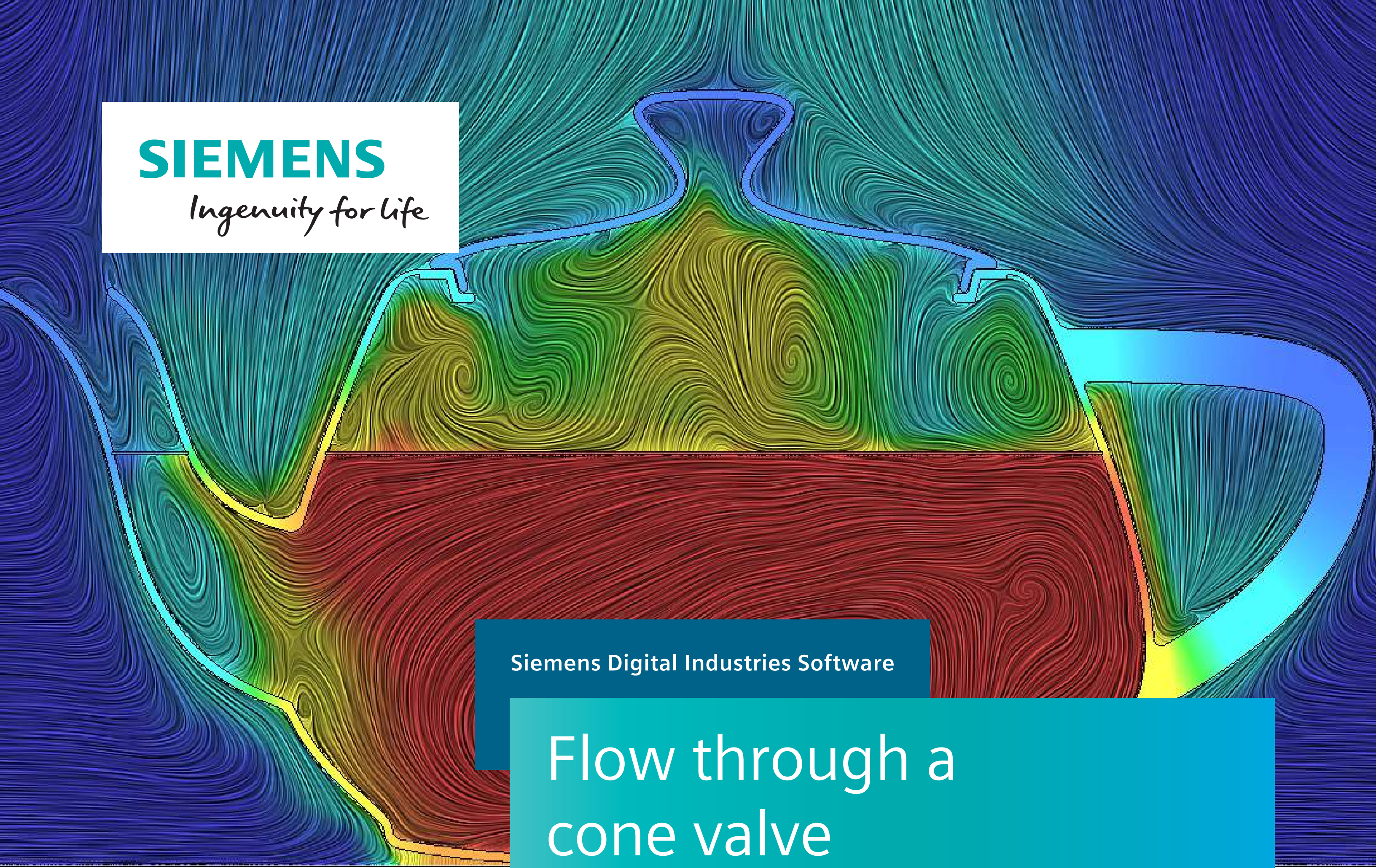

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Flow through a cone valve

Simcenter FLOEFD validation example 1

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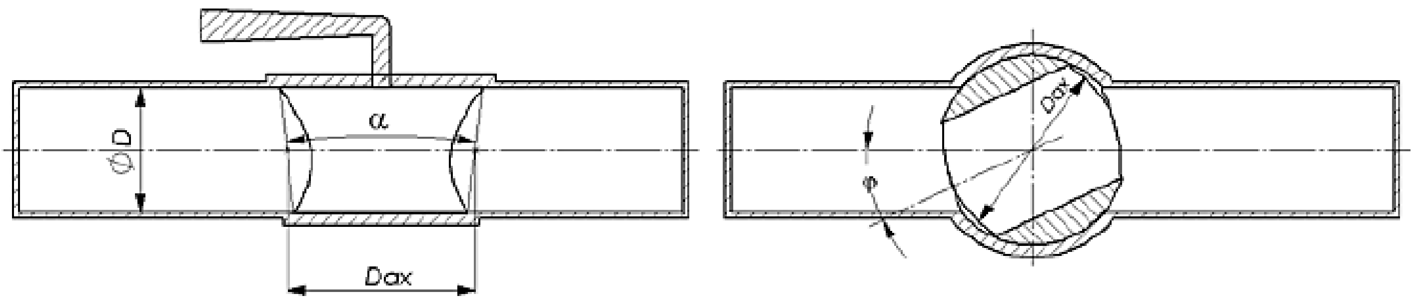

Figure 1. The cone valve under consideration: D = 0.206 m, D_{ax} = 1.515D, α = 13°40′.

Let us see how Simcenter FLOEFD™ software predicts incompressible turbulent 3D flows in a 3D cone valve taken from reference 1 (the same in reference 2) and having a complex flow passage geometry combining sudden 3D contractions and expansions at different turning angles φ (figure 1). Following the reference 2 and reference 1 recommendations on determining a valve's hydraulic resistance correctly, to avoid any valve-generated flow disturbances at the places of measuring the flow total pressures upstream and downstream of the valve, the inlet and outlet straight pipes of the same diameter D and of enough length (we take 7D and 17D) are connected to the valve, so constituting the experimental rig model (see figure 2). As in reference 1, a water flows through this model. Its temperature of 293.2 K and fully developed turbulent inlet profile (see reference 3) with mass-average velocity U ≈ 0.5 m/s (to yield the turbulent flow's Reynolds number based on the pipe diameter $Re_D = 10^5$) are specified at the model inlet, and static pressure of 1 atm is specified at the model outlet.

The corresponding model used for these predictions is shown in figure 2. The valve's turning angle φ is varied in the range of 0...55° (the valve opening diminishes to zero at φ = 82°30´).

The flow predictions performed with Simcenter FLOEFD are validated by comparing the valve's hydraulic resistance ζ_v, and the dimensionless coefficient of torque M (see figure 1) acting on the valve, m, to the experimental data of reference 1 (reference 2).

Since reference 1 presents the valve's hydraulic resistance (i.e. the resistance due to the flow obstacle, which is the valve) ζ_v whereas the flow calculations in the model (as well as the experiments on the rig) yield the total hydraulic resistance including both ζ_v and the tubes' hydraulic resistance due to friction, ζ_f, in essence, $\zeta = \zeta_v + \zeta_f$, then, to obtain ζ_v from the flow predictions (as well as from the experiments), ζ_f is calculated (measured in the experiments) separately, at the fully open valve (φ = 0); then $\zeta_v = \zeta - \zeta_f$.

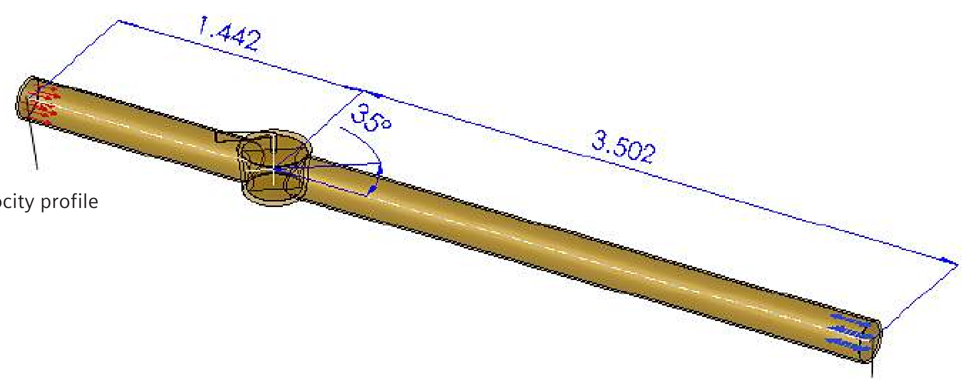

Figure 2. The model for calculating the 3D flow in the cone valve.

In accordance with reference 1, both ζ and ζ_f are defined as $(P_{o\ inlet} - P_{o\ outlet})/(\rho U^2/2)$, where $P_{o\ inlet}$ and $P_{o\ outlet}$ are the flow total pressures at the model's inlet and outlet, accordingly, ρ is the fluid density. The torque coefficient is defined as $m = M/[D^3 \cdot (\rho U^2/2) \cdot (1+ \zeta_v)]$, where M is the torque trying to slew the valve around its axis (vertical in the left picture in figure 1) due to a non-uniform pressure distribution over the valve's inner passage (naturally, the valve's outer surface pressure cannot contribute to this torque). M is measured directly in the experiments and is integrated by Simcenter FLOEFD over the valve's inner passage.

The Simcenter FLOEFD predictions have been performed at result resolution level of 5 with manual setting of the minimum gap size to the valve's minimum passage in the Y = 0 plane and the minimum wall thickness to 3mm (to resolve the valve's sharp edges).

Simcenter FLOEFD has predicted $\zeta_f = 0.455$, ζ_v shown in figure 3, and m shown in figure 4 it is seen that the Simcenter FLOEFD predictions well agree with the experimental data.

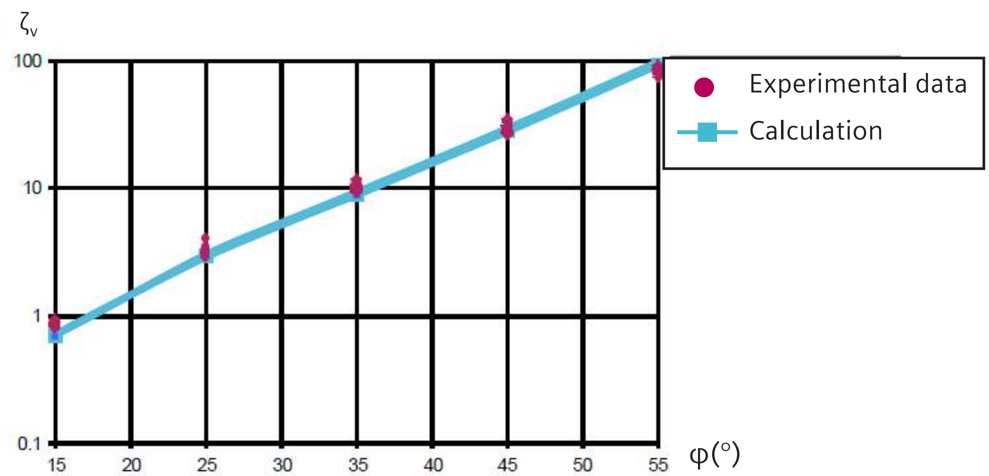

Figure 3. Comparison of the Simcenter FLOEFD predictions with the reference 1 experimental data on the cone alve's hydraulic resistance versus the cone valve turning angle.

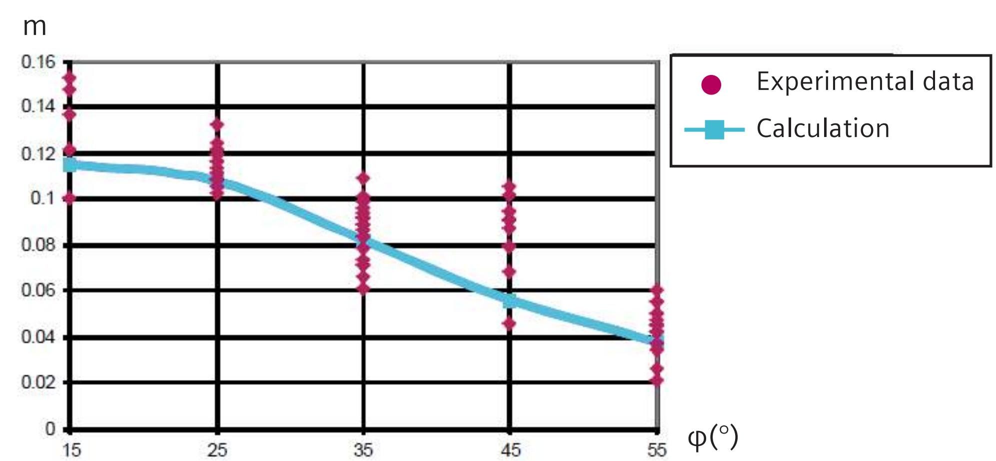

Figure 4. Comparison of the Simcenter FLOEFD predictions with the reference 1 experimental data on the cone valve's torque coefficient versus the cone valve turning angle.

This cone valve's 3D vortex flow pattern at φ = 45° is shown in figure 5 by flow trajectories colored by total pressure. The corresponding velocity contours and vectors at the Y = 0 plane are shown in figure 6.

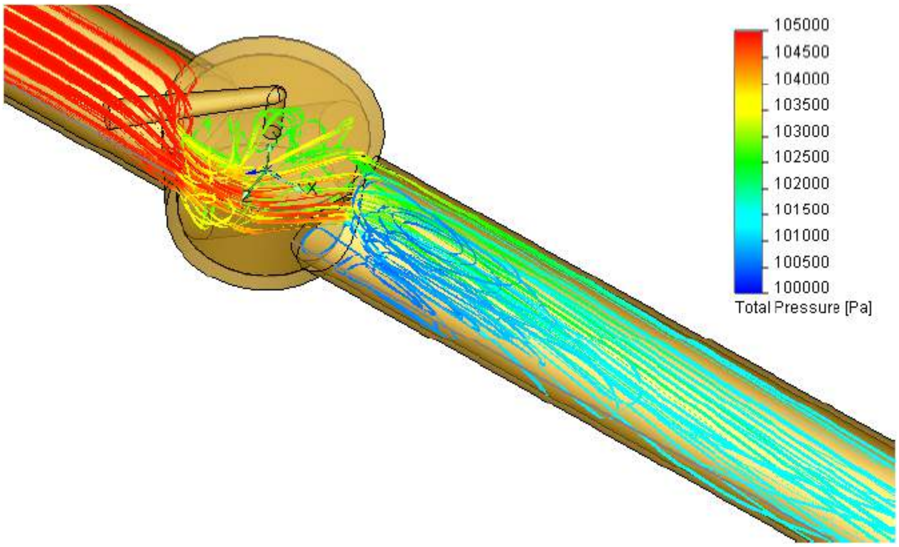

Figure 5. Flow trajectories colored by total pressure at φ =45°.

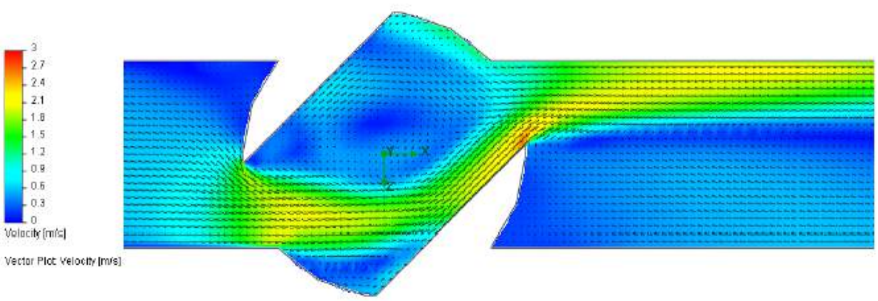

Figure 6. The cone valve's velocity contours and vectors at φ =45°.

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