ID: 6025

Numerical Evaluation of Flow Through a Microchannel with Sudden Contractions: Dynamic Aspects

Soufyane. Djellouli *[1], El Ghalia. Filali [1]
Laboratory LMESC, Faculty of Mechanical and Process Engineering, University of Science and Technology Houari Boumedienne, B.P. 32 El Alia, Algiers, Algeria
*djellouli.gm@gmail.com

ABSTRACT

The objective of the work presented is to characterize the dynamic aspect of a microchannel flow with a sudden contraction, for two aspect ratios σ (outlet cross-section/inlet cross-section) of 0.284 and 0.39 and hydraulic diameter of the outlet section is 0.08 mm and Reynolds number values varying from 100 to 1800. The results of this simulation showed the appearance of fluid flow contraction just after the sudden contraction. It can be seen that the dynamic flow parameters, namely, establishment length, reattachment length increase proportionally with Reynolds number and cross-section ratio σ. Our calculations are validated by comparison with experimental measurements and theoretical values, and by numerical correlations. A comparison of the results obtained with conventional theory showed a difference on the singular pressure drop coefficients, while our results are in good agreement with experimental results conducted in mini and microchannels, concerning the singular pressure drop coefficient. These results have been adopted by many researchers working in the field of mini and micro-fluidics. Based on our numerical simulation results, accuracy correlations have been established for Reynolds numbers ranging from 100 to 1800 for aspect ratios σ of 0.284 and 0.39.

Keywords: Fluid dynamics; Microchannel; Sudden contraction; singular pressure drop.

1. Introduction

the In recent years, there has been a rapid increase in the use of mini and micro-channels. Certain hydrodynamic processes appear to differ from those in conventional-sized channels. To identify the limits of validity of these models in microfluidics, several experimental and numerical studies have been conducted. The experimental study of pressure drops resulting from an abrupt contraction of the flow area in circular mini-channels has been conducted by Abdelall F.F et al [1], LI Zhuo et al [2], Chalfi T Y et al [3], Hang GUO et al [4], A. Kawahara et al [5] . However, several parameters differentiate these studies, including hydraulic diameter, cross-section type, fluid, boundary conditions, flow regime, and means of measurement. The authors observed differences compared to theoretical predictions The authors state that the theoretical model is inadequate for predicting pressure losses in a flow that undergoes a sudden constriction. The main objective of the thesis is to assess the validity of the classical correlations in the case of microchannels with abrupt shrinkage and to attempt to develop a physical model in the range of diameters studied.

2. Numerical resolution

The problem under study was resolved using the finite volume method in ANSYS CFX 19. The SIMPLE algorithm was employed to solve the coupling of velocity and pressure, and the equations for conservation of mass and momentum were discretized using second-order central differencing. A tetrahedral mesh was chosen due to its suitability for 3D cylindrical geometries. The node distribution was generated to ensure good refinement in areas close to the walls and singularity planes, where velocity and pressure gradients are significant.

DOI: 10.21467/abstracts.170 ISBN: 978-81-970666-1-0 (eBook)

3. Results and Discussion

The numerical simulation results for flow through a microchannel with abrupt contraction are similar to the experimental results and close to those predicted by numerical work on flow in conventional-sized pipes. However, the singular pressure drop coefficient is higher than the commonly accepted laws for conventional size pipes. It is worth noting that several authors have reported these results, including Abdelall F.F et al [1], LI Zhuo et al [2], and Hang GUO et al [4].

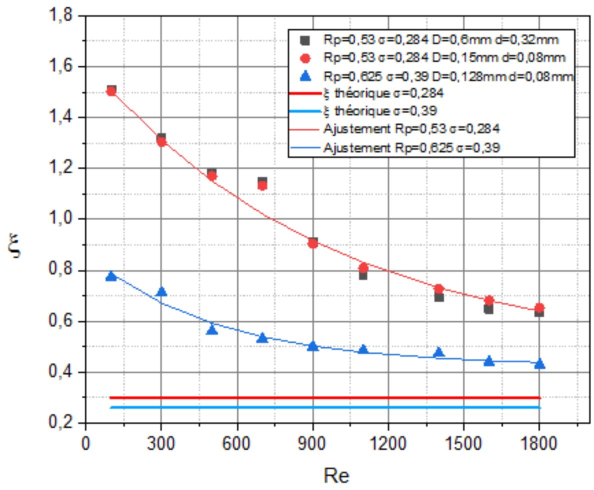

Figure 1: Variation of singular pressure drop coefficient as a function of Reynolds number.

4. Conclusions

The results obtained from the conventional theory indicate a difference in the singular pressure drop coefficients. Additionally, our findings are consistent with experimental results obtained in mini and microchannels in terms of reattachment length and friction coefficient. These findings have been confirmed by many researchers working in the field of mini and microfluidics across the studied Reynolds numbers. Our numerical simulation results have established fit correlations for Reynolds numbers ranging from 100 to 1800 for aspect ratios σ of 0.284 and 0.39. In conclusion, we have shown that the classical laws of hydrodynamics can be applied to micrometer scales, at least up to the values studied in the case of a laminar regime.

References

[1] Abdelall, F.F.; Hahn, G.; Ghiaasiaan, S.M.; Abdel-Khalik, S.I.; Jeter, S.S.; Yoda, M.; Sadowski, D.L, Pressure drop caused by abrupt flow area changes in small channels, Experimental Thermal and Fluid Science, 2005, Vol. 29, p 425–434.

[2] LI Zhuo, J. YU & C. MA ChongFang (2008) Characteristics of pressure drop for single-phase and two-phase flow acrosssudden contraction in microtubes, Science in China Series E: Technological Sciences, Vol. 51- 2, p 162-169

[3] Chalfi, T.Y.; Ghiaasiaan, S.M, Pressure drop caused by flow area changes in capillaries under low flow conditions, International Journal of Multiphase Flow, 2008, Vol. 34, p 2–12.

[4] Hang GUO, Ling WANG, Jian YU, Fang YE, Chongfang MA, Zhuo LI "Local resistance of fluid flow across sudden contraction in small channels" Front. Energy Power Eng. China, 4(2), p 149-154,(2010).

[5] A. Kawahara, M. H. Mansour, M. Sadatomi, W. Z. Law, H. Kurihara, H.Kusumaningsih (2016),Characteristics of gas–liquidtwo-phase flowsthrough a sudden contraction in rectangular microchannels. Experimental Thermal and Fluid Science, Vol. 66, p 243– 253.

ISBN: 978-81-970666-1-0

Series: AIJR Abstracts
DOI: 10.21467/abstracts.170