Karlsruhe Institute of Technology

Institute of Fluid Mechanics

September 2, 2024

Master-Thesis – numerical

Numerical simulation of secondary currents in arterial flows with stents

Background & Motivation

About 55% of all cardiovascular disease deaths are due to coronary heart disease caused by atherosclerosis and subsequent stenosis, a narrowing of the arteries that reduces blood flow to the myocardium, which in severe cases may lead to heart attacks. Stenosis is often treated with angioplasty, a surgical procedure that restores the artery diameter to about its original size. This is typically followed by the placement of a stent, a tube net that helps preserving the restored artery configuration over time. Stents are usually designed to maximise their mechanical performance and prevent rupture, whereas their effects on the artery hemodynamics are usually underestimated, especially at the scale of the artery diameter. This oversight is possibly due to the small thickness of stents (e.g., $\approx$ 0.1-0.2 mm for metallic stents and $\approx$ 0.3-0.5 mm for stent grafts) compared to the diameter of arteries (e.g., $\approx$ 3-5 mm for the coronaries and $\approx$ 15-30 mm for the aorta). This project aims at studying how stents, perhaps against intuition, may introduce secondary currents in arterial flows. The following questions remain unanswered: can stents introduce secondary currents? If so, how do these currents affect key flow properties, such as wall shear stress distributions and the transport of substances and cells?

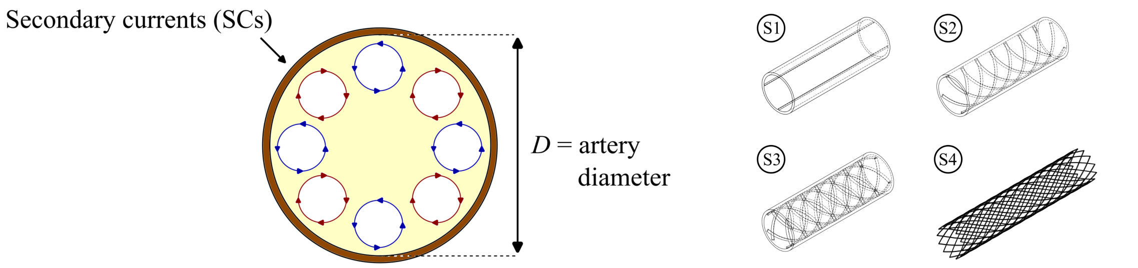

Figure 1: Secondary currents generated in a pipe flow (left) and the different levels of complexity for the numerical simulations (right).

Content of the Thesis

During your Master's Thesis, which may be partially conducted at the University of Padova, you will progress through three levels of simulation complexity. Initially, you will perform direct numerical simulations of smooth pipe flow in both laminar and turbulent regimes at low Reynolds numbers to validate the numerical tools. Next, semicircular ridges aligned with the flow direction (Figure 1, S1 configuration) will be introduced into the pipe, allowing you to investigate the formation of secondary motions. Finally, the geometry of these semicircular ridges will be modified to emulate a realistic stent structure (Figure 1, S4), with the ridges arranged in a helical pattern at a 45-degree angle to the flow direction (Figure 1, S2 and S3). The results from these simulations will be analyzed to uncover the mechanisms behind secondary motion formation and to assess flow statistics.

The project will be carried out in cooperation with Dr. Andrea Zampiron from the University of Padova, Department of Civil, Environmental and Architectural Engineering.

Start date:

Submission date:

Student:
Matrikel-Nr:

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Signature

Contact:
Dr.-Ing. Alexander Stroh

Institute of Fluid Mechanics
Kaiserstraße 10,
Building 10.23, 6th floor,
Room 601

☎ +49 721 608 43528
✉ alexander.stroh@kit.edu