BLOOD FLOW IN A BIFURCATION AND CONFLUENCE MICROCHANNEL: EFFECT OF THE CELL-FREE LAYER IN VELOCITY PROFILES

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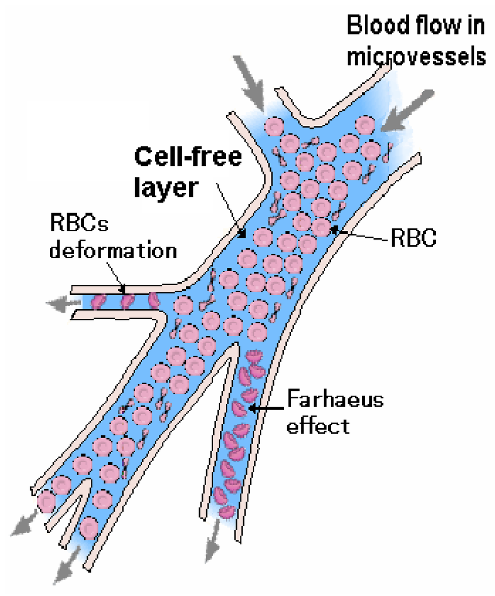
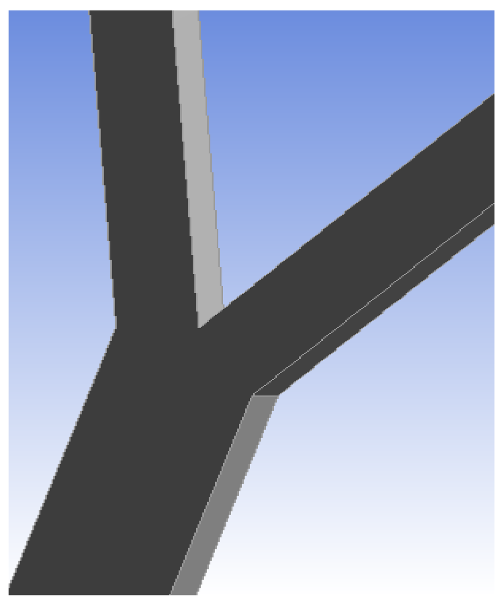
Introduction

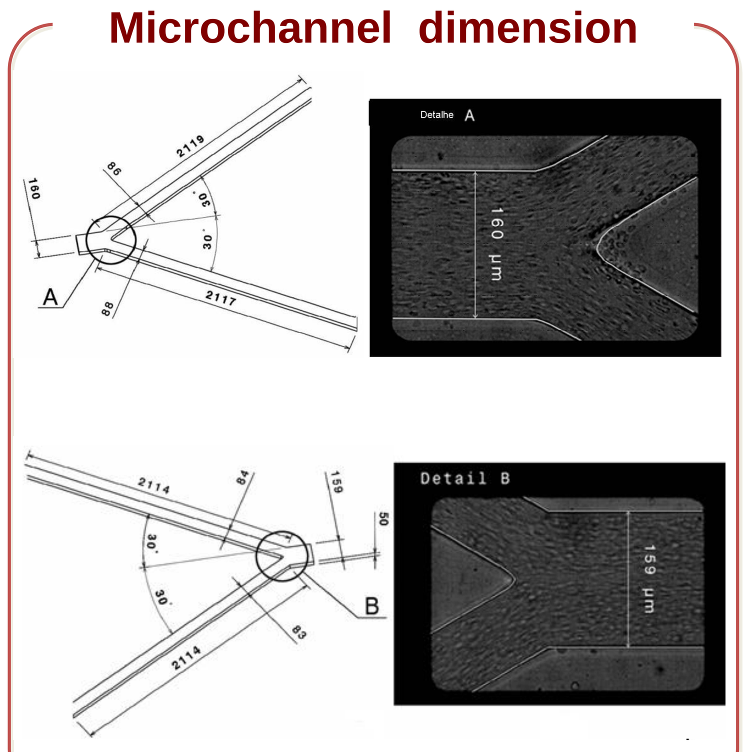


- In microcirculation, red blood cells (RBCs) flowing through bifurcations may deform considerably due to combination of different phenomena that happen at the micro-scale level, such as: attraction effect, high shear and extensional stress, all of which may influence the rheological properties and flow behavior of blood [4]. Then a few detailed studies have been performed in complex *in vitro* microvascular networks composed by bifurcations and confluences.
- A well known hemodynamic phenomenon, known as Fahraeus-Lindqvist effect [1, 2], observed in both *in vivo* and *in vitro* studies, results in the formation of a marginal cell-free layer (CFL) at regions adjacent to the wall [3]. Recently, studies have shown that the formation of the CFL is affected by the geometry of the microchannel and for the case of the confluences a CFL tend to appear in the middle of the microchannel after the apex of the confluence [4, 5]. By using the CFL experimental data, the main objective of this work is to implement a CFL in the numerical simulations in order to obtain a better understanding of the effect of this layer on the velocity profiles.
- The main purpose of the present work is to numerically simulate the flow of two distinct fluids through bifurcation and confluence geometries, i. e., red blood cells (RBCs) suspended in Dextran40 with about 14% of heamatocrit and pure water.
- The simulations of pure water and RBCs flows were performed resorting to the commercial finite volume software package FLUENT.

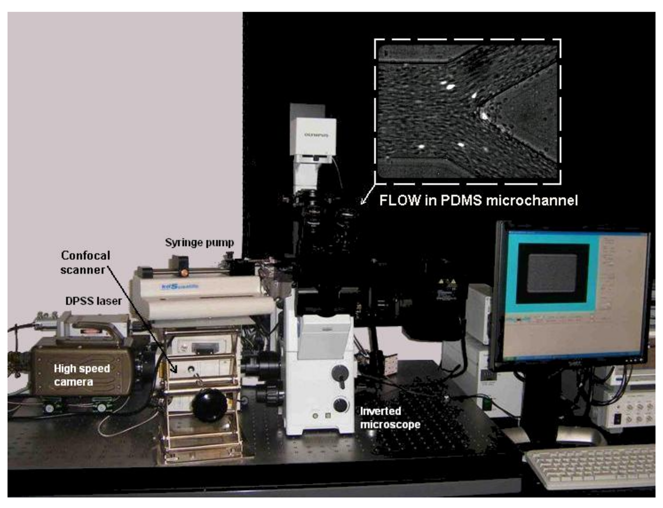


Materials and methods

Microchannel dimension



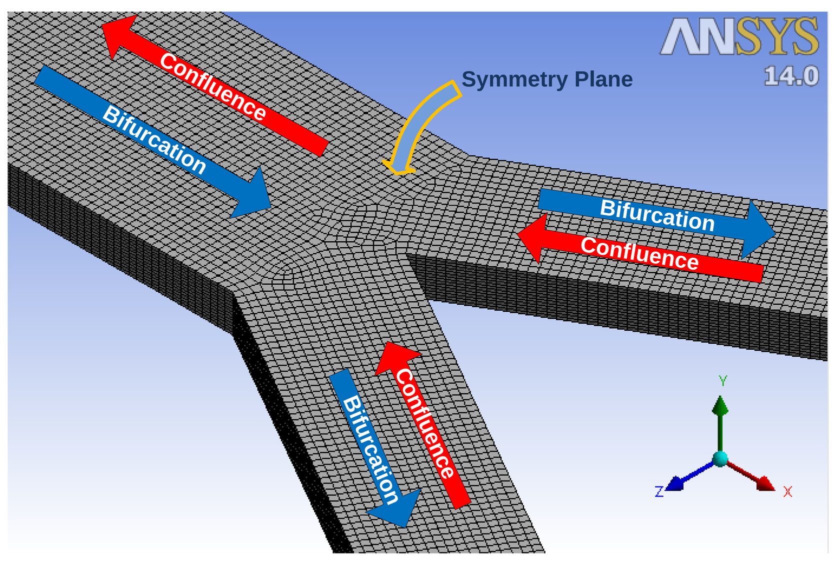
Experimental set-up



Experimental parameters

Human RBCs Fluorescent cell tracker (CM-DiLC-7000)	≈ 8 µm
Reynolds number	≈ 0.007
Magnification objective	32×
Capture frame rate	100 frames/s

Simulation method

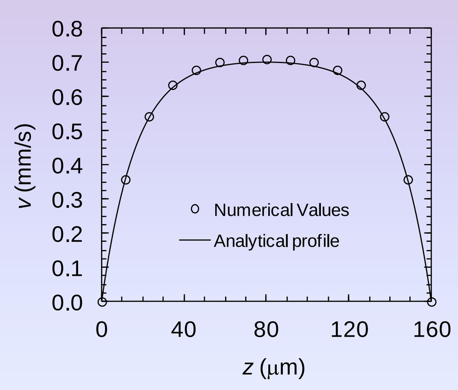


Numerical calculations for the Newtonian and non-Newtonian laminar isothermal flows were performed using the finite volume software package FLUENT.

The simulations were carried out in 3D geometries representing the microchannel's confluence and bifurcation.

The mesh used in the simulations was mainly constituted by hexahedral elements.

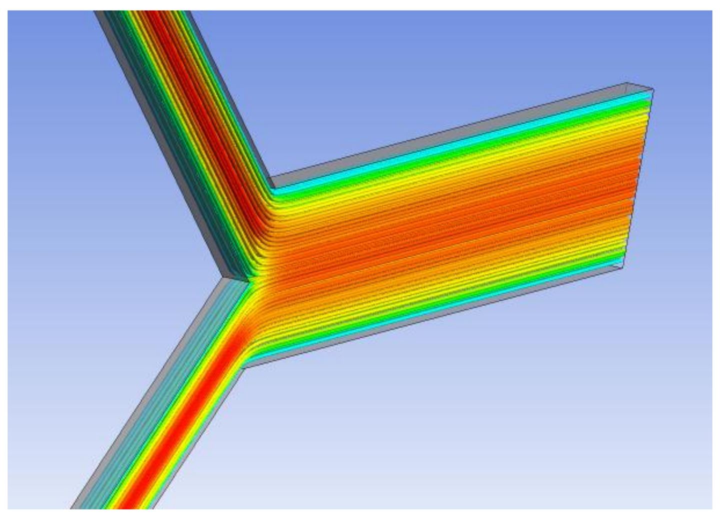
The validation of the numerical model was performed resorting to the analytical profile of velocity for rectangular channels. A good agreement was found between numerical and analytical values.



The pseudoplastic behaviour of blood was described by Carreau model.

Results and discussion

Streamlines



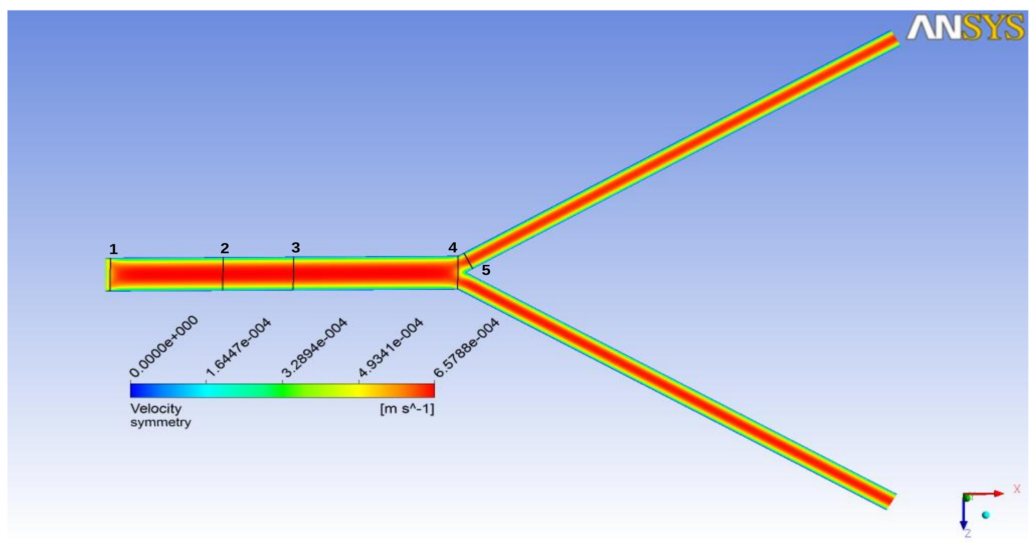
The fluid around the bifurcation/confluence follows the contour geometry, since we are studying a laminar viscous flow. This behaviour have been observed in previous experimental works [4].

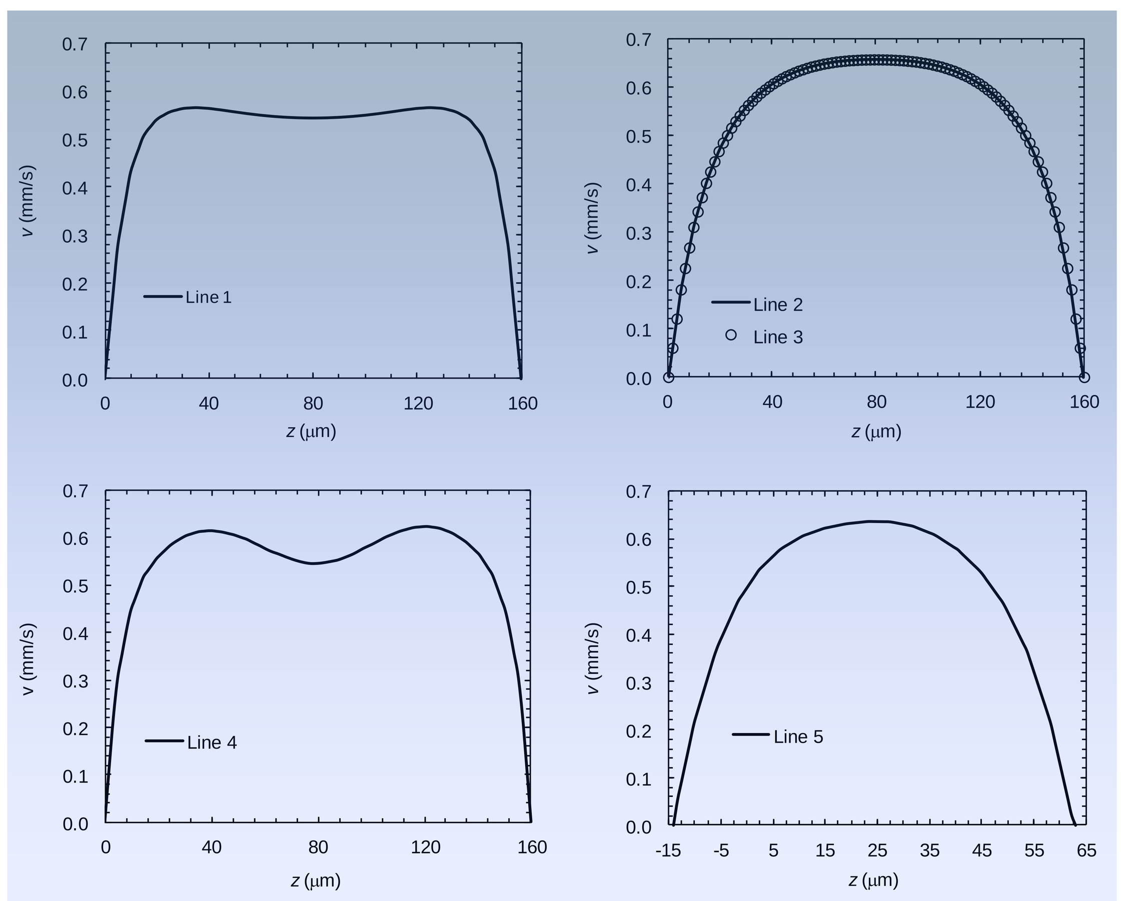
However, this behaviour doesn't happen in blood flow. This discrepancy between numerical results and experimental observations is due to the presence of red blood cells in real flows, not considered in this preliminary study of velocity profiles.

Velocity profiles

The velocity of non-Newtonian fluid along the channels was observed and compared with the velocity obtained for pure water. It was found that the velocities for the Carreau fluid were slightly lower that the ones observed for pure water.

The velocities for both fluids were determined considering non-slip at the walls.





Velocity profiles along the microchannel for Carreau Model.

Along the channel it was possible to analyse the variations of the velocity profile shape. In line 1 we can observe the entry effects, that are no longer present in lines 2 and 3, which allows to say that we obtained developed laminar isothermal flow before the bifurcation/confluence. Along line 4 the presence of the apex is evident, the decrease of the velocity in the middle of the channel being result of the zero velocity imposed in the apex. In the daughter channel (line 5) the velocity profile is once again a typical profile for flow in rectangular channels

The results for the microchannel with confluence are similar to the ones presented here.

Conclusion and future work

- Results presented in this work are a first step in order to introduce the effect of CFL in the of blood flow simulations in michochannels with both bifurcations and confluences.
- Simulations performed with the finite volume CFD program FLUENT emphasized the need of developing a multiphase approach, since the predictions for pure water are in agreement with previous experimental measurements, but don't predict the deviations of flow due to the presence of red blood cells.

References

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Acknowledgment

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