14th Workshop on Two-Phase Flow Predictions
Halle (Saale), Germany, 07.–10. September 2015

Separation Effects and Orientation Statistics of Fibres in Coiled-Pipe Suspension Flow

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KEYWORDS. Fibre suspension, Euler-Lagrange Simulation, Dean Flow, Multiphase Flow, Particle Size Separation, Tube Flow Fractionation

ABSTRACT

Suspension flow of elongated non-spherical particles, i.e. fibres, is widespread in industry, including the pulp and paper sector. Previous experiments of fibre suspension flow in coiled pipes (Laitinen, 2011) indicate an axial separation effect of fibres according to their length. Unfortunately, the exact reason behind this separation effect is still unclear, together with a conclusive mechanistic and quantitative description.

In this talk we will present our recent advances in the simulation of fibre suspension flow in coiled pipes. Simulation of the flow field is performed using OpenFOAM® (version 2.3.0), as well as the CFDEM® package, supplemented with new force and torque models. Fibres are modelled as stiff spherocylinders, which interact with the fluid through hydrodynamic forces and torques following the ideas of Lindström and Uesaka (Lindström, 2007). Interactions with the curved walls rely on a newly implemented spherocylinder-triangle distance calculation.

Fluid flow in coiled pipes is simulated directly following the ideas of Piazza and Ciofalo (Piazza, 2011). Simulation settings of our study cover moderate Reynolds numbers (*Re*) and curvature (κ), yielding steady-state and oscillating Dean flows. For oscillating Dean flow, the overall flow is not chaotic, but Dean vortices fluctuate periodically. Since the Dean flow is expected to mix fibres in the torus' cross section, oscillations of the Dean vortex might influence fibre mixing. Fibres are initially positioned and oriented randomly in the flow field. Simulations are performed for three fibre aspect ratios to illustrate the shape-dependency of the separation effect with a fibres density ratio of 1.3. Results (see figure 1) show a preferred accumulation of fibres in the pipes cross section depending on their size. Amongst other factors, intensity of the secondary motion proofed to have an effect on the separation. Findings are in qualitative agreement with literature data, as well as our own experiments that indicate that the fibres' aspect ratio affects the average relative fluid-particle speed.

Finally, we will present an in-depth statistical analysis of the fibres' spatial distribution, fibre orientation, and fibre velocity distribution. We conclude with a comparison of results obtained from the CFDEM® simulations and experimental studies performed with the Tube Flow Fractionator.

Acknowledgement
JDRP and SR acknowledge funding through the FLIPPR project (www.flippr.at), as well as the "NAWI Graz" project by providing access to dcluster.tugraz.at.

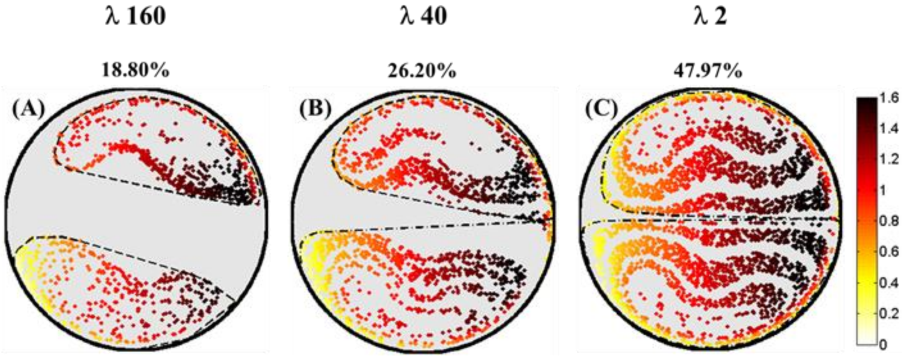

Figure 1 Fibre position in the tube cross section at t = 190. Figure A to C present results for fibres of aspect ratio λ equal to 160, 40, and 2. Fibres are colored by their stream-wise velocity. The number above the cross section states the fraction of fibres found in the upper half of the cross section. Case settings are Reynolds number Re of 3316 and curvature κ of 0.043.

REFERENCES

O. Laitinen, K. Kemppainen, T. Stoor, and J. Niinimäki, "Fractionation of Pulp and Paper Particles Selectively by Size", BioResources 6:672-685 (2011).
I.D. Piazza, and M. Ciofalo, "Transition to turbulence in toroidal pipes", J. Fluid Mechanics 678:72-117 (2011).
S.B. Lindström, and T. Uesaka, "Simulation of the motion of flexible fibers in viscous fluid flow", Physics of Fluids 19:113307 (2007).