Eccentric Taylor-Couette Flow with orbital motion of the inner cylinder

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The flow in a Taylor-Couette system is one of the most explored flows we know today. It is characterized by parameters like Reynolds number, radius and aspect ratio. If one look at devices such as journal bearings there are more parameters like changing eccentricity or displacement track of the shaft which additionally influence the flow. The final goal of the current project is to develop a 3D simulation tool for hydrodynamic journal bearings which resolves effects like crossflow from the oil feedings and also cavitation. Known methods based on the Reynolds equations fail to predict important flow characteristics in complex bearing geometries (like crossflow) due to their 2D nature. If sufficiently low local pressure areas occur cavitation-related damages may appear. That is why we are interested in the pressure distribution of the flow. On the way to reach this final abovementioned goal we developed at first an idealized journal bearing setup (Fig. 2, left) without oil feedings to estimate the numerical efforts. Here we choose a Taylor-Couette system with prescribed circular trajectory of the rotation axis of the inner cylinder as opposed to the usually more complex (Fig. 1) displacement of shaft that is governed by the flow and external loads.

Figure 1: realistic offset tracks: left [1], right [2]
We consider two cases. In the first case we look at a trajectory leading to constant eccentricity (Fig. 2 middle). In the second case we consider oscillating eccentricity (Fig. 2 right). The latter will be used as a benchmark for the simulation code. We use an incompressible finite-volume solver that solves the Navier–Stokes Equation on a moving mesh. The fluid is considered to be Newtonian.

![Figure 2: simple bearing model (left), idealized offset tracks leading to constant (middle) and oscillating (right) eccentricity](image)

The simulation starts concentric. The inner cylinder rotates overcritically and the flow develops Taylor vortices (TV). After an initial period the rotating inner cylinder moves on an orbital path. The eccentricity increases and exhibits its maximum value after half of the orbit. There is a range for eccentricities associated with relatively small gap widths where TV are suppressed (Fig. 3). This is the detailed benchmark for code. One should find onset and decay of TV during one orbit. Another tested parameter is the period of the orbit. If it will be too fast, the Taylor vortices couldn’t develop. There can be found interesting structures if the orbit is around the viscous time scale. In the smaller gap smaller vortices will arise and in the larger gap exists larger ones. There can be found a transition between 20, 22, and 24 vortices due to the choosen aspect ratio and the different gap widths.

Typically, however, these vortices do not appear in lubricant films such as those of journal bearings because of the very complex offset tracks and the extreme small dimension of the gap width. Fig.4 shows typical Reynolds numbers for journal bearings.

Furthermore there are less 3D numerical investigations for Taylor-Couette Systems with rotating eccentric inner cylinder and additional (orbital) motion. One of them is about the flow around a drilling rod during the oil production [3].
Figure 3: critically Reynolds number for Taylor Vortex Flow to the eccentricity

Figure 4: typically Re for journal bearings

References

