Annals of DAAAM for 2010 & Proceedings of the 21st International DAAAM Symposium, Volume 21, No. 1, ISSN 1726-9679
ISBN 978-3-901509-73-5, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2010
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Annals of DAAAM International

NUMERICAL STUDY OF THE HYDRAULIC LOSSES IN A PIPE ENLARGEMENT

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Abstract: *This paper presents the results of the 2D numerical simulation of the turbulent flow in a pipe enlargement, using commercial code FLUENT 6.3. At first the geometry of the pipe enlargement will be defined, after that the equations that govern the flow and the boundary conditions imposed on the computational domain will be described. The hydraulic losses were calculated for two different liquids and for five different flow rates and the results were compared. The structure of the flow is presented for the maximum flow rate for both liquids and the causes of the hydraulic losses are underlined.*
Key words: *hydraulic losses, numerical simulation*

1. INTRODUCTION

In this paper we analyze the flow through a pipe enlargement for two different types of liquids: water and oil, table 1.

A sudden pipe enlargement assures the connection between two pipes with different diameters, leading to local energy dissipation and an increase of the turbulent flow. The energy dissipation which appears in a sudden pipe enlargement is called hydraulic losses through shock. In the section after a sudden enlargement appears a jet structure, which is separated to the rest of the fluid trough a surface of separation, which it is decomposing and forms strong vortices. The hydraulic losses through shock are caused by the appearance of that strong vortices, (Idelcik, 1984).

For our numerical study of the flow we used the professional software FLUENT 6.3 and we investigated five different operating points characterised by different flow rates.

The aim of this paper is to put into evidence the causes of the hydraulic losses through shock and to make a comparison between the values of the hydraulic losses for the two types of liquids. Also we want to underline the presence of the jet structure in the section with larger diameter.

Fluid	Density ρ [kg/m^3]	Dynamic viscosity μ [kg/m*s]
water	1000	0.001
oil	952	0.1428

Tab. 1. Properties of the investigated liquids

2. COMPUTATIONAL DOMAIN, FLOW EQUATIONS AND BOUNDARY CONDITIONS

The computational domain, Figure 1, was generated using the pre-processor GAMBIT from FLUENT. The geometrical characteristic of the pipe enlargement are given in table 2.

d [mm]	L1 [mm]	L2 [mm]
100	180	200

Tab. 2. Geometrical characteristics of the pipe enlargement

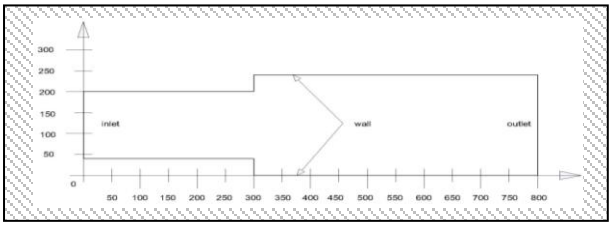

Fig. 1. Computational domain for the pipe enlargement

The generated mesh for the computational domain is structured and has 214,168 cells, (Thomson et al., 1997).

A steady 2D turbulent flow is computed in the computational domain using the continuity equation and the Navier-Stokes equation:

$$\nabla \cdot \vec{v} = 0 \quad (1)$$

$$\rho \frac{\partial \vec{v}}{\partial t} = \rho g - \nabla p + \mu \Delta \vec{v} \quad (2)$$

The numerical solution of flow equations (1) and (2) is obtained with the expert code FLUENT 6.3, using a Reynolds-averaged Navier-Stokes (RANS) solver.

The flow is calculated using the standard *k-ε* model of turbulence. The standard *k-ε* model is a two-equation model in which the solution of two separate transport equations allows the turbulent velocity and length scales to be independently determined, (Fluent, 2001).

We imposed on the inlet section of the domain a constant velocity, corresponding to the prescribed flow rates, together with the turbulence parameters.

On the outlet section of the computational domain a constant pressure equal with atmospheric pressure is imposed. For the remaining solid walls of the domain we imposed the no-slip boundary condition.

3. NUMERICAL RESULTS

The hydraulic losses were calculated using the following equation, (Anton et al., 2003):

$$h_p = \frac{p_{IN} - p_{OUT}}{\rho g} \quad (3)$$

The results obtained for the two liquids and for the 5 investigated operation points are presented in table 3 and 4.

Q [m^3/s]	p_{IN} [Pa]	p_{OUT} [Pa]	h_p [-]
0.01	80.25	64.9	0.001
0.02	317.04	257.8	0.006
0.04	1238.18	1007.29	0.023
0.1	7683.98	6278.52	0.143
0.2	30572.97	25038.53	0.564

Tab. 3. Calculated hydraulic losses for water

Q [m³/s]	p_{IN} [Pa]	p_{OUT} [Pa]	h_p [-]
0.01	132.73	74.91	0.006
0.02	462.84	285.8	0.019
0.04	1666.79	1104.17	0.06
0.1	9354.9	6690.18	0.285
0.2	34830.05	26046.39	0.94

Tab. 4. Calculated hydraulic losses for oil

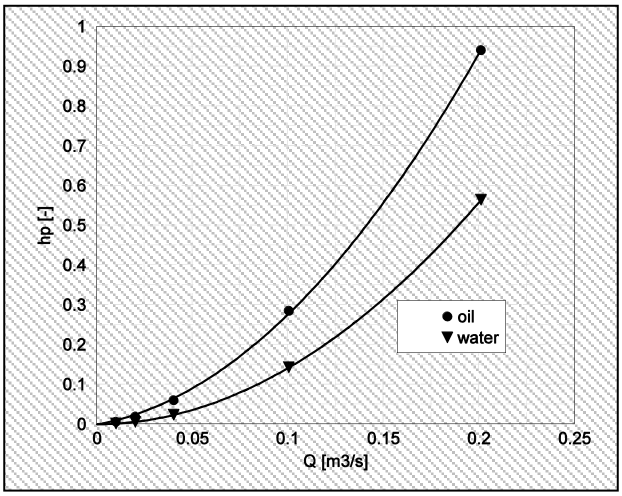

Fig. 2. Hydraulic losses through shock for the two liquids

From figure 2 one can observe that the hydraulic losses through shock for the sudden pipe enlargement are much larger for the case when oil is flowing than for the case and water is flowing. The explanation of this fact is that the viscosity of the oil is bigger than the viscosity of the water, and the viscosity has a major impact on the value of the hydraulic losses. An important impact on the magnitude of hydraulic losses has also the velocity. From figure 2 it results that for higher flow rates, that means higher velocities, the differences between the hydraulic losses for the two types of fluids are much larger than for the lower values of the flow rate.

Figures 3 and 4 put into evidence the presence of the central jet which is separated to the rest of the flow field, (Srikanth & Rathakrishnan, 1990). From the streamlines distribution presented in the figures 3 an 4 can be observed that in the corners of the domains, near the sudden enlargement of the pipe, two strong vortices are formed there and these vortices play an important role on the appearance of the hydraulic losses through shock.

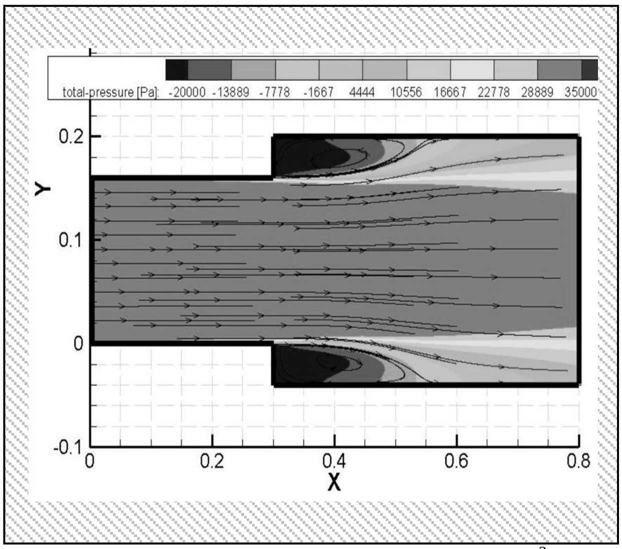

Fig. 3. Structure of the flow field for water for Q=0.2 m^3/s

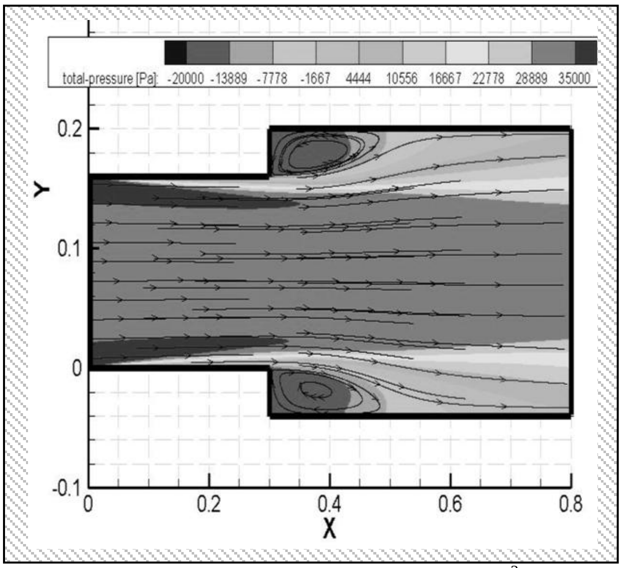

Fig. 4. Structure of the flow field for oil for Q=0.2 m^3/s

It can be observed that the diameter of the central jet is smaller for the oil, the liquid with higher viscosity. Also the diameter of the vortices which appear in the corners of the domains is larger for oil and that is one of the reasons why the hydraulic losses through shock are bigger for the oil than for the water.

4. CONCLUSIONS

This paper presents a complete methodology for the numerical investigation of the flow in a sudden pipe enlargement. The structure of the flow field is investigated for two different liquids. From the analysis of the two flow fields it results the mechanism that leads to the appearance of the hydraulic losses through shock.

From the comparison of the calculated values of the hydraulic losses it results that for the more viscous liquid, oil, the hydraulic losses are larger than for the less viscous liquid, water. This is leading to the conclusion that viscosity of the liquid has a major impact on the value of hydraulic losses through shock.

The approach used in this paper for the numerical analysis of the flow will be expanded to include other basic fluid mechanics problems as well as more complex phenomena concerning the turbomachinery hydrodynamics.

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