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[1.] Roman KIŠ, [2.] Martina JANOVCOVÁ, [3.] Milan MALCHO

THE EFFECT OF THE PIPELINE BENDING ON THE SHAPE OF THE NATURAL GAS STREAM FIELD BEFORE THE INLET TO THE ORIFICE PLATE IN THE HIGH-PRESSURE PIPELINES

[1-3.] Department of Power Engineering, University of Žilina, SLOVAKIA

Abstract: *Worldwide raising requirements for the heat and the energy have huge influence on decreasing amounts of the mineral resources and to increasing tendency of their prices. It is necessary to deal with them responsibly. One of these cases is using natural gas as an energy and heat source. Nowadays billions of normalized cubic meters of natural gas are transferred and used every day around the world. The most common flow measurement type, used in high-pressure pipelines, is measuring by pressure differential, which mainly uses orifice plates inserted in the pipelines. In this type of measurement it is very important to have a steady flow to avoid inaccuracies in the measurement. It could be difficult in the case of the measuring of the volumetric flow in the measuring stations, where one transit pipeline is dividing into the more pipelines of smaller diameters with lots of bendings in a small area. These bendings should have the impact on the stream field of the natural gas before the inlet to the orifice plate that could affect flowing of the gas behind the orifice plate and differential pressure measured on the orifice plate. The aim of this article is to show the magnitude of the impact of different pipeline bendings on the shape of the stream field in the high-pressure pipelines.*
Keywords: *orifice plate, high-pressure pipeline, natural gas, stream field, velocity profile*

INTRODUCTION

Natural gas flowing through the transit gas lines consists of seven major gases like methane, ethane, propane, butane, pentane, nitrogen and carbon dioxide. Majority of the volumetric percentage has methane with its 98.39 % Table 1.

Table 1. Composition of the natural gas in the volumetric percentage

gas	CH_4	C_2H_6	C_3H_8	C_4H_{10}	C_5H_{12}	N_2	CO_2
[vol %]	98.39	0.44	0.16	0.07	0.03	0.84	0.07

For this reason the paper will assume, that the natural gas used in the analysis will have physical and chemical properties like pure methane due to their nearly identical chemical compositions. In the simulations it will behave as an ideal gas.

MODEL PREPARATION

The whole analysis is calculated in the ANSYS Workbench. The model consists of three parts, two straight pipes and one 90° elbow in the middle of them (Figure 1). In the outlet of the longer straight pipe, there is a space for connection of the orifice plate for the measuring of the volumetric flow.

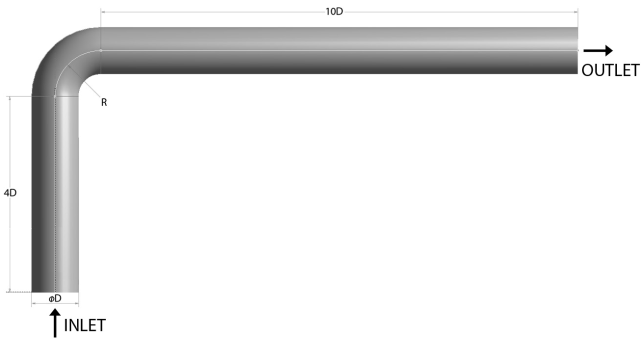

Figure 1. Geometry of the model

Four models with different dimensions were created. Diameter of the pipe was identical in the all cases D=730 mm. Inlet straight part lenght was set to four times diameter of the pipe, that is D=2920 mm. Outlet straight part lenght was set to 10D, that is D=7300 mm, as it is given in the standard ISO 5167-2:2003. The radius R of the *elbows were 700 mm, 600 mm, 500 mm and 400 mm.*

Mesh

The mesh of the body consists of 232566 tetrahedral cells and it has 96067 nodes. To gain better and more realistic behaviour of the gas flow near the walls was set an inflation. The inflation has 15 layers with the growth rate of 1.5 and it is bounded by the outer walls of all three parts of the model (Figure 2).

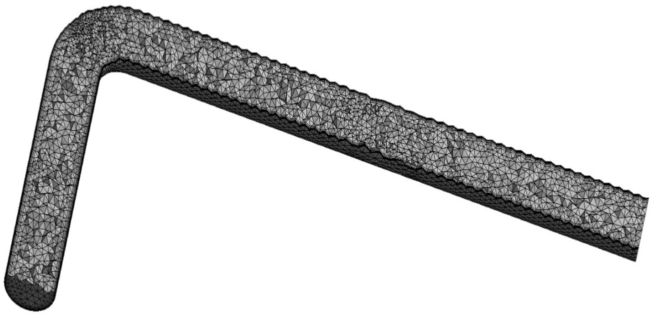

Figure 2. Meshing of the model

Boundary conditions and model solver

Behaviour of the model was set for the high-pressure pipeline with flowing methane as the fluid part. In the pipe methane behaves as the ideal gas. All boundary conditions in the inlet to the pipe are in the Table 2. Equivalent roughness of the surfaces of the pipes was set to Δ=0.1 mm. Boundary condition for the inlet was set to mass flow rate and for the outlet was set pressure outlet.

Table 2. Boundary conditions in the inlet to the pipe

Pressure	Temperature	Density	Mass flow rate
p [Pa]	T [K]	ρ [$kg.m^{-3}$]	m [$kg.s^{-1}$]
5.10^6	288.0	33.5	80.0

Density based model solver was selected due to the compressibility of the natural gas and because of the high Reynolds numbers and necessity of modelling flow near the wall was k-ω SST viscous model chosen.

ANALYSIS OF THE STREAM FIELD

The value of the bending radius has huge impact on the velocity profile as it is visible in the Figure 3. In all the models is maximum velocity value around the inner wall of the bending, where reaches up to 10.6 $m.s^{-1}$. Then the flow with the highest velocity continues flowing to the upper wall of the straight pipe part and in the lower wall appears flow with low velocity close to the zero value. The unstable flow behind the elbow has raising tendency with the decreasing radius value.

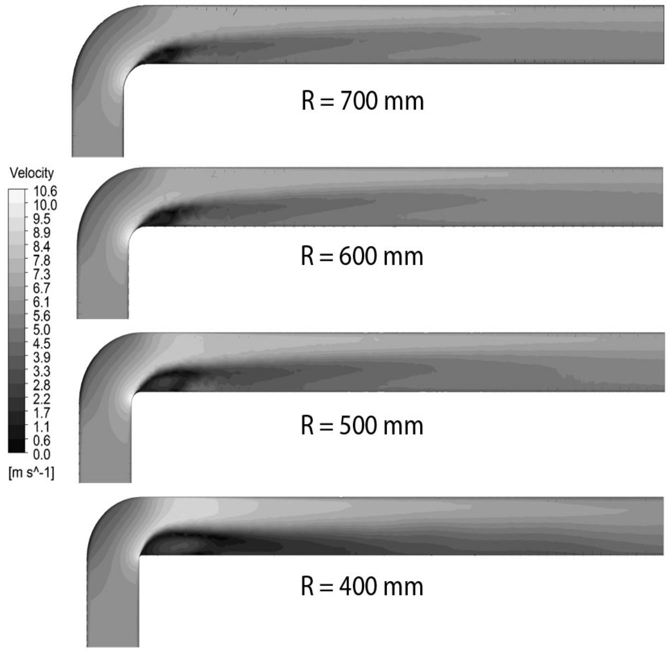

Figure 3. Velocity profiles in the sections through the models

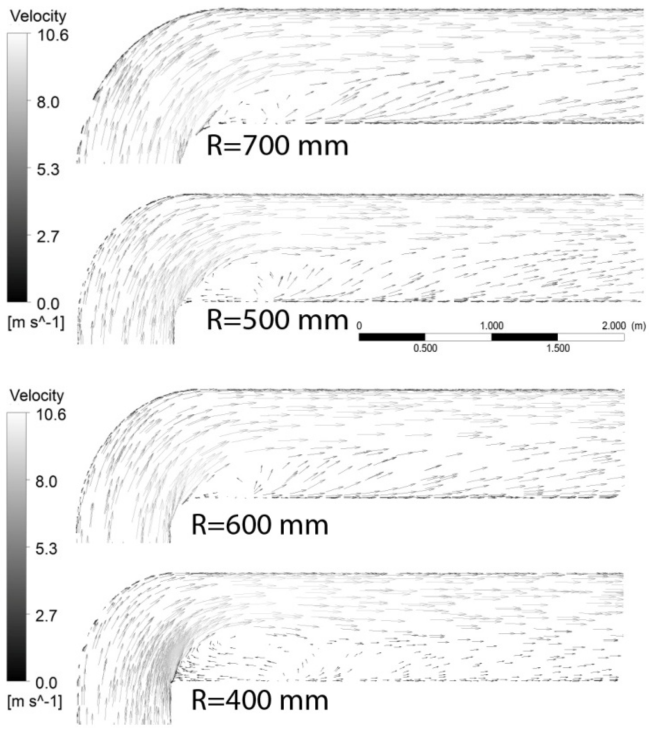

Figure 4 . Velocity vectors in the sections around the bending

With decreasing of the bending radius reverse flow near the lower wall becomes stronger and more visible (Figure 4). The stream field near the lower wall is more affected by the reverse flow and it takes longer distance to get stabilized with the *upper stream which is less affected by the bending radius.*

The standard ISO 5167-2:2003 mentions rules how to correctly measure by the orifice plates. For orifice plates with D and D/2 tappings , the spacing of the upstream pressure tapping is nominally equal to D. Velocity profiles in the distance of 1D from the outlet are shown in the Figure 5. The sections with the lower radius didn't reach the maximum velocity and their velocity profiles are more divided and influenced by the unstabilized flowing near the lower wall.

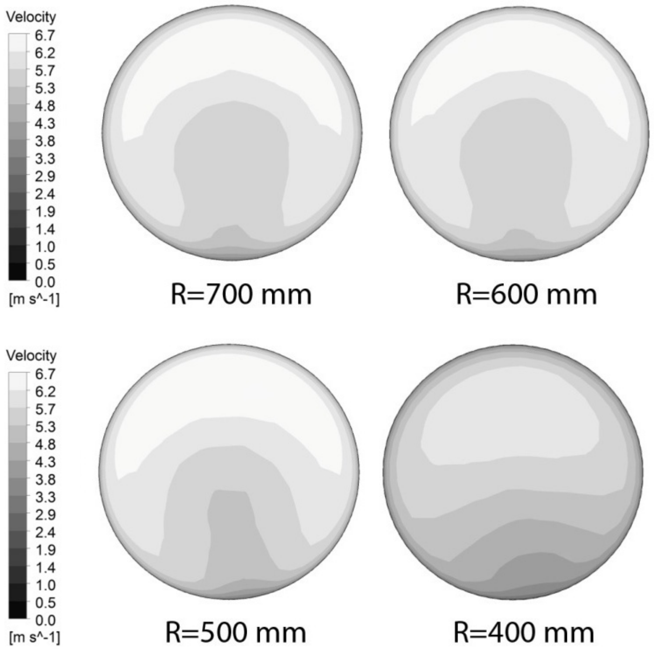

Figure 5. Velocity profiles in the sections in the distance of 1D from the outlet

CONCLUSION

The value of the radius has a big impact on the stream field in the high-pressure pipeline. The accuracy of the measurement could be affected if the flow has not had enough length to get stabilized all around the pipe. This knowledge could have a great importance in the measuring stations, where the natural gas is distributed in the pipeline system with lots of elbows and bendings in the small area. The final flow which is entering orifice plate can not be stabilized enough in the distance of ten times diameter of the pipe (lenght = 10D) as it is predicted in the standard ISO 5167-2:2003. Analyzing of the pressure fields in the pipeline system affected by the unstable velocity flow all around the pipe will be the next aim of the research.

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