HSLU Lucerne University of Applied Sciences and Arts

Engineering and Architecture
B.Sc.. Energy and Environmental Systems Engineering
Bachelor-Thesis

CFD Simulations of optimized 180° rectangular bends

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1. Introduction, Goals and Research Questions

Efficient fluid flow in duct systems is critical to reduce energy losses. Sharp 180° bends often cause flow separation and secondary vortices, increasing pressure losses. To improve performance, three bend geometries were studied: a standard (0s), a 3-side optimized (3s), and a 4-side optimized (4s) bend.

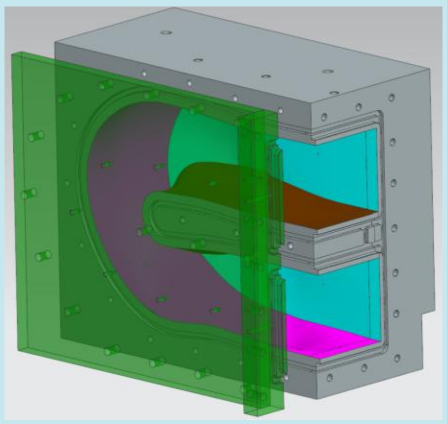

Figure: 3 sides optimized bend

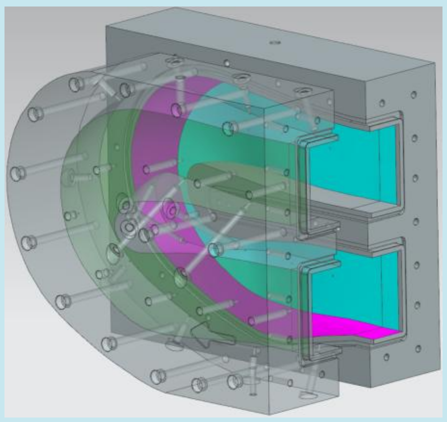

Figure: 4 sides optimized bend

The main objectives were:

- To simulate flow and pressure loss across the bend geometries using Ansys CFX and the HSLU solver CoupledNumerics (CN)
- To evaluate the 3 bend geometries with the SST, EARSM, BSLRS turbulence models.
- To compare CFD results with experimental measurements at the Reynolds number of 100'000, 200'000, and 300'000.

2. Method Overview and Materials

The three duct bends were discretized into control volumes and analyzed using the Finite Volume Method:

$$\frac{\partial}{\partial t}\int_V \rho\phi\, dV + \int_S \rho\phi \cdot \vec{n}\, dA = \int_S \Gamma\nabla\phi \cdot \vec{n}\, dA + \int_V S_\phi\, dV\mathrm{c}$$

The simulations were run with the CFX and CoupledNumerics solver. Each simulation was evaluated to ensure stable and realistic flow behavior. If results were unsatisfactory, the setup was adjusted (e.g., mesh, or simulation paramerters) and re-simulated. The simulations results were then compared with the laboratory results.

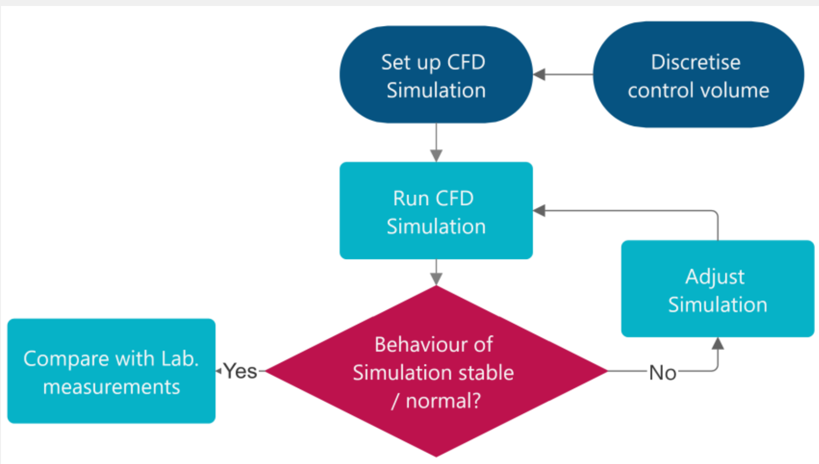

Figure: Workflow

Industry Partner **HSLU** Institute of Mechanical Engineering and Energy Technology IME

3. Results and Discussion

The simulated values were used to calculate the loss coefficient also called Zeta Value [ζ]. These were compared with experimental results to evaluate the accuracy of the simulations. The table shows the deviation of simulated ζ - Value for the standard and 4-side optimitzed bend. The 3-side optimized bend is not shown, as the simulation results were not considered due to unsatisfactory results.

The CFX simulations showed good agreement under certain flow conditions and for specific bend geometries. However, the accuracy was not consistent across all Reynolds numbers.

The CoupledNumerics solver with BSLRS achieved excellent accuracy at Re = 100’000. However, simulations at higher flow conditions are still required to confirm whether this level of accuracy can be maintained.

Table: Deviation of simulations results to measurements

Flow condition (Reynolds Number)	100'000	200'000	300'000
Deviation Zeta Value [ζ] 0s CN BSLRS	2%	N/A	N/A
Deviation Zeta Value [ζ] 0s CN SST	1%	N/A	N/A
Deviation Zeta Value [ζ] 0s CFX BSLRS	6%	28%	27%
Deviation Zeta Value [ζ] 0s CFX EARSM	1%	21%	21%
Deviation Zeta Value [ζ] 0s CFX SST	-6%	13%	14%
Deviation Zeta Value [ζ] 4s CN BSLRS	0%	N/A	N/A
Deviation Zeta Value [ζ] 4s CN SST	32%	N/A	N/A
Deviation Zeta Value [ζ] 4s CFX BSLRS	32%	24%	6%
Deviation Zeta Value [ζ] 4s CFX EARSM	32%	18%	6%
Deviation Zeta Value [ζ] 4s CFX SST	21%	18%	6%

4. Conclusion and Recommendations

The measurement results could only be partially reproduced by the simulations. While CoupledNumerics with the BSLRS model showed very accurate results at Re = 100’000, further simulations at higher Reynolds numbers are required to verify whether this accuracy can be maintained. The results for the 3-side optimized bend were not reliable and should be improved before meaningful comparisons can be made.

References

1. Emmengger, J. (2024). Messungen an einem optimierten 180° Rechteck-Krümmer [Industrieprojekt] Hochschule Luzern.
2. Lecardonnel, D. (2024). Geschwindigkeitsmessungen an optimierten 180°-Rechteck-Krümmern [Bachelorthesis]. Hochschule Luzern.

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