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MODELING OF FLOW THROUGH SUDDEN CONTRACTION IN A CRUDE OIL PIPE LINE USING FINITE ELEMENT METHODS

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Abstract

In this work, the effect of sudden contraction in a pipe line has been investigated using finite element methods and the obtained results have been compared to literature. The results show that the length of upstream flow separation in contraction plane increases with Reynolds number of 10^4. But the length of upstream flow separation decreases for greater Reynolds number. The flow separation exists for all of Reynolds number. By increasing the Reynolds number, the length of upstream flow decreases. The flow separation is not exist in downstream at Reynolds number less than 300. The results show that by increasing X/D ,the dimensionless velocity increases in pipe center. Further grid refinement did not cause significant changes in the predictions and therefore these results can be considered to be grid independent.

Keywords: Reynolds number; modeling; finite elements method; pipe contraction.

1. Introduction

When a flow passes through a sudden contraction, the flow direction changes abruptly and a recirculating bubble is observed past the contraction. Analysis of flows in pipes with sudden contraction has been subject of numerous publications. The numerical solution of incompressible laminar flows through a channel with 3:1 sudden expansion for power-law fluids was studied by Manica [1]. The influence of a porous insert in an incompressible turbulent in a pipe was studied by Orselli [2]. A modified homogeneous model was proposed by taking account the influences of Bond number, Weber number, Froude number, liquid Reynolds number, and gas quality and area ratio into the original homogeneous model by Wang [3]. For laminar flow regions, Durst *et al.* [4] carried out a comprehensive study for the Reynolds number range (based on the upstream pipe diameter) of 23 to 1213 for an area ratio of 0.285 using Dual Beam LDA system operating in the forward scatter mode with signal processing by a frequency tracker or transient recorder. Bullen *et al.* [5] proposed a detailed experimental setup to investigate turbulent flow field through a sudden pipe contraction. Pipe contraction flow field measurements for the turbulent flow regime have been reported by Khezzar *et al.* [6], who measured mean axial and radial velocities for a Reynolds number (based on upstream pipe diameter). An experimental study of turbulent water flow through abrupt contractions which resembles the present very much geometry was performed by Bullen *et al.* [5]**.** They carried out detailed experiment to determine the flow field. Wall static pressure measurements enabled the calculations of pressure loss coefficient for a range of contraction area from 0.13 to 0.69 over a Reynolds number variation from 4×10^4-2×10^5. Fossa and Gugliemini [7] experimentally investigated the void fraction in horizontal pipe with sudden contraction area. The experiments were aimed at analyzing the effect of the singularity characteristics on void fraction profiles and phase distribution. The experimental determination of contraction pressure loss coefficients in the turbulent flow regime were reported by Bendict *et al.* [8] and Gerami-Tajabadi [9]. Some measurements in the transition region up to

Reynolds number of 7×10^3 for one area ratio of 0.28 was reported by Kays [10]. Measurement of loss coefficients were given by Astarita and Grego [11] for a range of Reynolds number between 20 and 2×10^3 for one area ratio of 0.16. In all cases except Gerami-Tejabadi, the contraction was defined as sharp but had not been quantified in geometrical terms. Greami-Tejabadi [9] reported results for five different area ratios for a Reynolds number range of 5.0×10^4 to 2.3×10^4. Shih [12] proposed a new k-s eddy viscosity model that can be used for the accurate predictions of flows of high curvature such as the flow in pipe contraction.

2. Theoretical section

In this model two steps are considered for flow through a sudden pipe Contraction. The first step is taken as the geometry. The geometry was modeled with a two dimensional axisy metric grid of 100×60. The velocity profile for fully developed laminar flow was imposed at the inlet and the no- slip condition was applied at wall boundaries. The derivatives in the axial direction were set to zero. The CFD calculation was carried out using the SIMPLER algorithm and the hybrid differencing scheme. The partial differential equations were solved in MATLAB software to determine the velocity profiles. Numerical simulation runs were conducted to using finite element methods (FEM).

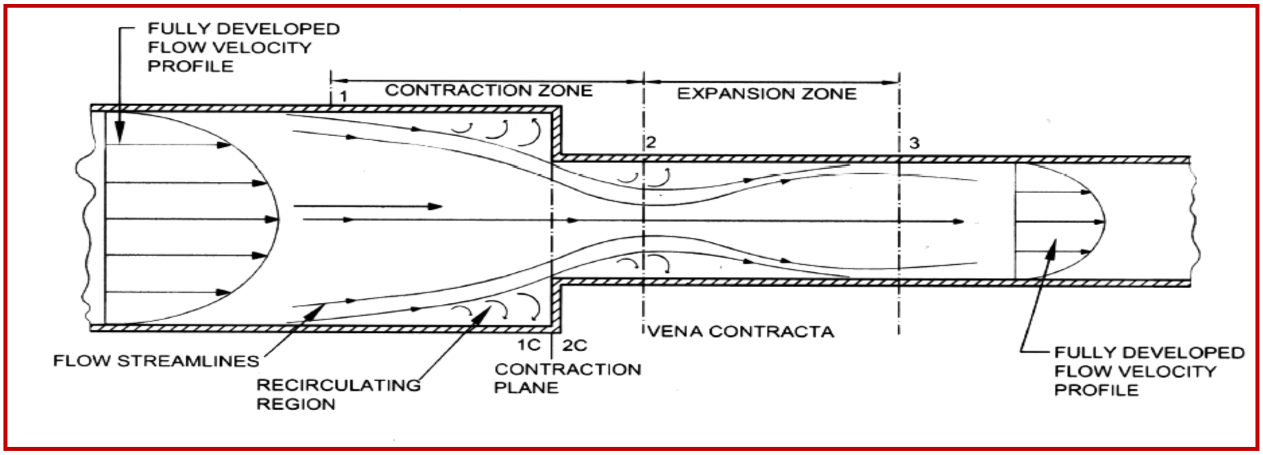

Figure 1. The flow through a sudden pipe contraction

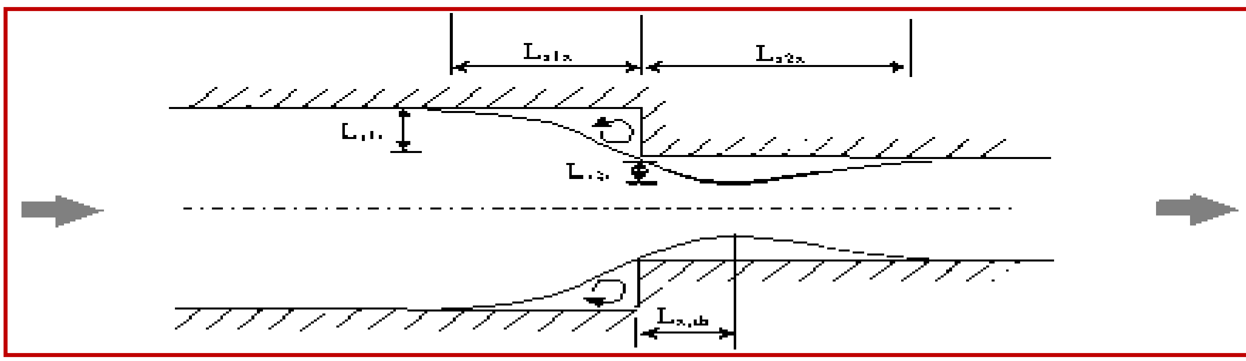

Figure 2. The upstream and downstream separations in the vicinity of the contraction

3. Results and Discussion

Since the flow is laminar, the governing equations are exact. To validate the model for calculating velocity profiles, numerical simulation runs were conducted for six oil flooding experiments performed in this work and six oil different cross- sections of the domain, three before, and three after, the contraction given in literature. The velocity profiles are shown in Figure 3. The experimental data of Durst [4] are also included for comparison. It can be found that the model predicts accurately the experimental data of Durst [4]. Further grid refinement did not cause significant changes in the predictions and therefore these results can be considered to be grid independent.

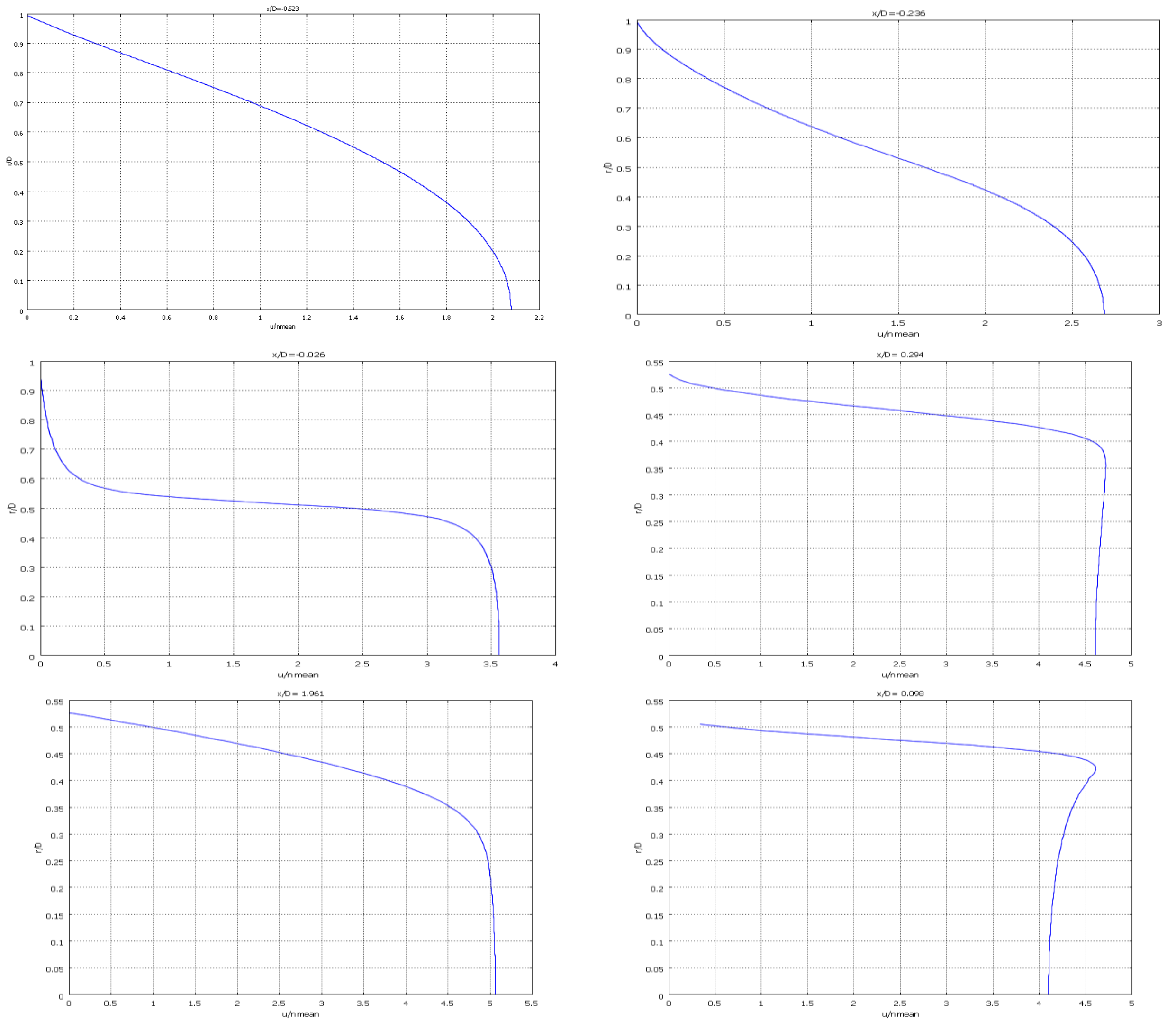

Figure 3.The velocity profiles for different cross section of the domain

Also, the predictions and experimental results have been compared in Figures 4 to 6 for different Reynolds numbers. It should be noted that comparisons for other Reynolds numbers also agree well with the experimental data [4]. The results show that the length of upstream flow separation in contraction plane increases with Reynolds number of 10^4. But the length of upstream flow separation decreases for greater Reynolds number. The flow separation exists for all of Reynolds number. By increasing the Reynolds number, the length of upstream flow decreases. The flow separation is not exist in downstream at Reynolds number less than 300. The flow separation increases by increasing Reynolds number. The results show that the model can predict more accurately the linear velocity in Reynolds number less than 300. But devation from the experimental data increases in more than Reynolds number. The results show that by increasing X/D ,the dimensionless velocity increases in pipe center.It should be noted that velocity profile has negative slop in X/D near to zero.But the velocity profile has positive slop in more Reynolds number .Also, the results show that the fully developed velocity profile is not affected by the contraction at one or two of upstream pipe line diameter. It was found that the effect of contraction of pipe is started near to contraction plane so that the flow has negative acceleration near wall and has positive acceleration in pipe center.

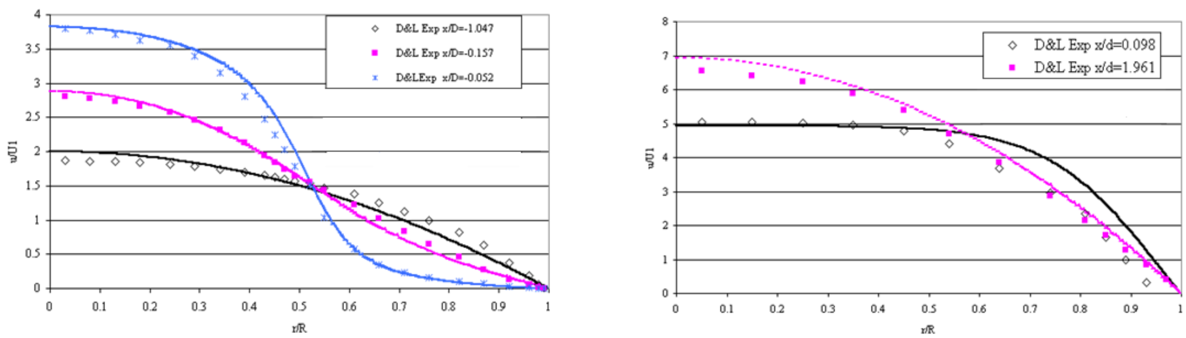

Figure 4. Comparison of predictions and experimental results at Re=23

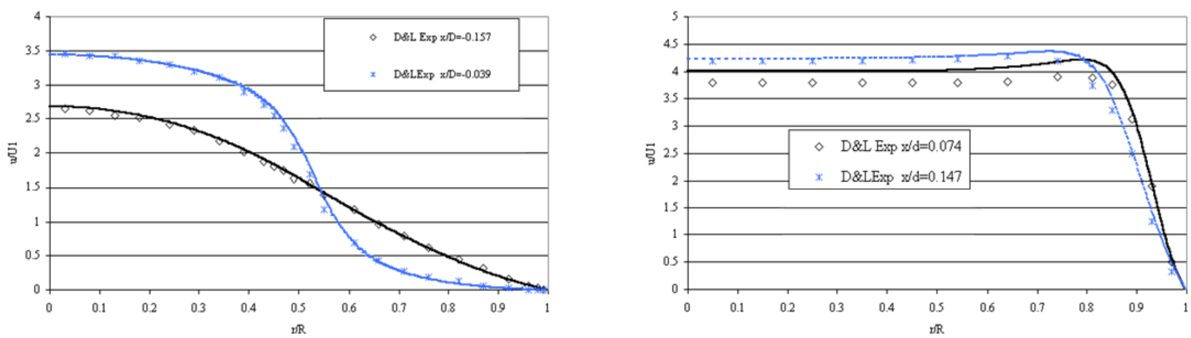

Figure 5 Comparison of predictions and experimental results at Re=196

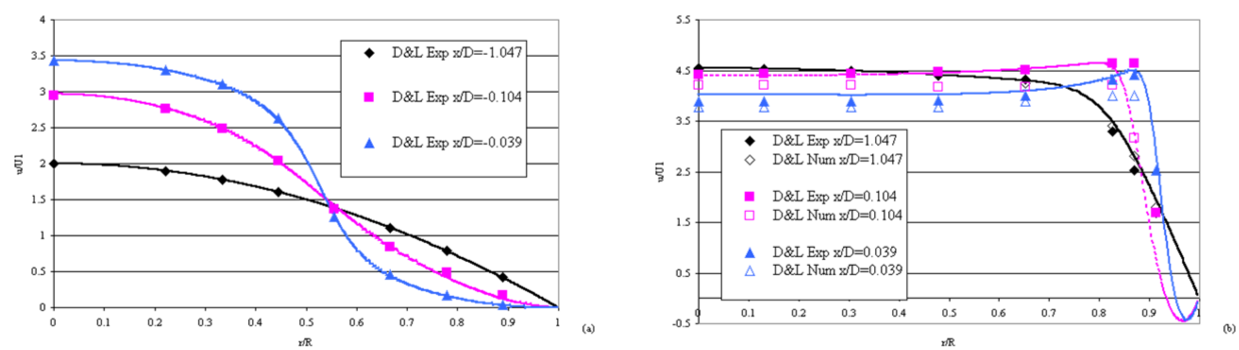

Figure 6 Comparison of predictions and experimental results at Re=1213

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