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FE-MODELING OF STARVED HYDRODYNAMIC LUBRICATION WITH FREE SURFACE EFFECTS

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Abstract. This work concerns a new finite-element formulation for solving hydrodynamic lubrication problems that include partially flooded regions, where the lubricant film behavior is governed by free surface flow.

Two rigid solids separated by a lubricant film are considered with the film assumed to remain attached to the lower of the solids. Depending on the amount of available lubricant the film may touch the upper solid or not, resulting in two distinct versions of the thin film flow equation with different boundary conditions at the top surface of the lubricant film. In fully flooded regions, the upper boundary of the film and its velocity are prescribed by the geometry and motion of the upper solid, while in partially flooded regions, a condition of prescribed pressure is employed with a capillary term superimposed to a given environmental pressure. These two distinct regimes are formulated as a complementarity problem with both a pressure field and a film thickness field as unknowns.

Due to the specific structure of the resulting equations, a C^1 continuous approximation of the film thickness field is required. In this work, both unknown fields are actually approximated with quadratic B-spline functions and the finite-element discretization of the governing PDEs is based on the Galerkin procedure. A new stabilization method is proposed to avoid oscillatory solutions around nearly discontinuous transitions of the film thickness field, which is is a consistent one, in the sense that it vanishes as the mesh is refined sufficiently.

The behavior of the developed model is illustrated by means of numerical examples and a parametric study with respect to different model parameters is presented in addition to mesh convergence studies.

Keywords: Hydrodynamic Lubrication, Thin Film Flow, Free Surface Flow, Finite-Element, Stabilization.