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Steady-state transmission pipeline models with diffusers and reducers

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Abstract

Pipeline diagnostics is crucial for assuring safe and efficient operation of transmission pipelines. Usually, such systems are model-based and the results of leak detection, isolation and identification are strongly dependent on the quality of the model used. On the other hand, real pipelines are often built as complex and nonhomogenous systems, where diffusers, reducers and T-junctions are used to couple pipes of different geometries.

In this work the issue of modeling couplers such as diffusers and reducers are addressed using the steady-state model of the pipeline flow.

Modeling approach

To model the behavior of reducers and diffusers it is assumed that each of them consists of a finite number of short pipelines of different diameters that are coupled together. It is also assumed, that for each segment the regular pipeline equations hold. It is a simplification (especially that the model was designed for long pipelines) and its effect will be investigated as a part of future research. The pictorial representation of diffuser and reducer used for modeling can be seen below along with the steady-state equations used.

Steady-state model

$$q|q| = \frac{DS^2}{\lambda\nu^2}\frac{p_i^2 - p_o^2}{L}$$

$$p = \sqrt{p_i^2 - \frac{p_i^2 - p_o^2}{L}z}$$

Pipe design and junctions discretization

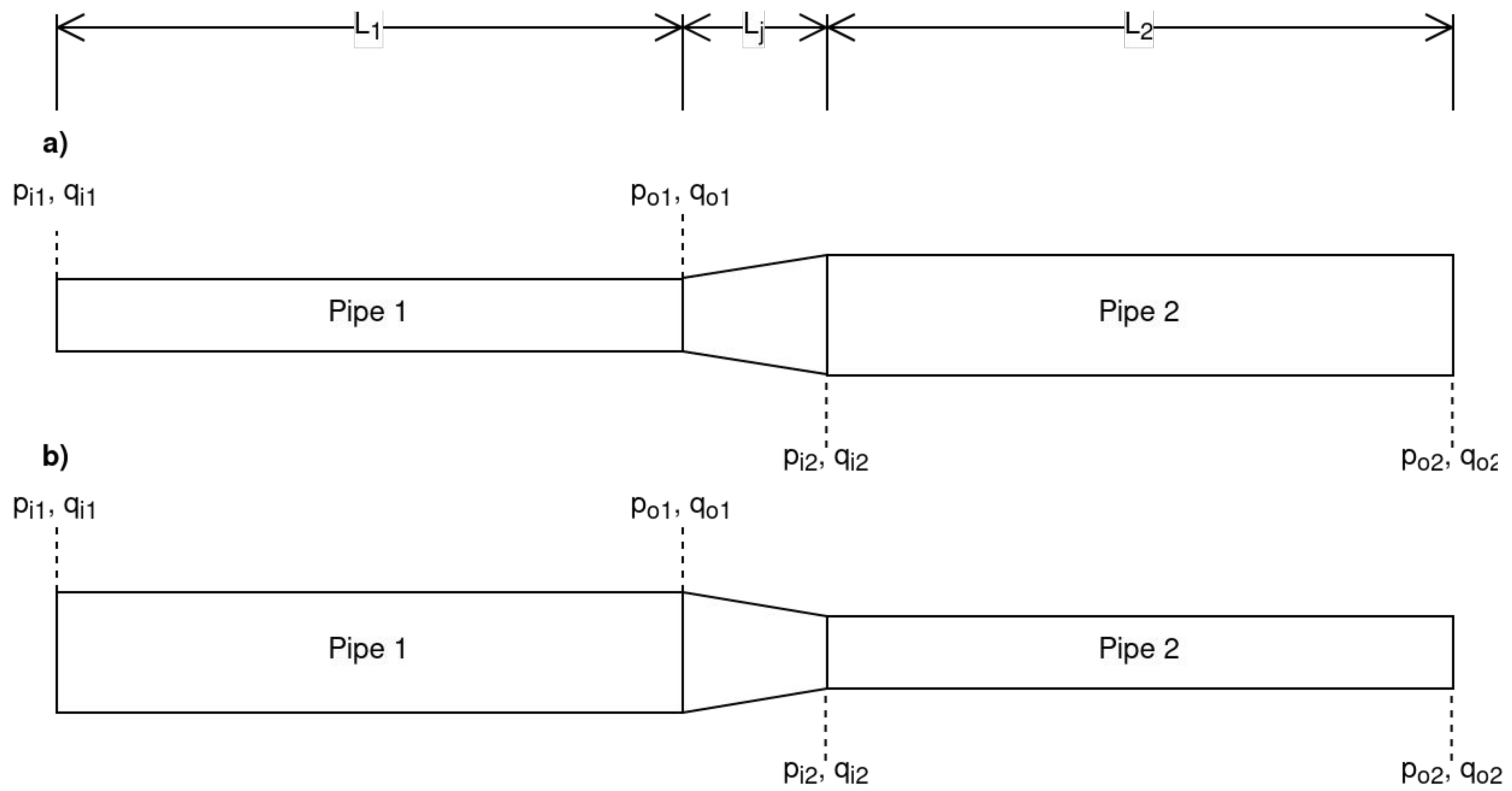

Fig. 1 Design of a pipeline with a) diffuser and b) reducer

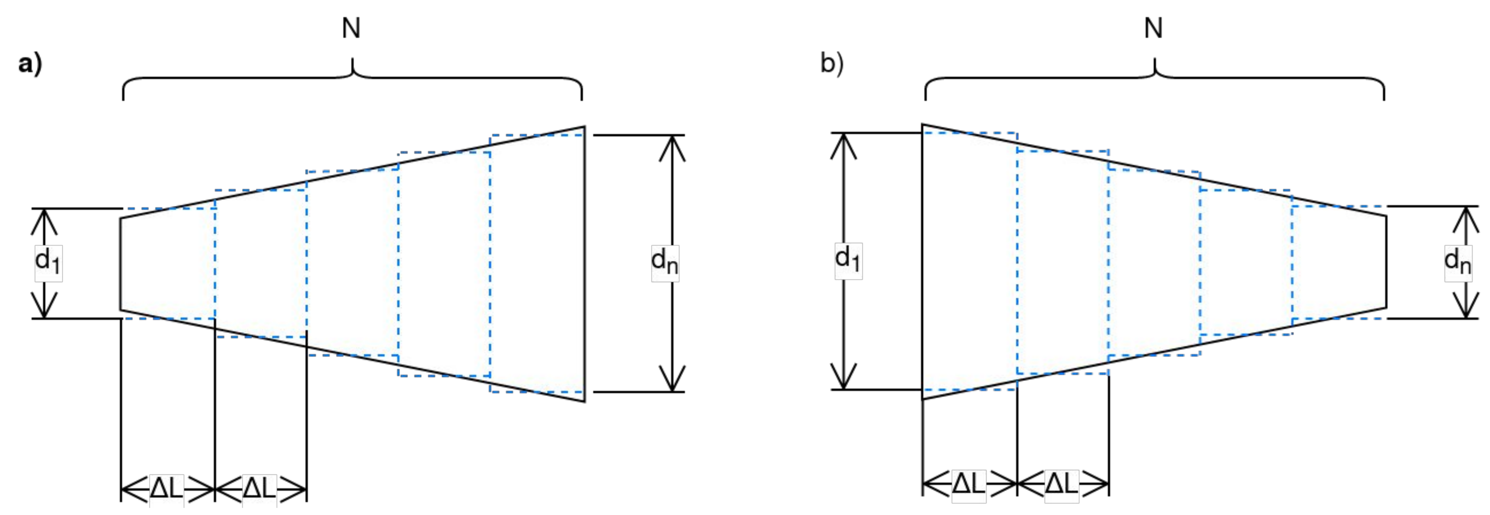

Fig. 2 Discretization method applied to a) a diffuser and b) reducer

Junction models

$$p_J(z)^2 = p_{iJ}^2 - \frac{4L_j\lambda\nu^2q^2}{\pi^2}\left(\frac{1}{(D_2D_1^4 - D_1^5)} - \frac{1}{(D_2 - D_1)\left(\frac{(D_2-D_1)}{L_J}z + D_1\right)^4}\right)$$

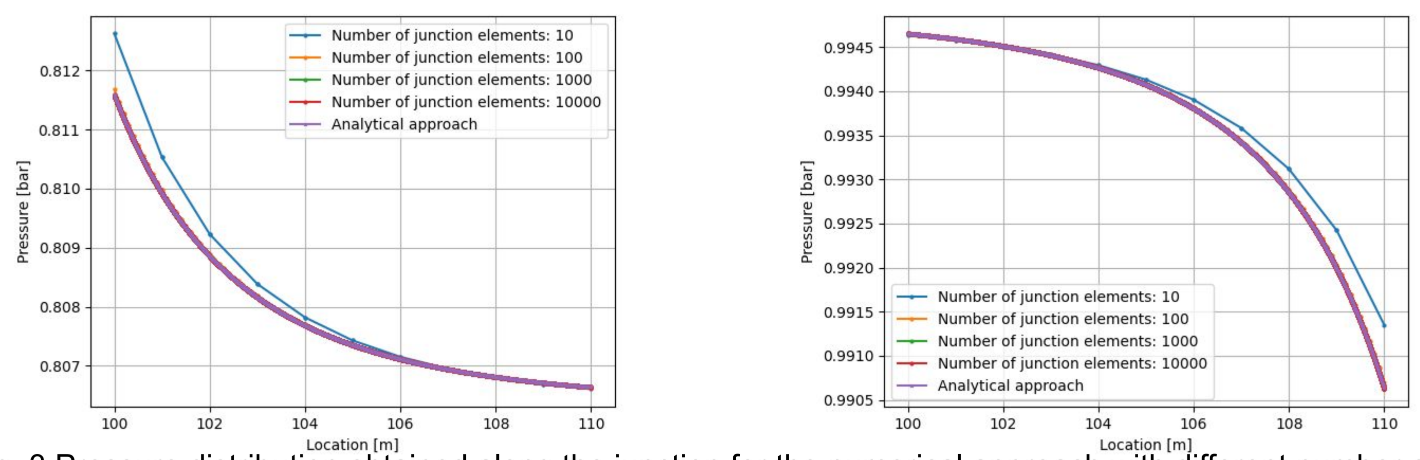

Fig. 3 Pressure distribution obtained along the junction for the numerical approach with different number of elements and analytical approach for a) diffuser and b) reducer

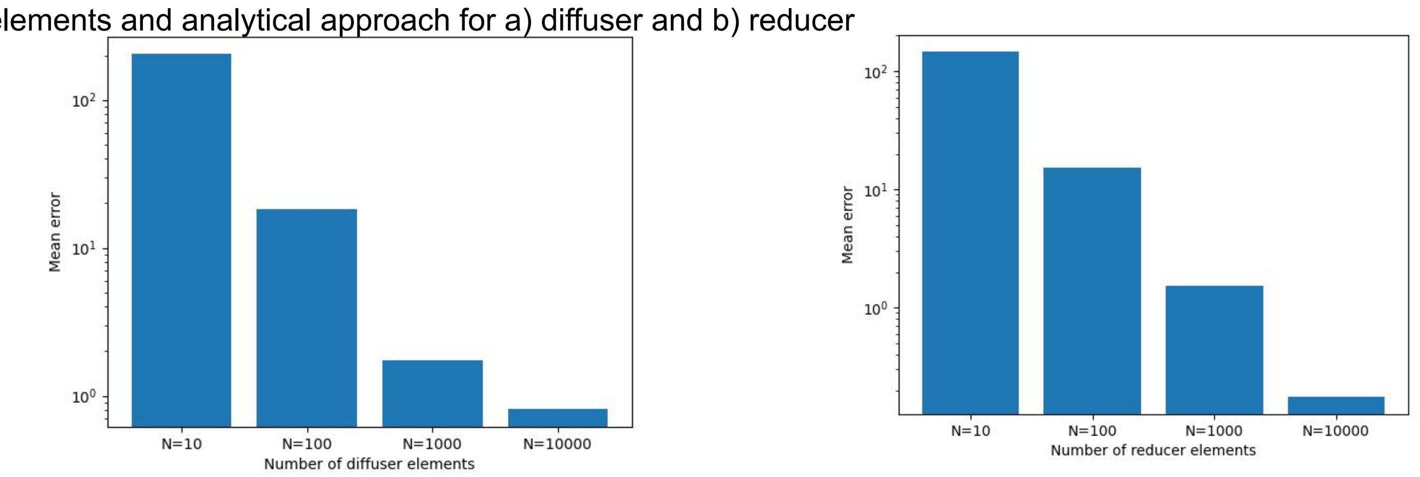

Fig. 4 Mean error between analytical approach and junction with different number of elements for a) diffuser and b) reducer

Simulation results

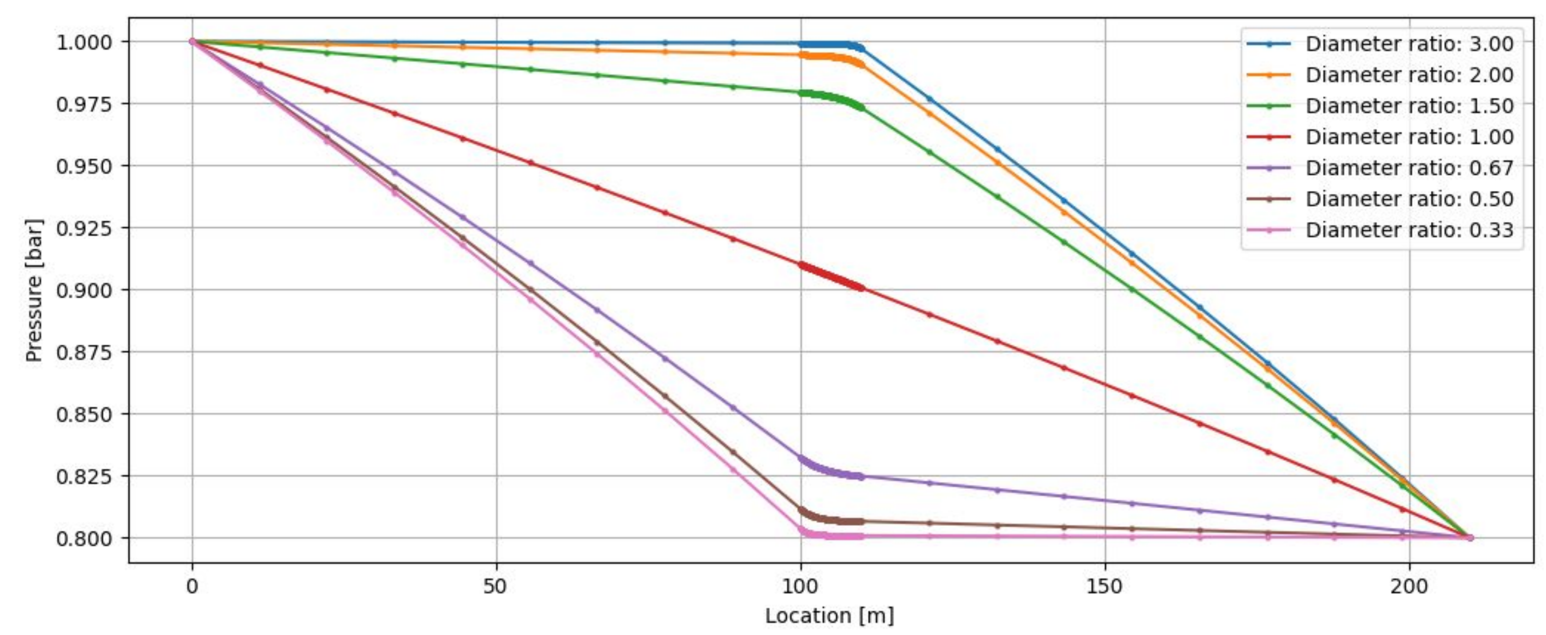

Fig. 5 Distribution of pressures for pipelines with different diameters ratio coupled with a junction

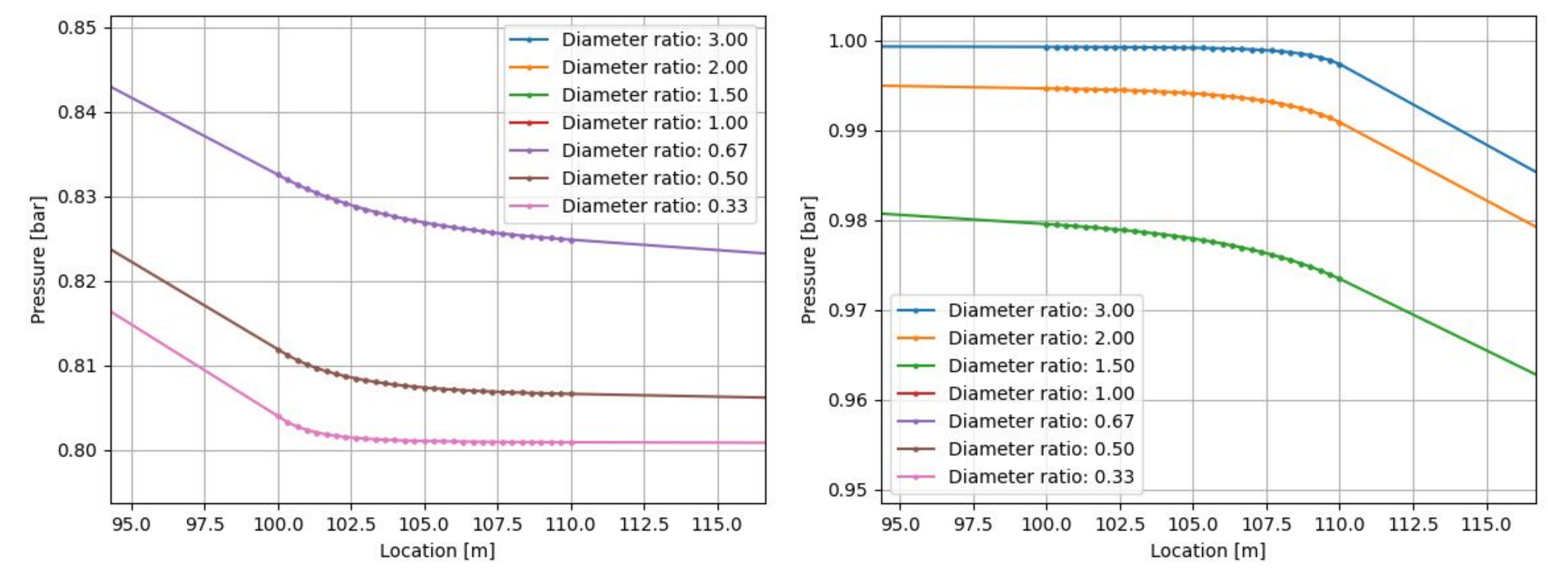

Fig. 6 Zoom on the pressure distribution of a junction for a) diffuser and b) reducer

Conclusions

A methodology for modeling diffusers and reducers has been proposed, where for both junctions the same modeling approach can be applied. As a result a model connecting inlet and outlet pressure of a pipeline system with parts of different diameters has been derived.

Moreover, the analytical model has been derived on the basis of integral counterpart of the derived model.

The model can be used to analyze the pressure distribution in junctions, and potentially in leak detection and isolation systems, which will be the focus of future research