Numerical study of lubrication properties of dry granulates and suspensions

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1. Introduction

Conventional liquid lubricants fail to perform adequately in extreme environments, i.e. at high temperatures and loads. As an example, modern turbine engines require bearings which can operate at up to 800 °C under loads of several MPa at relative velocities of up to 50 m/s. Granular lubricants are promising candidates for such applications [1]. Also under less extreme thermal conditions strong load bearing capabilities might be required in heavy machinery which can only be met by greases, pastes or dispersions.

2. Aims

Our goal is to establish a simulation framework for analyzing the lubrication behavior of complex fluids ranging from non-newtonian and viscoelastic fluids over dilute and dense suspensions to granular systems. The gathered knowledge should be beneficial for the design and optimization of tribological systems where not only friction minimization is important but also the ability to carry large normal loads.

3. Method

The particle-based simulation techniques we use are smoothed particle hydrodynamics (SPH) and the discrete element method (DEM). In DEM simulations each individual physical grain is represented by a discrete element which can be a sphere or can also have a more complex geometry [2]. Different grains interact by physical force laws such as Hertzian repulsion, Johnson-Kendall-Roberts cohesion or an Amonton friction law.

In SPH simulations the volume to be simulated is divided into particles, or rather "fluid lumps", and thereby the governing Navier-Stokes equations are converted into equations of motion for the center of mass ofthese particles. This approach allows free surfaces and multi-phase flows to be readily considered. Complex rheological behavior such as shear thinning, thixotropy or viscoelasticity can be taken into account by modifying the interactions of the fluid lumps.

Suspensions can be modeled explicitly by coupling discrete elements representing dispersed solids with the SPH fluid lumps [3]. Furthermore, it is also possible to model rigid walls as well as flexible walls (fluid-structure coupling). The associated deformation is modeled using elastic or plastic material laws.

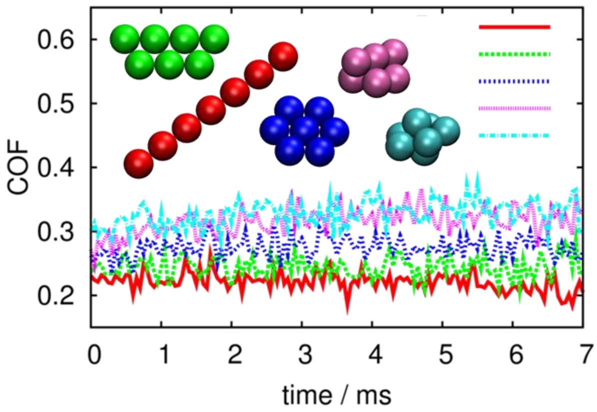

Fig. 1: Friction dependency on grain shape in dry granular lubrication.

4. Conclusions

The model ingredients enable us to study the dynamics of rough surfaces in relative motion with various types of rheologically complex lubricants.

In dry granular lubricants the effect of grain shape on the coefficient of friction will be presented (Fig. 1). Suspensions will be analyzed with respect to the transition between liquid and granular lubrication (Fig. 2).

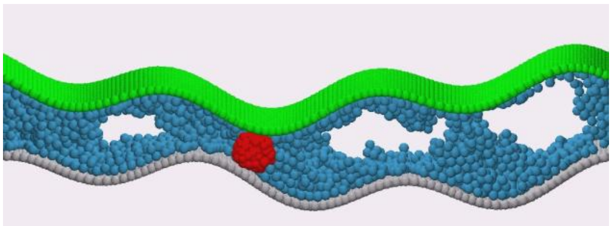

Fig. 2: Simulation snapshot of a lubricant with dispersed solid particle between rough surfaces.

5. References

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[3] Bierwisch, C., Kübler, R., Kleer, G., Moseler, M., *Phil. Trans. R. Soc. A* **369**, 2011, 2422–2430.