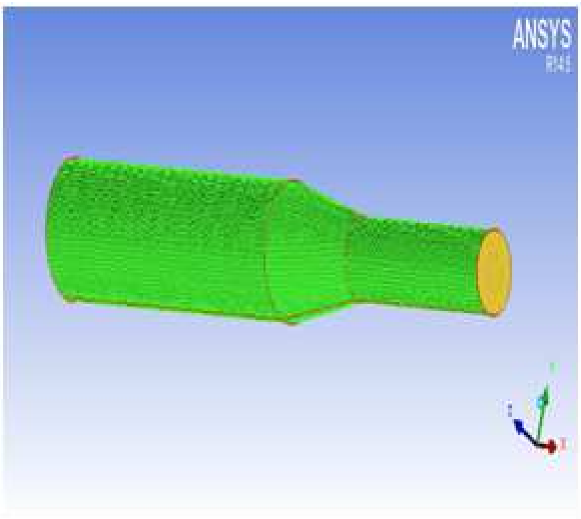


Figure 1: Mesh of Inlet Pipe with Reducer

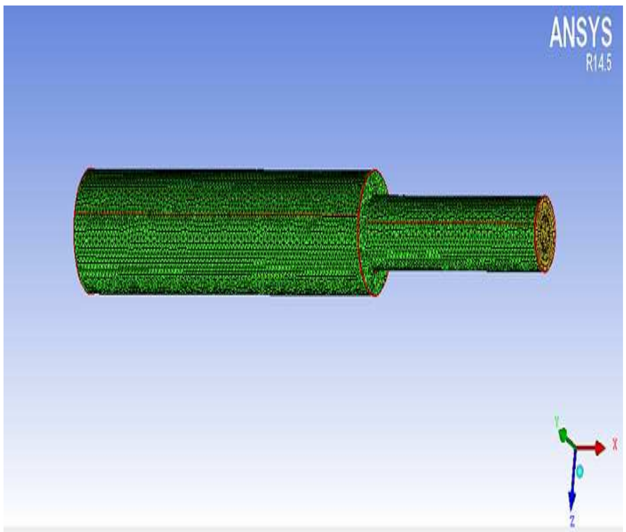


Figure 2: Mesh of Inlet Pipe without Reducer

ANALYTICAL CALCULATION

Given Data

Flow Rate (Q) =1680m^3/hr

Flow Rate (Q) =0.4667 m^3/s

T= 25°

D_1=500 mm

D_2=300 mm

SOLUTION

$A_1 = \pi/4 * (D_1)^2$=$\mathbf{0.1963\ m^2}$

$A_2 = \pi/4 * (D_2)^2$ =$\mathbf{0.07069\ m^2}$

By continuity Equation,

$Q= A_1V_1$

$V_1 = Q/A_1$ =**2.3773 m/s**

Similarly,

$Q=A_2V_2$

$V_2 = Q/A_2$ =**6.6021 m/s**

REYNOLD'S No:-

At T= 25°, μ = 0.894*10^{-3} Pas

$Re=\rho VD/\mu$

For D_1 =500 mm=0.5 m

$Re_1=\rho V_1D_1/\mu$

$\therefore Re_1$= **1329586.13**

For D_2= 300 mm=0.3m

$Re_2=\rho V_2D_2/\mu$

$\therefore Re_2$ =**2215469.799**

Friction Factor

Assuming smooth pipe,

For D_1=0.5m

$1/\sqrt{f} =2.03 \log_{10}(Re_1 \sqrt{f}) -0.91$………….. (Page No-608, **Modi & Seth**)

$\therefore$ f= **0.0110031**

By Nikuradse's Experiment,

$1/\sqrt{f} = 2.03 \log_{10}(Re_1 \sqrt{f}) - 0.8$

$\therefore$ f= **0.010774206**

For D_1=0.3m

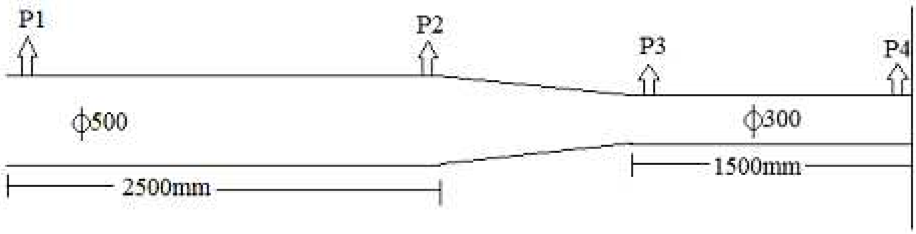
$1/\sqrt{f} = 2.03 \log_{10}(Re_2 \sqrt{f}) - 0.91$

$\therefore$ f= **0.010108751**

$1/\sqrt{f} = 2.03 \log_{10}(Re_2 \sqrt{f}) - 0.8$

$\therefore$ f= **0.010203682**

Case 1: Pressure drop with reducer.



Figure

P_1=**2.4 bar**………….(Given)

By Darcy Weisbach Equation,

For Region 1,

$h_f = fLV_1^2/2gD_1$

$\therefore h_f$ **= 0.01585 m**

$P_1 - P_2/\gamma = h_f$

P_2 =2.39844 bar

P_2 =239844 Pas

For Region 2,

By Bernoulli's Theorem,

$P_2/\gamma + V_1^2/2g = P_3/\gamma + V_2^2/2g + h_f$

h_f=4fQˆ2lˆ5/2g$\pi^2 D_2^5$[1/lˆ4-1/(L+l)ˆ4]……………… (Page No-475,**Modi & Seth**)

h_f=**0.02128**

$\therefore$2.39844*10ˆ5/9810+(2.3773)ˆ2/2*9.81=P_3/9810+(6.6021)ˆ2/2*9.81+0.02128

P_3=2.20666 bar

P_3=220666Pas

For Region 3,

$h_{f} = fLV_2\hat{}2/2gD_2$

h_f**= 0.112288m**

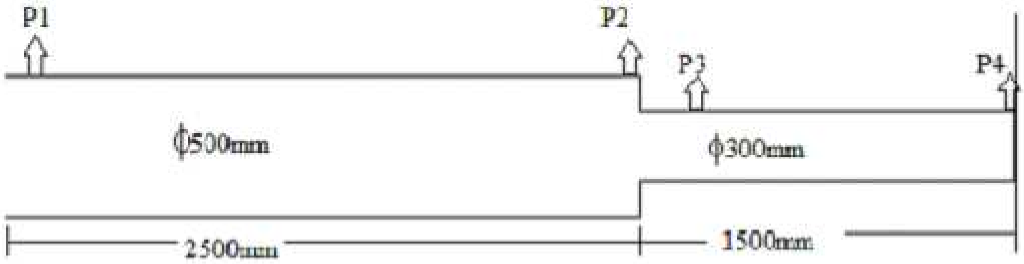
$P_3-P_4/\gamma= h_f$

$2.20666*10\hat{}5 - P_4/9810=0.112288$

P_4=2.19564 bar

P_4= 219564 Pas

Case 2:- Pressure drop without reducer.



Figure

For Region 1

P_1=2.4 bar…….(Given)

$h_f= fLv_1^2/2gD_1$

h_f =0.01585

$(P_1-P_2)/\gamma=h_f$

P_2=2.39844 bar

For Region 2

$P_2/\gamma+V_1^2/2g=P_3/\gamma+V_2^2/2g+h_L$

Assume Coefficient of Contraction(Cc)=0.5

$h_L=V_2^2/2g[1/Cc-1]^2$

$\therefore h_L$=2.2216 m

$2.39844*10^5/9810+2.3773^2/(2*9.81)=P_3/9810+6.6021^2/(2*9.81)+2.2216$

P3=1.99082 bar

For Region 3

$h_f=FLV_2^2/2gD_2$

h_f=0.112288 m

P_3-P_4/γ=h_f

$1.99082*10^5$-P_4/9810=0.112288

P_4=1.97980 bar

CFD ANALYSIS

Case1: Pressure drop with Reducer

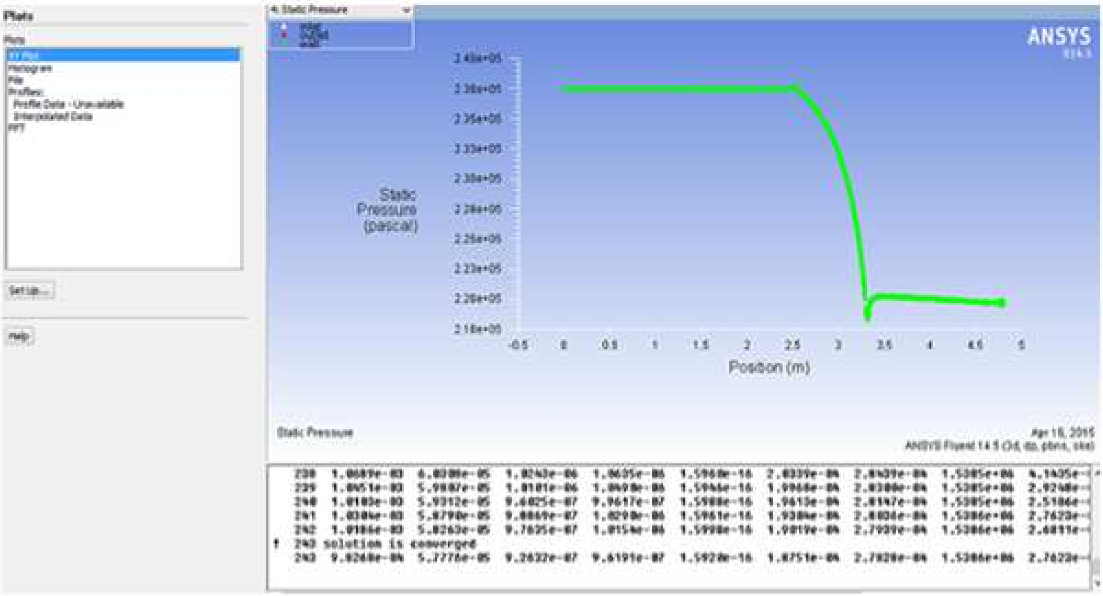


Figure 3: Graph of Pressure Drop in Pipe with Reducer

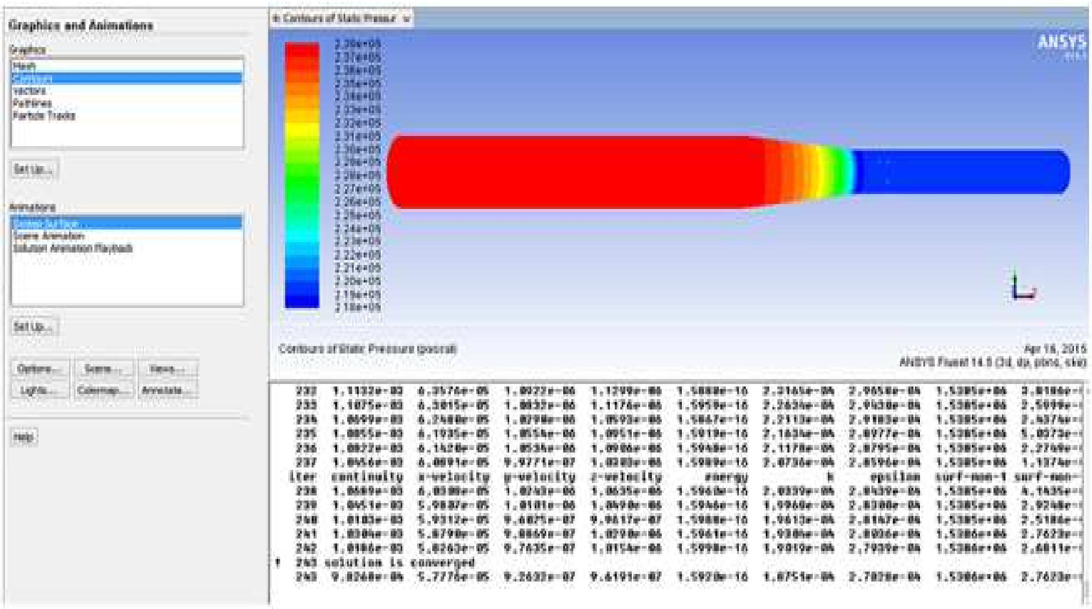


Figure 4: Variation of Pressure in Pipe with Reducer Using CFD Fluent

Case 2:- Pressure drop without reducer

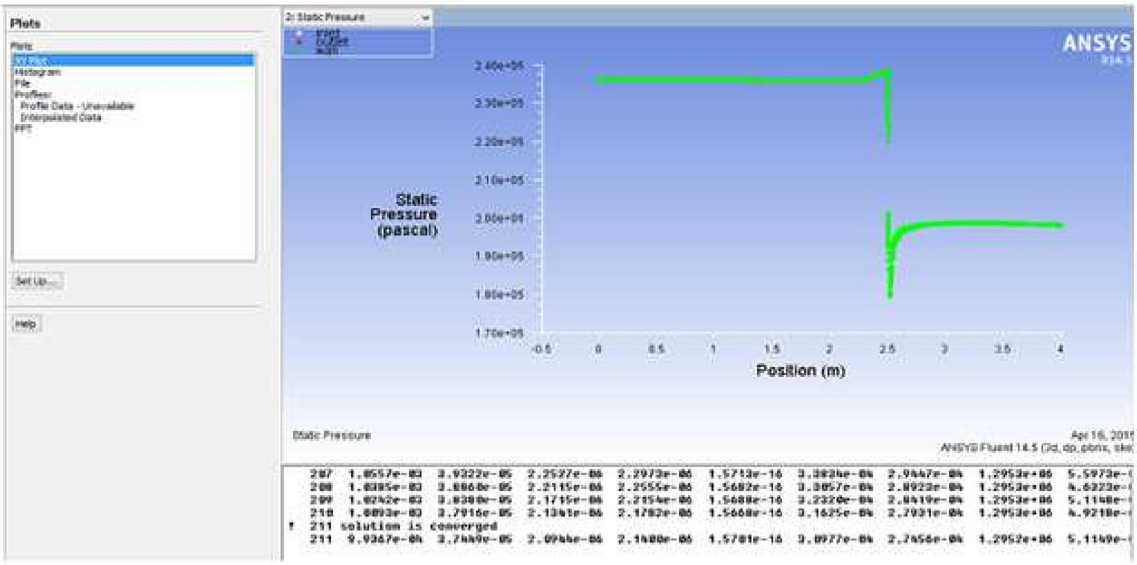


Figure 5: Graph of Pressure Drop in Pipe without Reducer

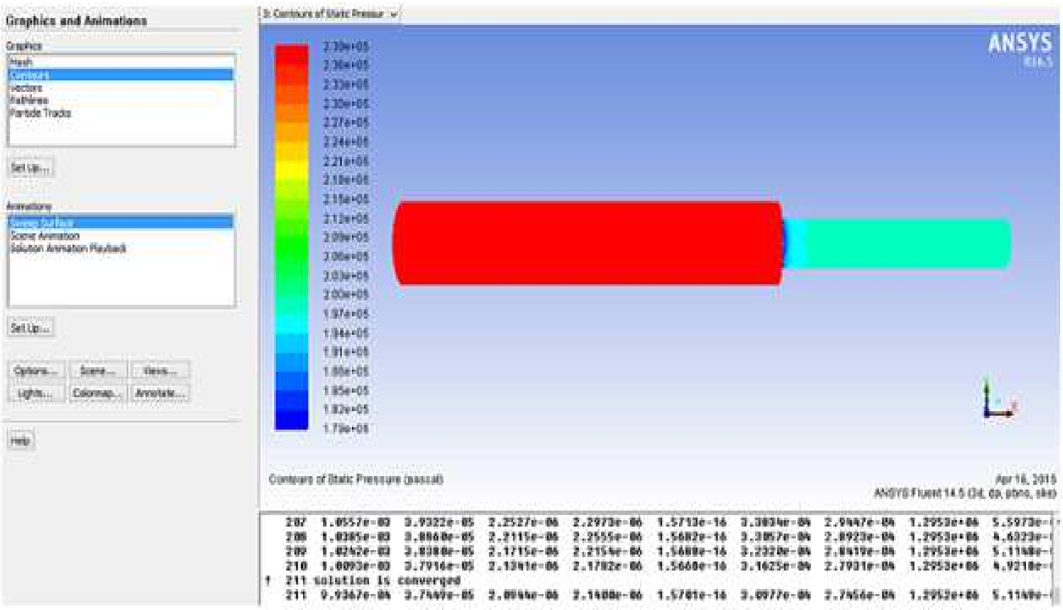


Figure 6:- Variation of Pressure in Pipe without Reducer

RESULT

Result of Pressure drop with reducer and without reducer by Analytical analysis and CFD analysis shown in following table.

	Pressure Drop with Reducer		Pressure Drop without Reducer	
	Analytical Analysis	CFD Analysis	Analytical Analysis	CFD Analysis
P_2	2.39844bar	$2.38e^{5}$bar	2.39844bar	$2.39e^{5}$bar
P_3	2.20666bar	$2.19e^{5}$bar	1.99082bar	$1.97e^{5}$bar
Pressure drop (P_2-P_3)	0.19178bar	$0.19e^{5}$bar	0.40762bar	$0.42e^{5}$bar

DISCUSSIONS

Thus the CFD result is calculated for inlet with reducer and without reducer. The pressure drop for inlet pipe with reducer is 0.19e^{5}bar and that for without reducer is 0.42e^{5}bar which is more than with reducer inlet pipe. Whereas analytical results are 0.19178 bar for with reducer and 0.40762 bar for without reducer inlet pipe. Therefore range of variation for analytical and CFD results is within 5%. Hence results are validated.

Now, from result, the pressure drop with reducer is less than pressure drop without reducer. Hence its observed that inlet pipe with reducer is better as compared to inlet pipe without reducer.

CONCLUSIONS

After performing all the analysis work for inlet pipe with reducer and without reducer the following observation had been done. From study of result as mentioned in table, after performing the calculation the pressure drop of inlet pipe with reducer and without reducer are 0.19178bar and 0.40762bar respectively which is nearer to the value mentioned in CFD analysis. As we change inlet pipe from with reducer to without reducer, the pressure drop (P_2-P_3) had been varied.

Analysis has been done by varying the inlet pipe and it is found that inlet pipe with reducer gives better pressure drop than inlet pipe without reducer.

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