Computational modeling of Taylor's vortices by the interaction between rigid body and liquid

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Abstract

The case of a thin layer of liquid between two rigid cylindrical surfaces is a phenomenon, which occurs very often, in technical applications. The cylinders either turn (for example journal bearings) or don't turn (for example SQUEEZE film dampers). During certain conditions, especially when the cylinders are rotating, unstable flow can be seen. This unstable flow during the transition from laminar to turbulent flow contains Taylor's whirls. The problem concerning flow with Taylor's whirls was first analyzed on the basis of experiments. It wasn't until later that many scientists tried to analyze the problem using computational methods. The Reynold's number is used for setting the boundary between laminar and turbulent flow. The Taylor's number, which has the form $\mathrm{Ta} = \left(rwd^{3/2} R_1^{1/2} \right) / h$, is used for setting the boundary for the formation of Taylor's whirls. When $\mathrm{Ta} \geq 41.2$ then Taylor's vortices are formed in the flow.

This contribution is aimed at the problems of computational modeling of dynamic properties of thin liquid films. The base equations are the Navier – Stokes equation, continuity equation and the boundary conditions. A three-dimensional model is analyzed with two types of boundary conditions on the face perpendicular to the axis of the shaft. In the first condition the pressure is set (speed is calculated) and in the second condition the speed is set (pressure is calculated). On the inner and outer surfaces the speed of the liquid and body is the same.

For the analysis of liquid flow, the method of control volumes is used. The equation of motion and the continuity equation are integrated through a pre-determined control volume where the Gauss–Ostrogradsky theorem is utilized. The Bézier body is used for approximating the solution as well as describing the geometrical area. For the solution it is important to assume that both the position of the shaft center as well as the speed and pressure are given by the sum of the stationary and non-stationary parts. For this reason the entire analysis is comprised of two steps. In the first the stationary part is analyzed and in the second the non-stationary. It is possible, in both steps, to use a suitable transformation to separate the movement of the body and liquid from each other. It is this separation which gives new insight on solving this problem.

Non-stationary analysis allows solving the eigen-value problems, which forms the base for analyzing Taylor's whirls. The contribution will introduce the theoretical approach to the solution as well as the modeling test case results.