International Journal of Advance Research in Science and Engineering
Vol. No.5, Issue No. 12, December 2016
www.ijarse.com
IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

EFFECT OF COMBINATION OF Z TYPE ARRANGEMENTS ON PRESSURE DROP AND FLOW DISTRIBUTION

Manasi Herlekar[1], Harshal Khanapure[2] , Pavan Damkonde[3]

[1]*Assistant Professor, Department of Mechanical Engineering, G. S. Moze College of Engg., Pune (India)*
[2]*Assistant Professor, Department of Mechanical Engineering, G. S. Moze College of Engg., Pune (India)*
[3]*Assistant Professor, Department of Mechanical Engineering, JSPM RSCOE, Pune (India)*

ABSTRACT

Flow distribution from manifold to parallel channel found in various application such as fuel cell, irrigation system, municipal water distribution system, solar thermal collector, polymer processing. Uneven flow distribution causes reduction in thermal and fluid dynamic performance. The three ways to calculate pressure drop and flow distribution in system are analytical model, discrete model and CFD. In this paper pressure drop and flow distribution is calculated using analytical model with and without considering the manifold friction. The results are validated with computational fluid dynamics (CFD).

Keywords: Flow Distribution, Pressure Drop, Friction, Uniform Flow, Imbalance

I. INTRODUCTION

It is important to maintain equal flow in all paths of flow distribution system to maintain pressure in all system. There are four basics types of flow distribution systems namely, dividing, combining, reverse and parallel. The reverse and parallel flow systems are combinations of dividing and combining flow systems. In a dividing flow system, the main fluid stream is decelerated due to the loss of fluid through the lateral

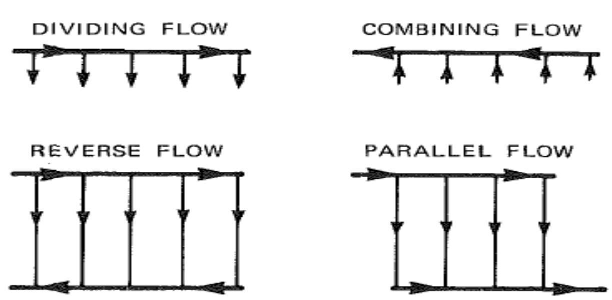


Figure 1: Four basic types of flow distribution systems

IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

tubes therefore; pressure will rise in the direction of flow if the friction effects are small where as in combining flow system, the main stream pressure will fall along the header. The performance of each system can be predicted by applying the continuity and momentum equation. The applications in which flow distribution systems plays major role are municipal water distribution systems, automobile engine, high technology devices such as microchannel heat sink and critical biological systems such as blood circulation in body.

Generally there are three approaches to predict flow distribution likely analytical, discrete and CFD. CFD is somewhat detailed approach. The pressure drop and flow distribution can be predicted using this approach without the knowledge of flow coefficients. In discrete model, the structure is represented as a network of multiple junctions traversed by the fluid flow then, mass and momentum conservation equations can be built at each junction. Finally, a set of difference equations is solved using an iteration program. Analytical model is also called the continuous model in which flow is considered to be continuously branched along intake and exhaust manifolds. A main advantage of analytical models over the CFD and the discrete models is that it is simple and flexible to designers.

A great number of literatures are available dealing with flow distribution systems. Bajura [1] developed first general theoretical model for flow single phase flow distribution. Primary emphasis was placed on configurations in which lateral tubes formed sharp edged junctions at right angles to manifold axis. Bajura and Jones [2] extended the previous model and predictions for flow rates and pressures in the headers for the dividing, combining, reverse and parallel manifold configurations. S. Mahaharudrayya, S. Jayanti, A. P. Deshpande [6] predicted the performance of parallel type arrangement by neglecting the momentum term. The analytical results are validated by comparing the results with those obtained from CFD analysis. M. K. Bassiouny, and H. Martin [3] calculated flow distribution and pressure drop in plate heat exchanger by neglecting the momentum term. The analysis shows that there is a general characteristic parameter (m) for all the plate heat exchangers, which determines the flow behavior. J. Wang [4] calculated pressure drop and flow distribution in parallel channel configuration for Z type arrangement. He solved the model without neglecting friction or momentum term. The equation obtained is inhomogeneous nonlinear differential equation.

II. PROBLEM DEFINITION

Consider a parallel channel configuration with inlet header (also called dividing header), outlet header (combining header) and number of parallel tubes of identical dimensions. The pressure in both the intake and exhaust manifold changes due to momentum change as a result of the flow branching in the tubes.

The objective of study is to predict, for given mass flow rate to inlet header, the flow rate through each of tube and the overall pressure drop between inlet and outlet. The mass and momentum equations given by J Wang are considered for prediction of pressure drop and flow distribution.

IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

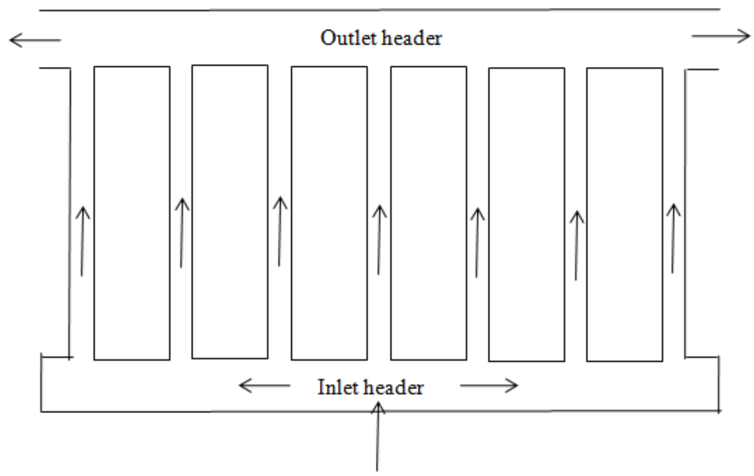


Figure 2: Schematic of combination of two Z type arrangements

2.1 Intake Manifold

Consider control volume in intake manifold. The mass and momentum equations can be written as follows.

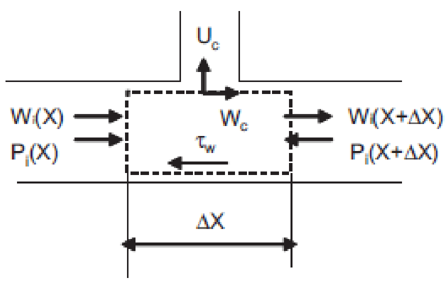


Figure 3: Control volume for intake manifold

Mass conservation

$$\rho F_e W_e = \rho F_e (W_e + \frac{dW_e}{dX} \Delta X) + \rho F_c U_c \qquad \text{.............(1)}$$

Where

$$\Delta X = \frac{L}{n} \qquad \text{...............(2)}$$

Channel velocity is given by

$$U_c = - \frac{F_e L}{F_c n} \frac{dW_e}{dX} \qquad \text{.............(3)}$$

Momentum conservation

$$P_i F_i - (P_i - \frac{dP_i}{dX} \Delta X) F_i - \tau_w \pi D_i \Delta X = \rho F_i (W_i + \frac{dW_i}{dX} \Delta X)^2 - \rho F_i W^2 + \rho F_c U_c W_c \qquad \text{.........(4)}$$

IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

After substituting Darcy-Weisbach formula, neglecting the higher orders of ΔZ and collecting the terms, one obtains,

$$\frac{1}{\rho}\frac{dP_i}{dX} + \frac{f_i}{2D_i} W_i^2 + 2\, W_i \frac{dW_i}{dX} + \frac{F_c n}{F\, L} U_c W_c = 0 \qquad \text{…………..(5)}$$

Wc, stands for the axial velocity component of the fluid in the dividing header, which will be branched off through the channels. It can be smaller or larger than W, depending on the dimensions of the header and the location of the channels.

$W_c = \beta_i W_i$

So above equation becomes,

$$\frac{1}{\rho}\frac{dP_i}{dX} + \frac{f_i}{2D_i} W_i^2 + (2 - \beta_i)\, W_i \frac{dW_i}{dX} = 0 \qquad \text{…………..(6)}$$

2.2 Exhaust Manifold

Similarly the mass and momentum equations are applied to control volume in exhaust manifold.

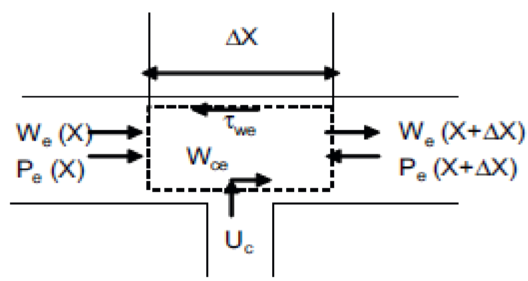


Figure 4: Control volume for exhaust manifold

Mass Conservation

$$\rho\, F_e W_e = \rho\, F_e \left(W_e + \frac{dW_e}{dX}\Delta X\right) + \rho\, F_c U_c \qquad \text{…………..(7)}$$

Channel velocity can be given as,

$$U_c = -\frac{F_e L}{F_c n}\frac{dW_e}{dX} \qquad \text{…………..(8)}$$

Inter-manifold continuity equation,

$$W_e = (W_0 - W_i)\frac{F}{F_e} \qquad \text{…………..(9)}$$

Momentum conservation,

$$P_e F_e - \left(P_e - \frac{dP_e}{dX}\Delta X\right) F_e + \tau_w \pi D_e \Delta X = \rho\, F_e \left(W_e + \frac{dW_e}{dX}\Delta X\right)^2 - \rho\, F_e W_e^2 + \rho\, F_c U_c W_c \qquad (10)$$

IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

After substituting Darcy-Weisbach formula, neglecting the higher orders of ΔZ and collecting the terms, one obtains

$$\frac{1}{\rho}\frac{dP_e}{dX}+\frac{f_e}{2D_e}W_e^2+2W_e\frac{dW_e}{dX}+\frac{F_c n}{F\,L}U_c W_c=0$$ ....(11)

Wc, stands for the axial velocity component of the fluid in the dividing header, which will be branched off through the channels. It can be smaller or larger than W, depending on the dimensions of the header and the location of the channels.

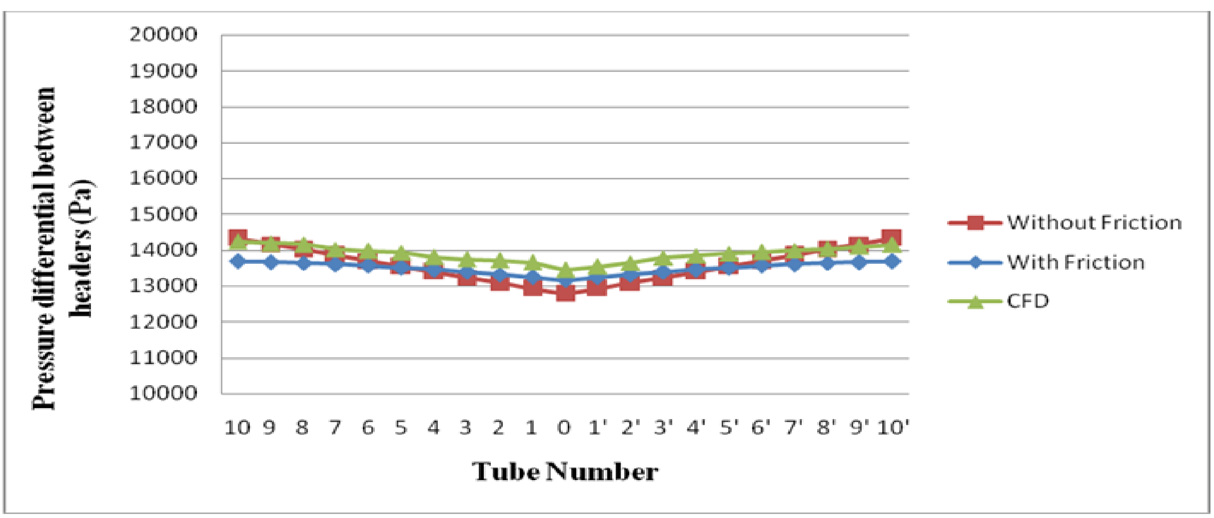
$W_{ce} = \beta_e W_e$

$$\frac{1}{\rho}\frac{dP_e}{dX}+\frac{f_e}{2D_e}W_e^2+(2-\beta_e)W_e\frac{dW_e}{dX}=0$$ ....(12)

By solving above equations (6) & (12) one can get flow distribution in the system. M. K. Bassiouny and H. Martin calculated the pressure drop and flow distribution in plate heat exchanger by neglecting the frictional term in above equation. Bassiouny et al. defined one general characteristic parameter (m) which determines the flow behavior. Junye Wang calculated pressure drop and flow distribution in parallel channel configurations of fuel cells by considering both momentum and frictional effect. The governing equation was formulated to second order inhomogeneous nonlinear ordinary differential equation. In the present paper, comparison is made neglecting and considering friction term. The CFD analysis is also done to validate the results obtained from analytical solution. Calculation are done for 21 tubes with OD of 63.5mm and SCH 40 thick and 9100 mm length, manifold of nominal diameter 350 mm and SCH 80 thick and 85mm pitch. A thermic fluid is allowed to flow in the system with the flow rate of 115 Kg/s and the results obtained are as follows.

III. RESULTS AND DISCUSSIONS

Pressure differential between headers v/s tube number



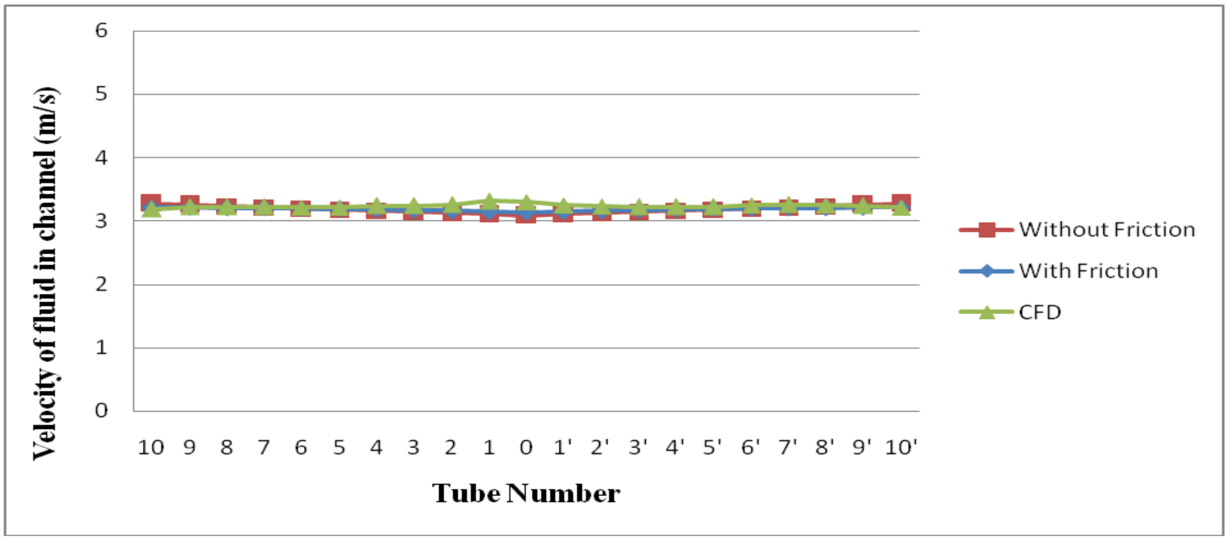
IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

Fluid enters from middle of inlet header with 10 tubes on each side. For solution the geometry is divided in two half sections and calculations are done for only one half section as the geometry is symmetric about the inlet section. The results obtained from CFD are also same as the analytical results. Hence one can solve the equations for only half section for symmetric geometries; it will give the correct results.

All the three results show same increasing trend

The results of analytical calculations with friction term, without friction term and CFD are plotted for comparison. The above plot shows the pressure differential between headers increases from first tube to last tube. This is because the pressure along the header increases from inlet to outlet because of momentum effect. The increasing trend of the pressure in inlet header also indicated that the momentum overcomes the friction effect. Also pressure in the exhaust header decreases along the flow direction. This is because the pressure differential between headers i.e. the pressure difference across the tube increases.

2. Velocity of fluid in tubes v/s tube number



It is found that velocity of fluid in tube increases from first tube to last tube. This because the pressure difference across the tube increases from first to last tube as shown in above plot. The results obtained by with friction term without friction term and CFD are nearly same.

3.1 Effect of Various Parameters On Flow Distribution

1. Area ratio

   It is the ratio of total lateral cross-sectional area to the total header area. A large area ratio contributes to the flow maldistribution. As the area ratio increases, value of dimensional number increases.

2. Lateral resistance

   Variation of branch tube resistance coefficient can be changed by changing length of branch tube. Longer branch tube cause increase in branch tube resistance. Pressure distribution in header tends to more uniform as a result of increase in system resistance.

IJARSE
ISSN (O) 2319 - 8354
ISSN (P) 2319 - 8346

3. Effect of pitch variation.

   Increase in pitch distance will increase share of friction resistance in the decrease of static pressure in the header along the flow direction. Discrete model reflects this trend. Continuous failed to explain.

4. Effect of increase of number of the tubes.

   Increase of number of tubes reduces flow rate in each tube which causes reduction in pressure drop of the system which increase non-uniformity of pressure distribution in header.

IV. CONCLUSION

In the present paper, the analytical model has solved in two ways. In first case, calculations are done considering only momentum term. The resulting equation obtained is in the form of ordinary differential equation and solved using boundary conditions. In second case, calculations are done considering both friction and momentum term. The equation obtained is inhomogeneous nonlinear ordinary differential equation. The comparison between two results is shown in above plot. It is found that the results obtained considering friction term are closer to the results obtained from CFD.

V. REFERENCES

1) Bajura R. A., "A model for flow distribution in manifolds" J. Eng Power Trans ASME 1971; 93:7-12.

2) Bajura R. A., Jones Jr EH. "Flow distribution in manifolds" J Fluids Eng, Trans ASME 1976; 98:654- 665.

3) Bassiouny MK, Martin H., "Flow distribution and pressure drop in plate heat exchanger. Part II. Z-type arrangement" Chem Eng Sci 1984;39(4):7001-704.

4) Juney Wang, "Pressure drop and flow distribution in parallel channel configurstions of fuel cells: Z – type arrangement" International Journal of Hydroenergy 35 (2010) 5498-5509.

5) Jafar M. Hussan, Wahid S. Mohammed, Thamer A. Mohammed, Wissam H. Alawee, "Review on single phase flow distribution in manifold" International Journal of Science and Research(IJSR) 2319-7064.

6) S. Maharudrayya, S. Jayanti, A. P. Deshpande, "Flow distribution and pressure drop in parallel channel configurations of planar fuel cells" Journal of Power Sources 144 (2005) 94-116.