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IMMERSED BOUNDARY METHOD APPLIED TO SIMPLIFIED DRILLING PROBLEMS

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ABSTRACT

Flows found in well drilling processes are much more complex than the flows often studied, as Taylor-Couette and Taylor-Couette-Poiseuille flows, because there are other additional characteristics, for instance: eccentric movement determined by the interaction of internal and external flows and fluids with changeable viscosity due the stress rate (non Newtonian fluid). In this context, a project was initiated in order to develop a computational tool to analyse flows associated with the drilling technology in deep waters using the immersed boundary method (IBM) with physic virtual model (PVM) to represent the fixed and moving channels. This paper presents the first three-dimensional results of internal flows using IBM with PVM methodology applied to three simplified drilling problems: Taylor-Couette flow, Taylor-Couette-Spiral flow and eccentric Taylor-Couette flow.

The IBM methodology uses a Cartesian grid for the Eulerian domain and a Lagrangian grid to the solid interface domain. The IBM (Peskin, 1977) considers an additional Eulerian force, which represents the force that the solid interface excerts over the fluid, in the incompressible and isothermal Navier-Stokes equations. The Eulerian force is obtained from the distribution of Lagrangean force through a distribution Gaussian-like function. The interfacial force is modelled using de PMV proposed by Lima e Silva et al. [1], that consist in apply a momentum balance over the interfacial surface. The finite volume method is applied with a staggered Eulerian grid and second order temporal-spatial schemes were used. The governing equations were solved with a fractional time-step method. Initially, the validation was performed for laminar Hagen-Poiseuille flow by comparing with analytical solution (White, 2005).

The computational domain is defined by $L \,\mathrm{x}\, L \,\mathrm{x} 0.6\, L$ dimension in x, y, z directions, where L is height. Bur, the interest domain is formed for annular space between two cylindrical channels of radii R_i (inner) and R_o and axial length L_a. The numerical analysis was performed for several values of Taylor number (Ta) and Reynolds number (Re), fixed radius ratio R_i/R_o = 3.2, aspect ratio $L/R_o = 1$ and rotating anticlockwise inner channel. A periodic boundary condition was used in axial direction and a non-uniform Eulerian grid of 42x42x24. Fig. 1 shows the Taylor-Couette and Taylor-Couette-spiral flows (with imposed axial velocity at inner channel) through the axial velocity and the velocity vectors fields. In Fig 1(a) one can bee a pair of counter-rotating vortices (Taylor vortices) with forced wave-length of L/R_o . In Fig 1(b) one can

find Taylor vortices and an undulated axial flow (winding flow [2]), that represent helical structures and that advect the Taylor vortices in axial direction. For $Re = 25$, only helical structures remain. This results agree with experimental and numerical dates of [2,3].

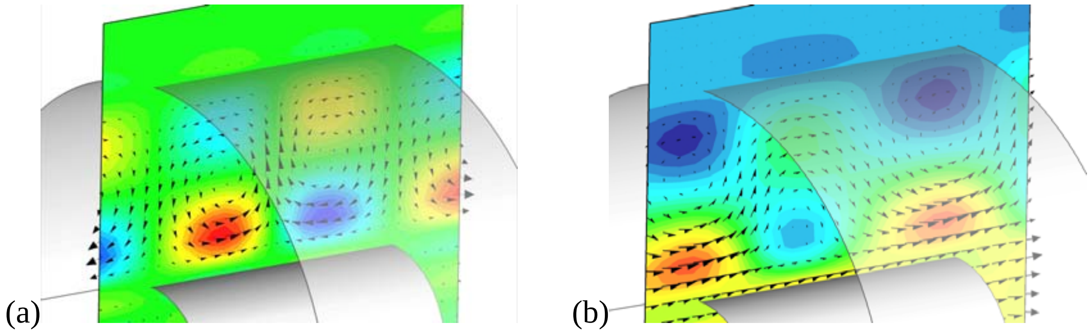

Figure 1. Concentric annular flow at $Ta = 100$; (a) Taylor-Couette flow , (b) Taylor-Couette-Spiral flow at $Re = 17$.

On the outer hand, for Taylor–Couette flow with eccentric movement was defined the eccentricity parameter $\varepsilon = 0.182$. After permanent regime attain with fixed eccentricity (initial position, Fig. 2a), the periodic movement of inner channel, around the central line of the outer channel, begin with frequency of $4\pi \ s^{-1}$, as visualized in Fig. 2. In this figure, instantaneous axial velocity iso-surfaces are shown, where the counter-rotating structures deform along a tangential direction as function of the space annular reduction and the effects of inertia. Up to $Ta = 140$, the Taylor vortices remain stables.

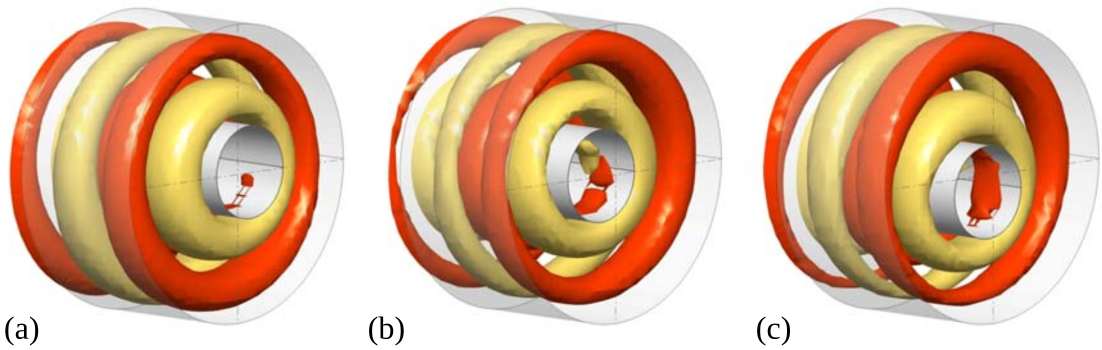

Figure 2. Eccentric Taylor-Couette flow to $Ta = 100$ at three instants; (a) 4.0 s , (b) 4.25 s, (c) 4.35 s.

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REFERENCES

[1] A.L.F. Lima e Silva, A. Silveira-Neto and J.J.R. Damasceno, “Numerical Simulation of Two-Dimensional Flows Over a Circular Cylinder Using the Immersed Boundary Method”, *J. of Comp. Phys.*, Vol. **185**, pp. 351–370, (2003).

[2] R.M. Wereley and R.M. Lueptow, “Velocity Field for Taylor-Couette Flow with an Axial Flow”, *Phys. Fluids*, Vol. **11**(12), pp. 3637–3649, (1999).

[3] J-Y. Huang and K-S. Yang, “Numerical Study of Taylor-Couette Flow with an Axial Flow”, *Comp. & Fluids*, Vol. **33**(12), pp. 97–118, (2004).