RECONSTRUCTION OF TESLA MICRO-VALVE USING TOPOLOGICAL SENSITIVITY ANALYSIS

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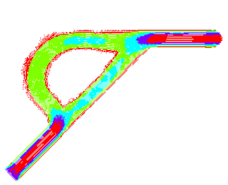
Abstract. The Tesla micro-valve is one of the most widely used no-moving-part micro-valve. In this work, we use topology optimization related to the non stationary Navier Stokes equations to reconstruct the Tesla micro-valve. The proposed approach is based on a sensitivity analysis of a shape function with respect to the insertion of a small obstacle in the fluid flow domain. Some numerical results show the efficiency of the proposed method.

1. Introduction

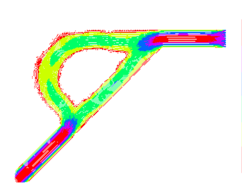
Tesla valves are no-moving-part valves that utilize fluidic inertial forces to inhibit flow in the reverse direction. After being patented by Nikola Tesla in 1920 as a "Valvular conduit", the Tesla micro-valve has found many applications such as drug delivery, microbiology and medical applications like the treatment of hydrocephalus. The most important parameter to evaluate the performance of the Tesla micro-valve is the diodicity, which is the ability of allowing forward flow while inhibiting the reverse one.
In this work, we use the topological sensitivity analysis method to reconstruct and improve upon the original intuition-driven design of Nikola Tesla.

2. Topology optimization of Tesla micro-valve

The Tesla micro-valve topology optimization problem is solved using the forward energy dissipation as an objective function and the diodicity as a constraint. We illustrate the strengths of this approach namely the ability to find optimal design based only on boundary condition and constraints without the need of an initial design. The optimal domain is constructed through the insertion of some obstacles in the initial one. The problem leads to optimize the obstacles location.
In this work, we present two main results. The first one devoted to the topological sensitivity analysis for the non stationary Navier-Stokes equations. We derive an asymptotic expansion for the variation of the shape function with respect to the insertion of a small obstacle inside the fluid flow domain. The obtained result is general and valid for large class of shape functions. The second one concerns the numerical investigation of 2D Tesla micro-valve design optimization. We build a simple and fast numerical reconstruction algorithm based on the topological gradient method. The efficiency of the proposed approach is performed by some numerical results. The following figure illustrates the Tesla micro-valve design obtained at moderate Reynolds number (Re=100).



(a)Forward flow velocity field



(b) Backward flow velocity field