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A finite element fully-coupled approach to solve EHD problems - How to build an EHL solver in less than ten minutes?

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1. Introduction

Nowadays, scientific and technical studies have to be carried out quickly with the lowest achievable cost and reliable results. This is why numerical approaches are more and more taking over experimental ones. Over the last few decades, the trend in EHL modelling was to develop finite difference home made codes based on a semi-system resolution of the different equations involved (i.e.: these are solved separately and an iterative procedure is established between their respective solutions). Some advanced techniques had been developed to improve the performance of these models. These advances involve sophisticated techniques that make these codes more and more complex. In addition, their implementation requires much of expertise and restricts their use to well experienced people. In this paper, the authors present a more user friendly approach based first, on a finite element approach, and second, on the use of advanced numerical tools that allow building an EHL solver from scratch in less than ten minutes…

2. Finite Element Full-System approach

The method employed in this work is based on a finite element fully-coupled Newton-Raphson resolution of the EHL equations (Reynolds, Elasticity and load balance equations).

Find (P,U,H_0) such that $\forall\left(W_P,W_U,W_{H_0}\right)$, one has:

$$\begin{cases} \int_{\Omega_c} -\varepsilon \nabla P \cdot \nabla W_P \, d\Omega + \int_{\Omega_c} \bar{\rho} H \frac{\partial W_P}{\partial X} d\Omega - \int_{\Omega_c} \xi \cdot P^{-} W_P \, d\Omega = 0 \\ \int_{\Omega} -C\varepsilon_s(U) \cdot \varepsilon_s(W_U) \, d\Omega + \int_{\Omega_c} -P \cdot \vec{n} \, W_U \, d\Omega = 0 \\ \int_{\Omega_c} P W_{H_0} d\Omega - \frac{2\pi}{3} W_{H_0} = 0 \end{cases}$$

Where Ω corresponds to the geometrical domain of the solid bodies and Ω_c to that of the contact area on the surface of Ω. The free boundary problem arising at the outlet of the contact is handled using a penalty method [1]. The latter consists in using a penalty term ξ that forces the negative pressures that arise at the exit of the contact towards zero. Special stabilized formulations based on artificial diffusion techniques are used to extend the solution towards highly loaded contacts which are known to be particularly difficult to solve [2]. Besides being fast and easy to implement, this model also appears to be easy to handle due to a friendly graphical user interface (See *Fig. 1*). This makes it more flexible for introducing complex and realistic rheological models. From a performance point of view, it can compete with the state-of-the-art models due to its fast convergence properties. These stem from the full-coupling of the different equations (i.e.: these are solved simultaneously) and the use of the Newton method which is known to have fast convergence properties when the initial guess for the solution is chosen suitably. In addition, the use of the finite element method enables non-regular non-structured meshing which considerably reduces the size of the matrix system to solve, compared to finite difference based models.

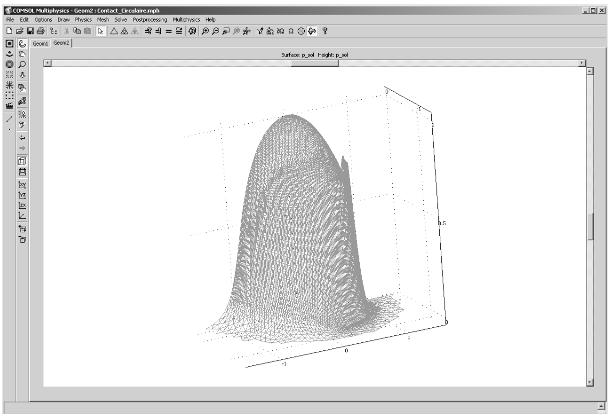

Figure 1: Scheme of the friendly graphical user interface of the current model

3. Conclusion

The current paper provides an alternative less complex approach to modeling EHL problems. Besides being easy to tackle, this approach also provides an attractive computational performance, satisfying the never-ending demand for reduced cpu times…

4. References

[1] Wu S.R., “A Penalty Formulation and Numerical Approximation of the Reynolds-Hertz Problem of Elastohydrodynamic Lubrication”. *International Journal of Engineering Science*, 1986; **24 (6)**: 1001-1013.

[2] Habchi W, Eyheramendy D, Vergne P and Morales-Espejel, G. A, “Full-System Approach of the Elastohydrodynamic Line / Point Contact Problem”, *ASME Journal of Tribology* 2008; **130 (2)**, DOI: 10.1115/1.2842246.

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