# Resistance at junctions in pipe network simulation

Supervisor: Johan Romate (Shell/TUD)

**Problem background**

In the oil and gas industry the flow through systems of pipes, valves, pumps, compressors and other equipment can be simulated by modelling them as a flow network. To keep simulation times low the equations describing the fluid flow through the network need to be simplified sufficiently while the essentials of the flow need to be retained for the purpose of the simulation. Typically, flow through pipes is modelled as one-dimensional flow, where the flow is a function only of the coordinate along the pipe. In cross-sectional directions the flow is averaged. Along pipes mass conservation needs to be ensured and momentum or energy conservation is used to derive pressure drop behaviour along the pipe. Flow through equipment is usually modelled as zero-dimensional, i.e. it has no spatial dimensions and any geometry is taken into account in coefficients of the zero-dimensional model. At junctions of pipes, mass conservation is imposed, but geometry and resulting pressure drop are usually neglected.

In pipe networks where the pipes are relatively long and straight, neglecting the pressure drop at junctions has little influence on the flow solutions, but this is different in networks where pipelines are short and where there are many junctions. Then the geometry of the junction can have a a noticeable influence and should not be ignored. A similar argument plays a role for pipe bends and/or other geometric changes such as sudden changes in the pipe cross-sectional area. Such geometric features can be modelled by cutting the pipe at that location and introducing a new junction connecting the two pipe halves and the problem of describing its influence is reduced to modelling the geometry at a junction again.

**Assignment**

In this assigmnent the influence of the geometry of pipe junctions on the flow is considered. We assume steady-state flow conditions. The aim is to develop a very simple junction model which can be used together with the other network equations to solve the flow and pressure distribution through the network for cases where the geometry of the junction cannot be neglected. The model of a junction must be simple enough to avoid substantial increase in computation time of solving a network flow, and add enough information to be an improvement over the assumption that only mass conservation is needed. In hydraulics engineering an extra pressure drop $\Delta P$ due to a local geometric feature is typically modelled as (see [1])

$$\Delta P = K.\frac{1}{2}\rho U^2, \tag{1}$$

with $\rho$ the fluid density, $U$ the local mean velocity, and $K$ the *loss coefficient*. The geometry influence is then incorporated in the value of $K$. Whether this approach can be used to give a suitable junction model for network simulation is not clear yet and has to be investigated.

A junction model for our purpose has to satisfy several criteria:

1. The junction model needs to be symmetric in the flow directions in the sense that the model is still valid if the flow changes direction. This is required because in a junction it may not be known in which direction the flow goes.

2. Adding a junction model to a network system may not affect the well posedness of the system.

3. The junction model must be valid for subsonic laminar and turbulent flow.
4. The junction model must be applicable to pipes of different cross section and area.
5. The junction model must be valid for incompressible flow. Extension to compressible flow is not required, but may be investigated if time allows.
6. The junction model must be valid for time-independent (steady-state) flow.

The assignment can have the following parts:

1. Formulation of problem, assumptions and applicable fluid flow equations. Formulation of possible junction models.
2. Model selection and investigation of mathematical and numerical properties. This includes well-posedness criteria, domain of validity of the model, and numerical formulation.
3. Implementation for a junction of 3 equal pipes at various angles. A computer program (e.g. in Matlab) needs to developed in which the simulations can be done.
4. Extension to more arms and other options such as pipes with different areas. Also three-dimensional configurations may be included.
5. Model validation against published data.
6. Writing the thesis.

**Literature**

[1] D.S. Miller: Internal flow systems. BHRA, Cranfield, 1990.