Fluid Flow Simulation Of The Original Tesla Valve

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Abstract

A Tesla valve has a fixed geometry and its purpose is to be a check valve. This valve is named after its inventor Nikola Tesla and the patent to this has been published in the year 1920 [1]. In the reverse direction, the flow resistance is higher compared to the flow resistance in forward direction. The ratio of these two flow resistances respectively the necessary pressures is the so-called diodicity. Tesla had assumed that this diodicity could perhaps reach a value of Di = 200, but to his time the possibility of applying computational fluid dynamics (CFD) had not been given. For the geometry of the fluid flow simulation studies here, the original sketch of Tesla's patent has been used as the basis for a CAD reconstruction. Fluid flow simulations of this geometry are numerically challenging, because there are many geometric deflections. Therefore for a wide range of Reynolds numbers, numerical stabilization methods are applied in stationary studies. In 2D and 3D - simulations of this geometry the flow distribution is visualized and the diodicity is determined. The occurring eddies or vortices are displayed in detail. Most of the studies are performed applying an algebraic turbulence model [2]. This is compared to other common turbulence models in 2D and the algebraic turbulence model called 'Algebraic yPlus' in this special case seems to be more accurate while needing less calculation time. The same boundary conditions are then applied to 3D-simulations with a comparable fineness of the finite element mesh compared to the 2D-case. The simulated diodicity for one of the considered relatively high Reynolds numbers of $Re = 10^4$ is $Di(Re = 10^4; 2D) = 5.123 \lll 200$ for the 2D-case, while this diodicity has a simulated value of $Di(Re = 10^4; 3D) = 1.679$ for the 3D-case and the relative difference between these two cases is large.

Reference

[1] Tesla, N. (1920). Valvular conduit (US Patent No. US1329559A). United States Patent and Trademark Office. weblink: https://patents.google.com/patent/US1329559A/en
[2] Ferziger, J. H., Perić, M., & Street, R. L. (2020). Computational methods for fluid dynamics (4th ed.). Springer. weblink: https://link.springer.com/book/10.1007/978-3-319-99693-6

Figures used in the abstract

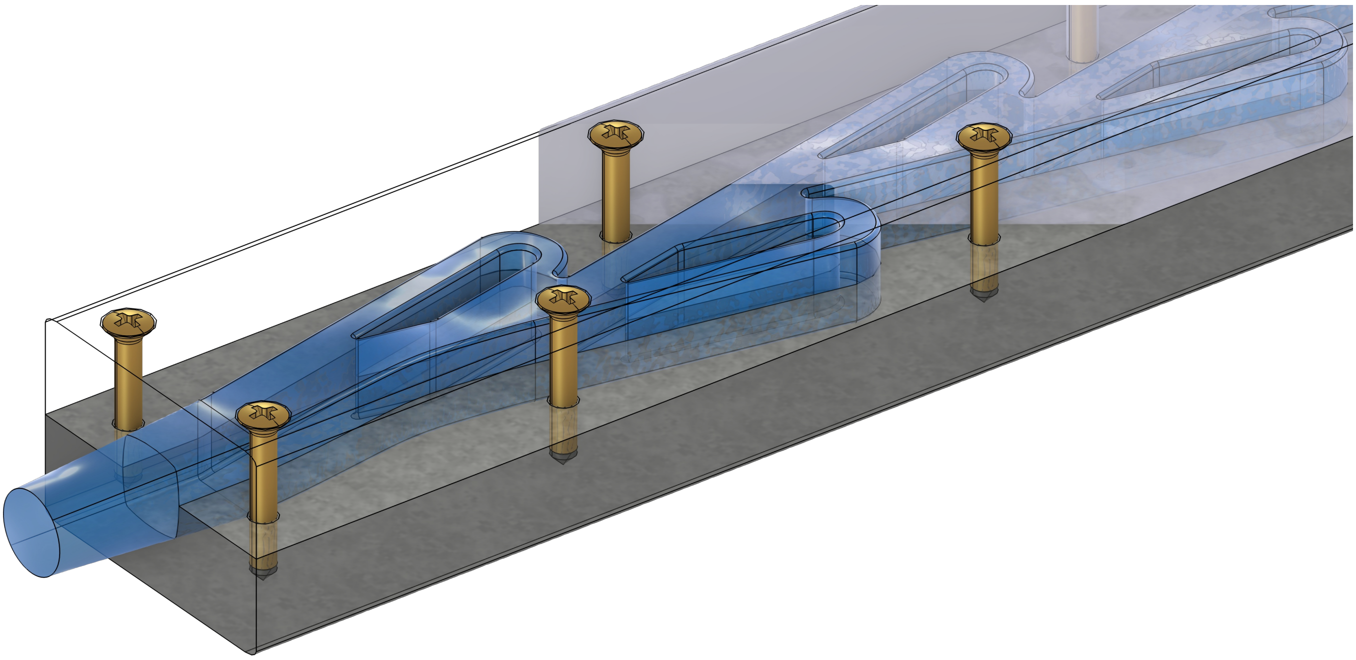

Figure 1 : CAD-modeled 3D-geometry of the Tesla valve

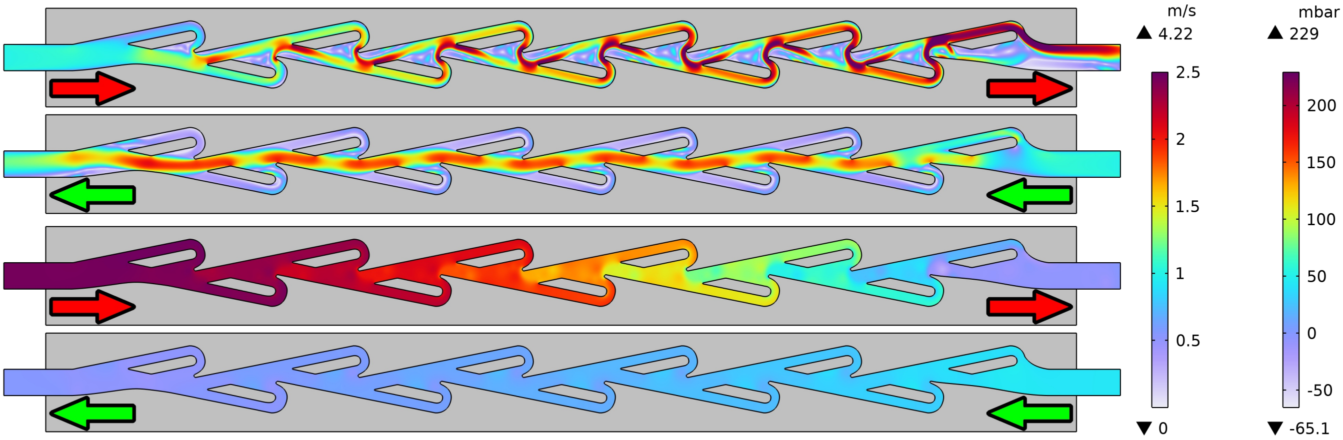

Figure 2 : 2D-simulation: Display of the velocity (upper illustrations) & pressure (lower images) for both directions for Re = $1{\cdot}10^4$

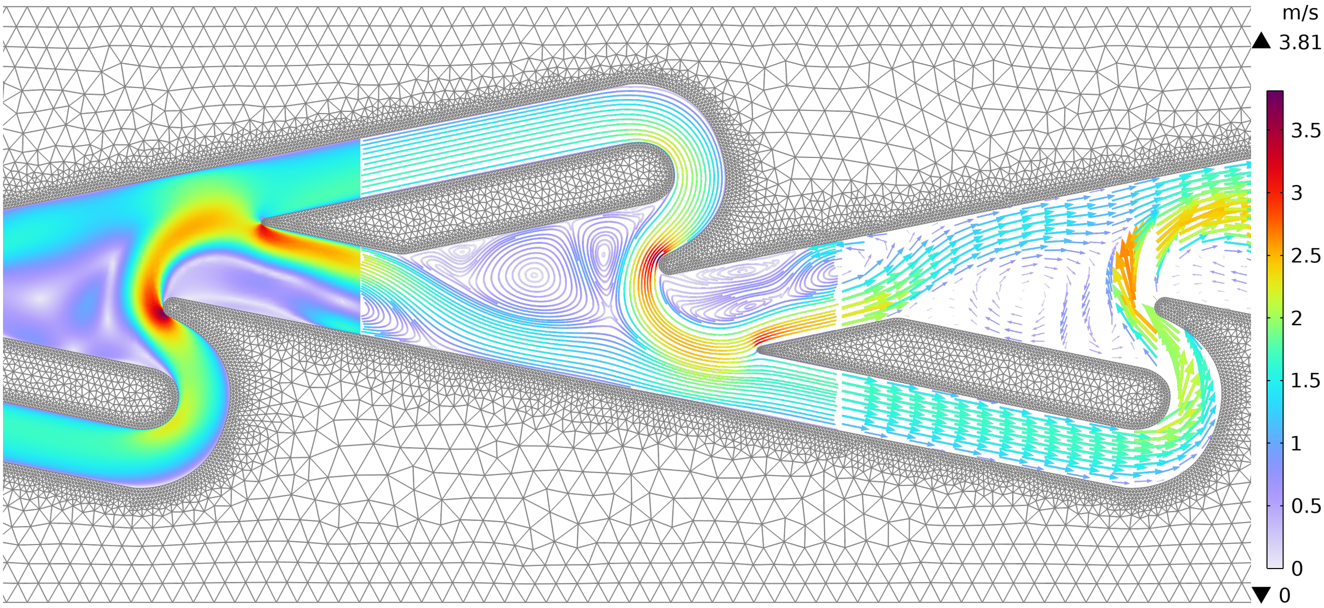

Figure 3 : 2D-simulation: Display of the velocity (absolute value) partially with streamlines and vectors for Re = $1{\cdot}10^4$

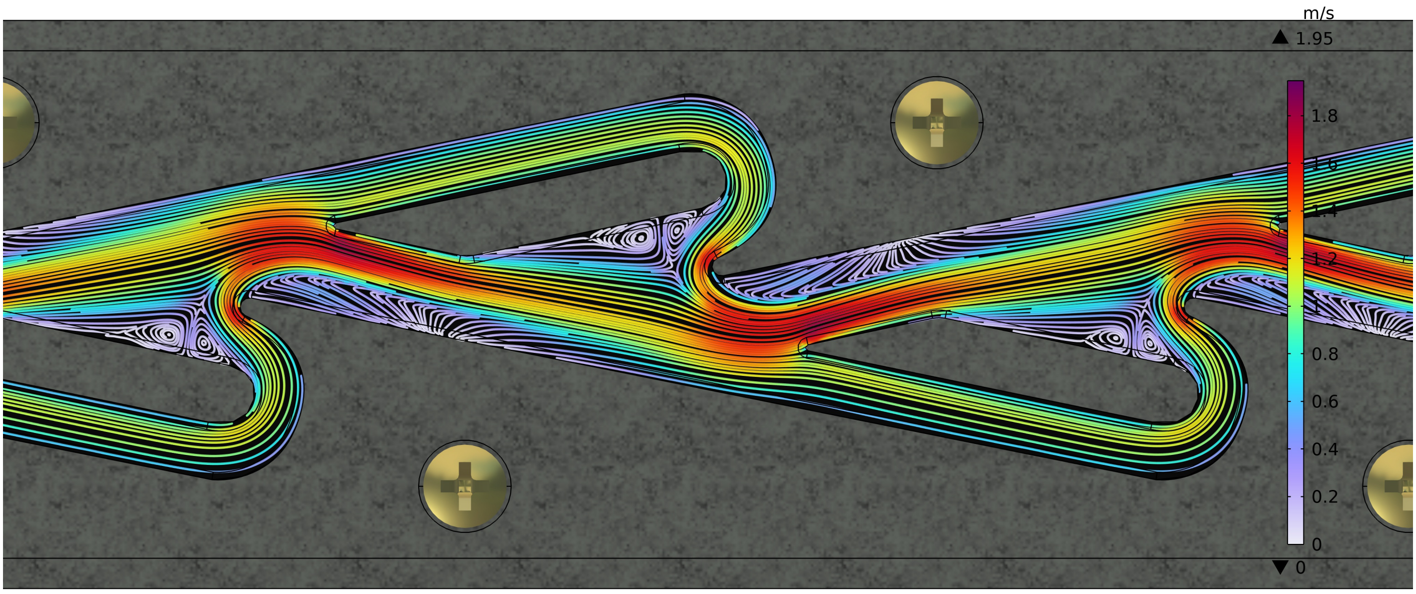

Figure 4 : 3D-simulation: Display of streamlines colored with the velocity for a centered horizontal sectional view for Re = $1{\cdot}10^4$