A Computational Fluid Dynamics Study and Analytical Verification of Change in Various Parameters of Fluid during its Flow through Pipes

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Abstract— In the Industry it is very important to know the power required to operate an actuator. In order to optimize this power requirement one should have an accurate knowledge of the fluid parameters in the system. Knowledge of properties of fluid at significant points in the system enables one to consciously avoid overdesigning of system components. For instance whenever fluid is supplied to a system through pipes, a pressure drop occurs. To ensure that this pressure drop does not affect system parameters the industry often supplies an excess pressure to the system and the remaining is throttled at the destination. This results in power loss. This project aims at finding out the exact requirement of pressure that must be supplied at the inlet to a particular application used in industry. For this i will be finding out the pressure drop occurring while the fluid is flowing through pipes through computational fluid dynamics and analytically. This project aims to provide the industry with a standard database for ready future reference. Using this reference the industry can optimize the power requirement at the input to minimize wastage.

Key words: CFD, FLUENT

I. INTRODUCTION

This project will accurately predict, calculate and measure these changes in fluid parameters and prepare a database for future reference. This project deals with the study of various parameters that must be considered during transmission of fluid through pipes.

The following parameters are studied:

1) Pressure changes
2) Diameter of pipe
3) Length of pipe

II. AIMS AND OBJECTIVES

This project aims at finding out the exact requirement of pressure that must be

Supplied at the inlet to a particular application used in industry. For this i will be

Finding out the pressure drop occurring while the fluid is flowing through pipes.

This work will be carried out in following 4 stages:

1) Analytical solution to find out the pressure drop
2) Verification of solution using CFD analysis

This project aims to provide the industry with a standard database for ready future reference. Using this reference the industry can optimize the power requirement at the input to minimize wastage.

A. Specifications of Pipe:

The Industry uses hydraulic pipes of only specific diameters throughout their installations and the following pipe specifications are used for analysis.

Sr.No.	Pipe I.D(mm)	Pipe O.D(mm)	Pipe Length(mm)
1	4.00	6.00	500
2	4.00	6.00	1000
3	4.00	6.00	1500
4	8.00	12.00	500
5	8.00	12.00	1000
6	8.00	12.00	1500
7	12.00	15.00	500
8	12.00	15.00	1000
9	12.00	15.00	1500
10	18.00	22.00	500
11	18.00	22.00	1000
12	18.00	22.00	1500
Pipe Material	M.S Seamless		

Table 1: Pipe Specifications

III. CFD ANALYSIS

The following procedure was followed to simulate the pipes in ANSYS and calculate pressure drop using Computational Fluid Dynamics

The procedure comprised of 4 main steps

A. Geometric Modeling:

In this step quarter portion of the pipe is modeled. A quarter portion is modeled to reduce the calculation time and processing.

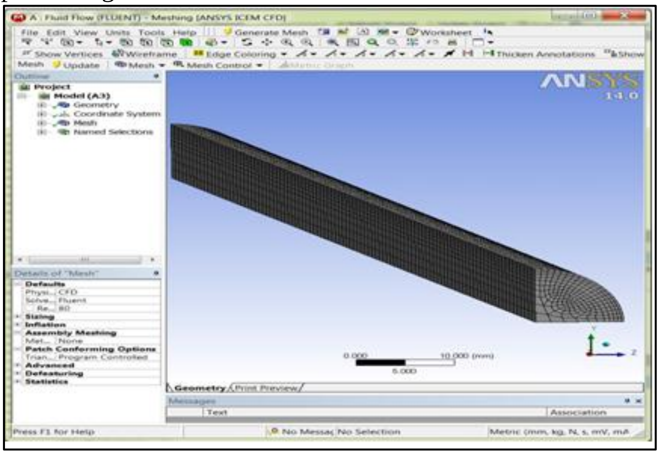

Fig. 1: Geometric Modeling

B. Fluent:

Fluent setup is configured for double precision. Fluid properties for ISO VG

68 are setup. The model used for solving is Viscous Laminar. To specify boundary conditions the pipe regions defined in meshing are used. For inlet, inlet velocity is specified. Convergence Criterion is increased to $1xe^{-6}$

C. Results:

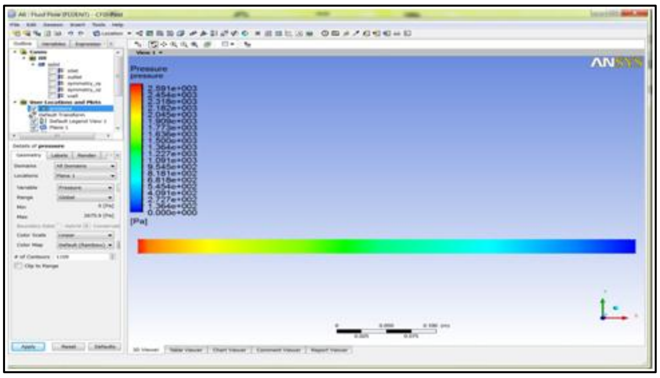

Fig. 2: Result

Following are the results obtained through CFD analysis

Sr.no.	Pipe Dia. Mm	Pipe Length mm	Press. Drop By CFD Bar
1	4	500	10.717
2	4	1000	20.044
3	4	1500	29.418
4	8	500	0.669
5	8	1000	1.254
6	8	1500	1.838
7	12	500	0.132
8	12	1000	0.247
9	12	1500	0.363
10	18	500	0.026
11	18	1000	0.049
12	18	1500	0.071

Table 2:

IV. ANALYTICAL SOLUTION

The first step in our project was the analytical solution i.e. finding out the pressure drop with the help of standard formulae or equations. There are various standard formulae for pressure drop calculations but out of all these formulae Darcy -Weisbach equation is more commonly used, so according to that following procedure is followed to find pressure drop

A. 7.1 Assumptions:

1) Flow is steady
2) Fluid has an ideal behavior
3) Flow is irrotational
4) Flow is fully developed

1) Darcy-Weisbach Formula:

h= (f.L.v²)/2.g.D

Where,

h = head loss, (m)

g = acceleration due to gravity 9.81 (m/s²)

v = velocity of flow, (m/s)

D = Inside diameter, (m)

f = coefficient of Friction

L = length of the pipe, (m)

Here, to find head loss h we need to find friction factor f.

2) To find coefficient of friction(f):

The Reynolds number is given by Re = v.D / ν

Where,

Re= Reynolds Number.

ν= Kinematic viscosity, m²/s

v= flow velocity=Q/Am/s.

After finding Reynolds Number its value is used to decide type of flow as follows,

Type of Flow & Reynolds Number

Laminar Flow- Re < 2,000

Transition Flow Zone -2,000 ≤ Re ≤ 4,000 Turbulent Flow- Re > 4,000

For Laminar flow, friction factor f is given by,

f = 16 / Re

So now by knowing friction factor f we can find head loss h and then pressure drop.

3) Pressure Drop:

Pressure drop is calculated by following formula

Where,

= Density of fluid.

g = Gravity constant, 9.81 m/s² h = Head loss, m.

So, finally after following this procedure we get the pressure drop.

B. Sample Calculation:

For pipe having following specifications D = 4 mm, L = 500 mm

V = 15.923 m/s, ν = 6.8 *10-5 m2/s, Q = 12 lpm.

1) Reynolds Number

Re = v.D / ν

= 15.923*0.004/6.8*10-5 = 936.68

As Re < 2,000 flow is Laminar.

For Laminar flow, friction factor f is given by, f = 16 / Re

= 16/936.38

= 0.01708 2) Head Loss

h= (f.L.v²)/2.g.D

= 0.01708*0.5*15.9232/2*9.81*0.004 = 110.37 m

2) Pressure Drop

= 865*9.81*110.37

=936624.2 N/m2

= 9.3662 bar.

V. ANALYTICAL RESULT TABLE

Pipe Dia m	Pipe Length m	Flow Velocit y m/s	Reynolds Number	Coeff. Of Frictio n	Head Loss metr e	Press ure Drop Bar
0.018	0.5	0.78	208.15	0.076	0.26 9	0.022 8
0.018	1	0.78	208.15	0.076	0.53 8	0.045 6
0.018	1.5	0.78	208.15	0.076	0.80 7	0.068 5

1.20E-02	0.5	1.76	312.22	0.05	1.362	0.1156
1.20E-02	1	1.76	312.22	0.05	2.725	0.2312
1.20E-02	1.5	1.76	312.22	0.05	4.088	0.3468
8.00E-03	0.5	3.98	468.34	0.034	6.898	0.5853
8.00E-03	1	3.98	468.34	0.034	13.797	1.1707
8.00E-03	1.5	3.98	468.34	0.034	20.695	1.7561
0.004	0.5	15.92	936.68	0.017	110.377	9.3662
0.004	1	15.92	936.68	0.017	220.754	18.732
0.004	1.5	15.92	936.68	0.017	331.132	28.0987

Table 3:

A. *Comparison of Results*

Pipe Dia. Mm	Pipe Length mm	Analytic PressureDrop Bar	Press. Drop By CFD Bar	% diff. between analytic & CFD %
4	500	9.366	10.717	14.4
4	1000	18.732	20.044	7
4	1500	28.098	29.418	4.6
8	500	0.585	0.669	14.4
8	1000	1.170	1.254	7.1
8	1500	1.756	1.838	4.7
12	500	0.115	0.132	14.7
12	1000	0.231	0.247	6.8
12	1500	0.346	0.363	4.7
18	500	0.022	0.026	15.2
18	1000	0.045	0.049	7.4
18	1500	0.068	0.071	4.7

Table 4:

Also Graphs were plotted for pressure drop v/s Pipe Diameters for various pipe lengths.

1) For 500mm Long Pipes

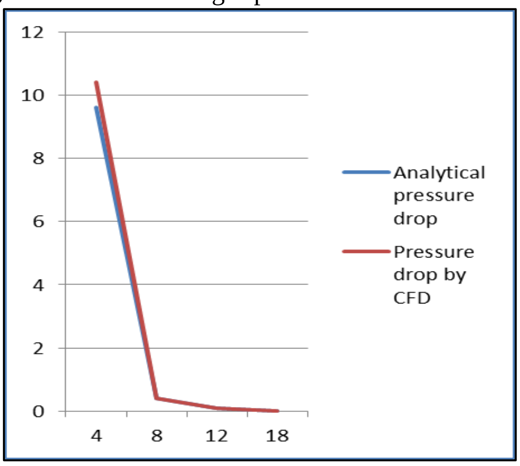

Fig. 3:

Graphs of Pressure drop v/s length of pipe for a given diameter were also plotted

2) For 4 Mm Diameter Pipe

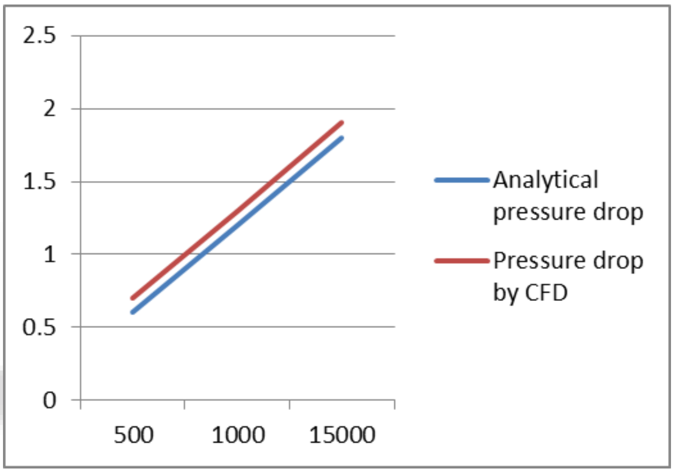

Fig. 4:

VI. CONCLUSION

This project's aim was to find out the exact requirement of pressure that must be supplied at the inlet to a particular application used in company.These obtained results were compared with results simulated using CFD analysis and the results which were the analytically determined

I have provided the industry with a standard database of pressure drops which will be occurring when the pipes are used. Using this reference the industry can optimize the power requirement at the input to minimize wastage.

Following are the conclusions drawn from the results

1) As diameter increases for a constant length pressure drop decreases
2) As pipe length increases for a constant diameter pressure drop increases

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