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Variable cross sectional area

Bob Eisenberg <bob.eisenberg@gmail.com> Wed, Apr 30, 2014 at 8:37 AM
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Dear Lina

I wanted to address the 1D vs 3D issue in a bit more detail since it can be very confusing.

The attached paper with Gardner says everything succinctly. Carl is a superb writer and teacher. NOTE his comment about nozzles in case you want to discuss this with Prof. Shen.

The Am J Physics paper shows that IN GENERAL your concerns are correct. It is ONLY when the system is narrow that the cross sectional area type approximation is valid.

Now we turn to the region JUST OUTSIDE the channel.

This is described best in the Gardner paper. The Nonner paper used this approach first in print I think although Chen and I had done it much earlier.

The key idea here is that SOMETHING must be done to link the channel to the far away baths in a 1D model that does not allow the bath to dominate the problem because in the real world the bath is not very important.

If the channel is just extended to far away, with different stuff in it in the baths, the resistance in the bath will dominate the problem which is simply not the way the world is.

If the boundary conditions (i.e., electrodes) are moved close to or just next to the channel, boundary layers THAT ARE ENTIRELY IRRELEVANT TO THE CHANNEL FUNCTION spread into the channel and screw things up totally.

A compromise is to include a taper of diameter (rapid expansion of cross sectional area) so the region outside the channel (i.e., the bath) exists, and separates the channel from the boundary conditions, but does NOT dominate the problem.

This compromise is just that and results must be actually checked to be sure they are not sensitive to the assumptions about the region just outside the channel.

We have done two other papers on this access issue, which I attach. The Luchinsky one is really quite important because it shows NONLINEAR coupling between access region and the channel which is likely to be very important in some cases.

If you are interested, I imagine Prof. Shen and Liu can help you with a singular perturbation analysis of the narrow channel case and Prof. Weishi Liu (Kansas) will be at Suzhou and can talk to you about a GEOMETRICAL (and rigorous) perturbation theory for that case and (maybe) for the access problem as well.

As ever
Bob

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5 attachments

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