Effects of confinement-induced non-Newtonian lubrication forces on the rheology of a dense suspension

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Modelling concentrated suspensions in particle-based methods is typically performed taking into account short-range Newtonian-approximation lubrication contributions,\textsuperscript{1} with instances of contact frictional forces.\textsuperscript{2} From tribology, macroscopically Newtonian liquids under strong confinement exhibit significant deviation from their bulk behavior,\textsuperscript{3} in the form of strong thickening and shear-thinning when sheared within extremely small gaps. This is connected to the significant zero-shear-rate viscosity increase under extreme confinement reported by Jabbarzadeh et al.,\textsuperscript{4} rising several orders-of-magnitude over its bulk value, and which has been interpreted as a glass transition.\textsuperscript{5} This supports the idea that a lubricant’s fluid-like description is still appropriate under strong confinement. In this work, we assume a purely-hydrodynamic (frictionless lubrication) inter-particle interaction description and explore the effects of confinement-induced non-Newtonian lubricant rheology on the material properties of concentrated suspensions. We start from and use the effective lubrication algorithm proposed in Prasanna Kumar et al.\textsuperscript{1,6} and develop a new gap-size-dependent biviscous lubrication model able to capture qualitatively the main phenomenology of confined lubricants. In contrast to pure Newtonian lubrication interactions, distinct suspension viscosity thinning and thickening regimes are observed and discussed in terms of particle micro-structure and the lubricant rheology. In addition, normal-stress response is negative in both $N_1$ and $N_2$, which is difficult to achieve with contact frictional models.

\textsuperscript{1} S.S. Prasanna Kumar et al., J. Comp. Phys. 427, 110001 (2021).
\textsuperscript{4} G. Luengo et al., Wear 200, 328 (1996).