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Determination of the constant pressure loss for a new segmented orifice with an inclined inflow plane

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ABSTRACT

This work provides the first experimental quantification of the permanent pressure-loss ratio ($\Delta p_{loss}/\Delta p$) for a segmented orifice with an inclined inflow plane, a geometry not covered by current norms. The method combines laboratory testing (DN50, water, $4100 < Re < 18100$) with CFD (ANSYS Fluent 2020R1; Transition SST) used to pre-select pressure-tap pairs. Three modules m = 0.102, 0.273, 0.470 were examined for γ' = 90° and γ' = 60°, maintaining near-wall resolution Y^+ = 2.29–2.92. Results show lower $\Delta p_{loss}/\Delta p$ for γ' = 60°, yielding average reductions vs γ' = 90° of ~1.3% (m = 0.102), ~3.2% (m = 0.273), ~4.9% (m = 0.470) for Re > 10 000. CFD agreed with experiments within ≤ 2.5% Δp deviation, and Transition SST consistently converged within the iteration limit, outperforming k-ω SST ITM in stability. The inclined design thus offers a cost-effective, energy-efficient alternative, especially for contaminated fluids.

OBJECTIVES

- Determine experimentally and numerically the permanent-to-total differential pressure ratio ($\Delta p_{loss}/\Delta p$) for a segmented orifice with an inclined inflow plane in DN50 piping.
- Compare *γ′ = 90°* vs *γ′ = 60°* for three modules *m = 0.102, 0.273* and *0.470*.
- Optimize pressure-tap locations (flanged, corner, D & D/2) via CFD to maximize usable Δp.
- Assess Reynolds number influence over $4100 < Re < 18100$ on $\Delta p_{loss}/\Delta p$.
- Benchmark turbulence models (k-ω SST ITM vs Transition SST) for convergence and accuracy.
- Document mesh quality (Y^+ = 2.29–2.92) ensuring viscous sublayer resolution.
- Quantify energy implications from reduced permanent losses (up to ~4.9% improvement).

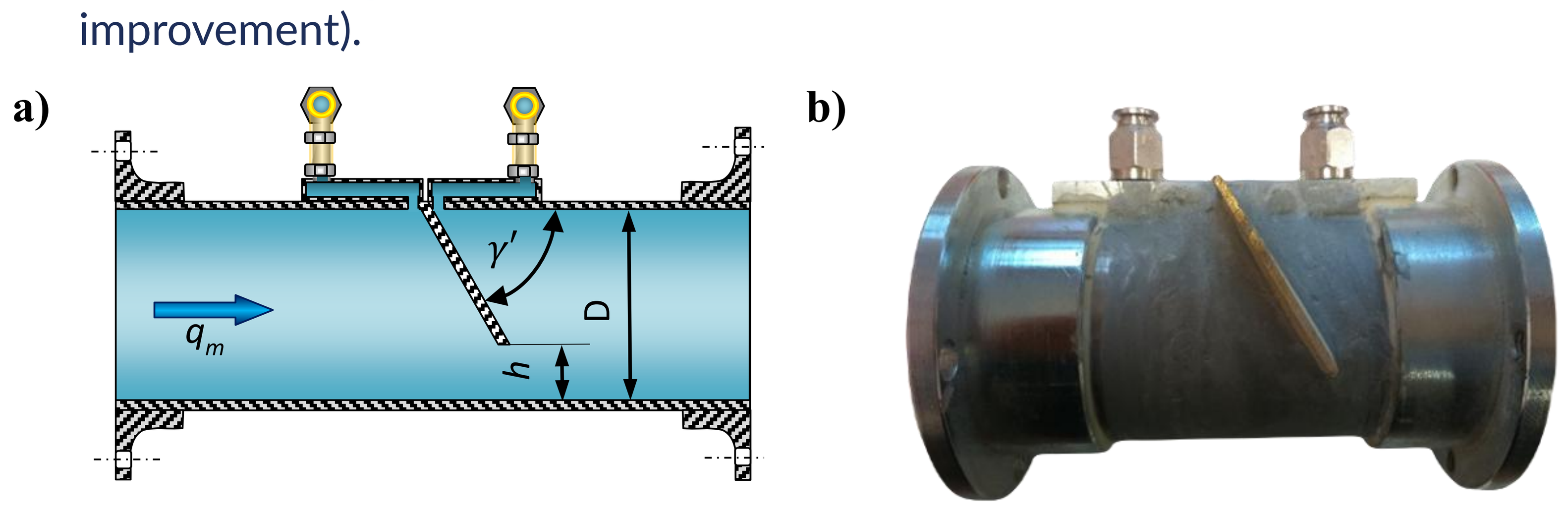

Figure 1. a) Schematic diagram of a segmented bore flow meter with an inclined inflow plane with pressure points located on the dials,
b) *Segmented orifice flowmeter with the inflow plane inclined by an angle γ°= 60° and module m = 0.273*

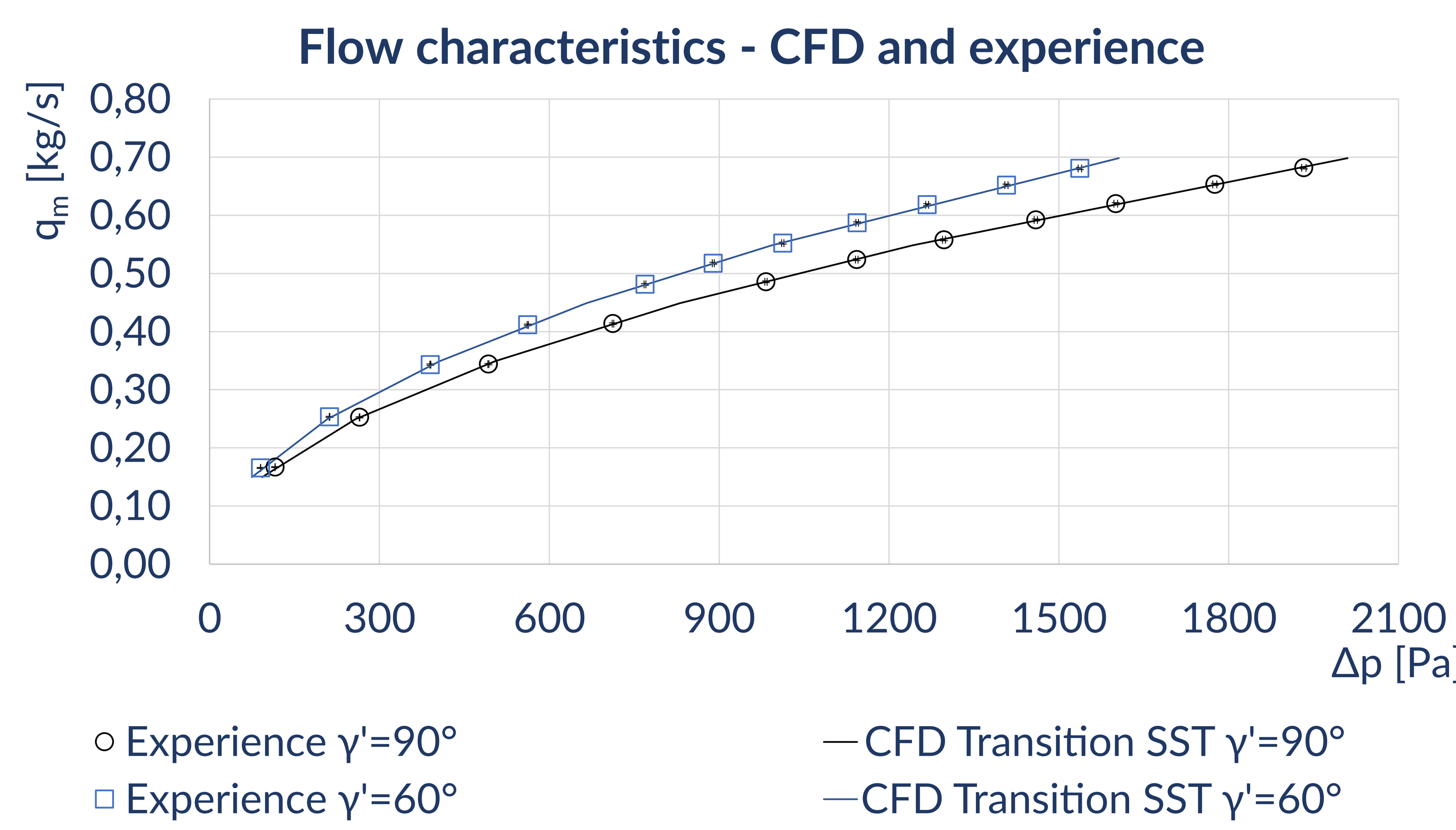

Figure 2. Comparison of flow characteristics determined on the basis of experimental study and CFD simulation with marked limit instrumentation errors.

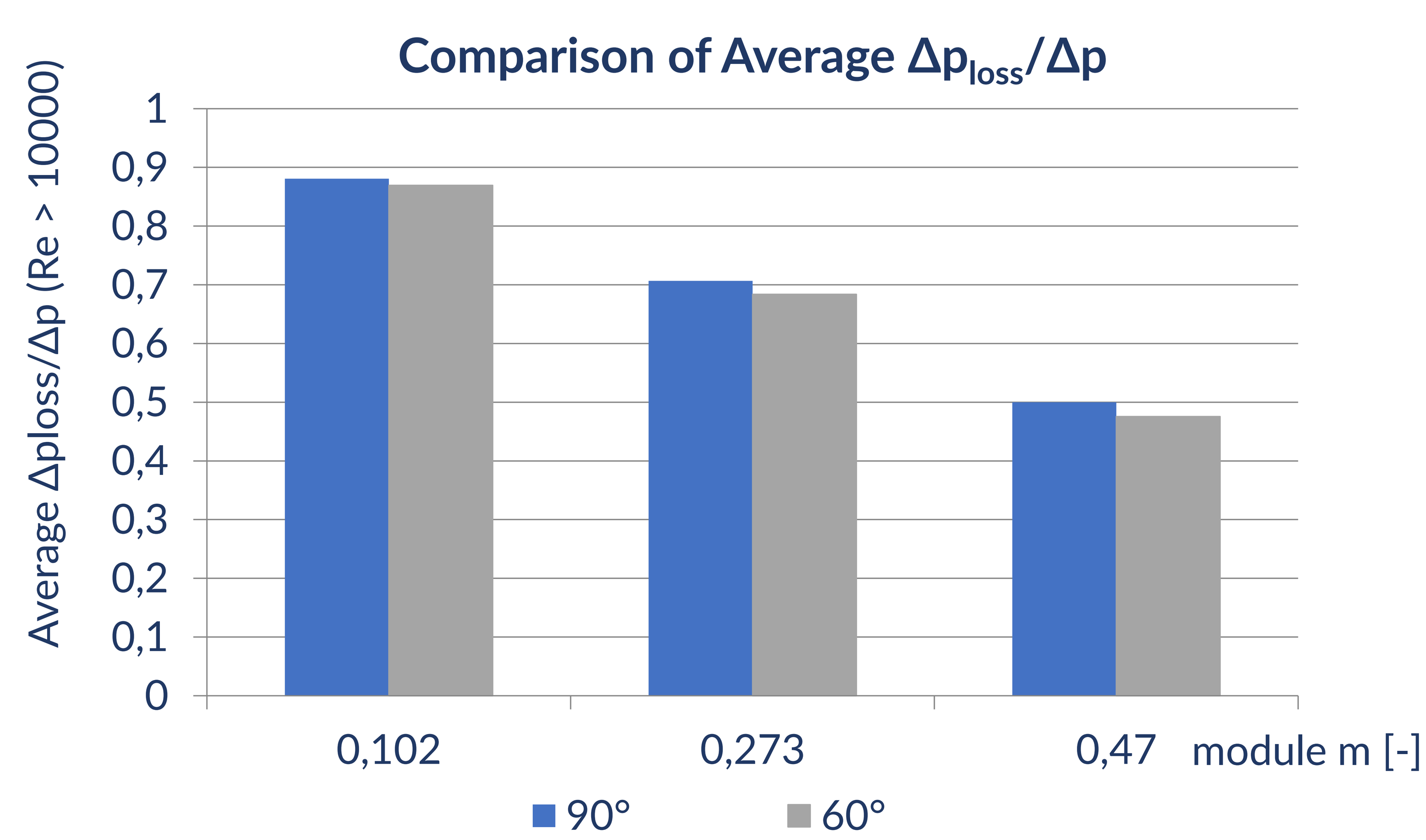

Figure 3. Average values of $\Delta p_{loss}/\Delta p$ for three modules, comparing 90° and 60° inflow angles. Data based on experimental results for Re > 10 000.

CONCLUSIONS

- Inclination to γ′ = 60° reduces Δp_loss/Δp versus γ′ = 90° across all modules, with the largest benefit at m = 0.470 (~4.9%) for Re > 10 000.
- Transition SST is numerically more stable and efficient than k-ω SST ITM at higher fluxes.CFD–experiment agreement ≤ 2.5% confirms model credibility and mesh adequacy (Y+ ≈ 2.3–2.9).
- Tap placement can be tuned to maximize practical Δp without significant bias among standard locations.
- The inclined segmented orifice is promising for contaminated liquids due to self-cleaning tendencies and lower energy losses.

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