SOLVING THERMOHYDRODYNAMIC PROBLEMS IN SLIDER BEARINGS: FINITE DIFFERENCE OR FINITE VOLUME METHODS?"

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Abstract

The thermal effects in fluid film lubrication are known since a long time, but it is mainly during the last fifty years that researchers analyzed their influence on the behavior of (hydrodynamic) bearings. In 1962, Dowson generalized the Reynolds equation in order to take into account the local thermal effects. The thermohydrodynamic (THD) solution requires the coupled solving of the generalized Reynolds equation, the energy equation in the fluid film and the heat transfer equation in the bearing elements, applying realistic boundary conditions. Simple approaches were initially proposed, using a global energy balance or other simplified assumptions like infinite bearings. The availability of computers has then permitted the development of THD bearing software.

Different numerical methods and algorithms were proposed. Because of their simplicity, the finite difference methods (FDM) were firstly employed: it was easy to solve the case of the plane-inclined slider bearing operating under usual conditions. The journal bearing case was a little bit more complex because of the rupture zone and because of the recirculation of hot oil and the mixing in the feeding groove. The major problem induced by this method appeared in the cases where a backflow occurred at the inlet zone of the lubricated film (a high shaft eccentricity or a large inlet to outlet film thickness ratio): several techniques were proposed in order to obtain the THD solution. A description of the method we used is presented for the case of the plane-inclined slider bearing.

Finite element methods (FEM) were also used by numerous researchers and they are still used, mainly for the analysis of both thermal and solid deformation effects, i.e. under thermoelastohydrodynamic (TEHD) regime. Compared to FDM, FEM is significantly more complex and difficult to program, but it permits the modeling of complex domains with severe backflows. FEM was the only alternative to finite differences methods for quite some time, until the introduction of the finite volume method (FVM), in 1972.

The finite volume method quickly gained ground in the field of computational fluid dynamics (CFD), becoming nowadays the base of most commercial CFD codes. Compared to FDM or FEM, the finite volume approach has the advantage of enforcing the flow continuity (mass conservation), while also being the simplest method to program. It is also the easiest method to teach, being directly related to physical phenomena rather than mathematical treatment of the different equations. Complex geometries as well as severe recirculation are modeled with ease, thus providing a simpler alternative to the FEM. The FVM was not easily adopted by tribologists, despite its first application in THD bearing simulations dating from 1990. With the increasing complexity of the studied configurations (high eccentricities, hydrostatic-lift pockets, inlet grooves), the FVM gained ground and is becoming more and more popular in the field of tribology.

Comparison between the FVM and FDM solutions is done for the plane-inclined slider bearing. The thermohydrodynamic problem of the pocket slider bearing is also presented and discussed. Other applications where the finite volumes method proved very convenient (the mixed lubrication of hydrodynamic bearings, the lubrication of textured surfaces) are briefly presented.