Multiphysics Simulation of Needle Clogging in Prefilled Syringes

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Introduction

Needle clogging in prefilled syringes can occur during long-term storage or during storage under non-ideal conditions. Such clogging can impede drug product injection and negatively impact drug product quality.

Computer simulations provide a useful tool to understand clogging mechanisms and elucidate design strategies to minimize or avoid clogging. In this poster, we present simulations of clogging in a needle syringe prefilled with a particulate suspension.

Methods

Veryst used computational fluid dynamics (CFD) to simulate the flow of a particulate suspension through a needle syringe under a steady applied plunger force. Clogging is said to occur above a threshold force of 20 N.

Rheological data for a surrogate fluid, cornstarch in a glycerol-water mixture, was used model the non-Newtonian fluid mechanics [1]. The particle diameter and volume fraction were varied in the simulations to determine their effect on the plunger force and clogging probability.

Results

Shear rheology data for the surrogate fluid exhibits discontinuous shear thickening above a critical volume fraction, which leads to clogging (Fig. 1).

Veryst fit the rheological data (markers in Fig. 1) to a non-Newtonian fluid model (dashed curves) to capture the rapid rise in viscosity [2]. Fluid mechanics simulations with this rheological model show a rise in the plunger force for large particles at high volume fraction. The microscopic mechanism of this rise in plunger force is depicted in Fig. 2. As the suspension flows from the barrel hub into the needle, initially well-lubricated particles are brought into frictional contact. When a sufficient number of particles are in frictional contact, the suspension clogs.

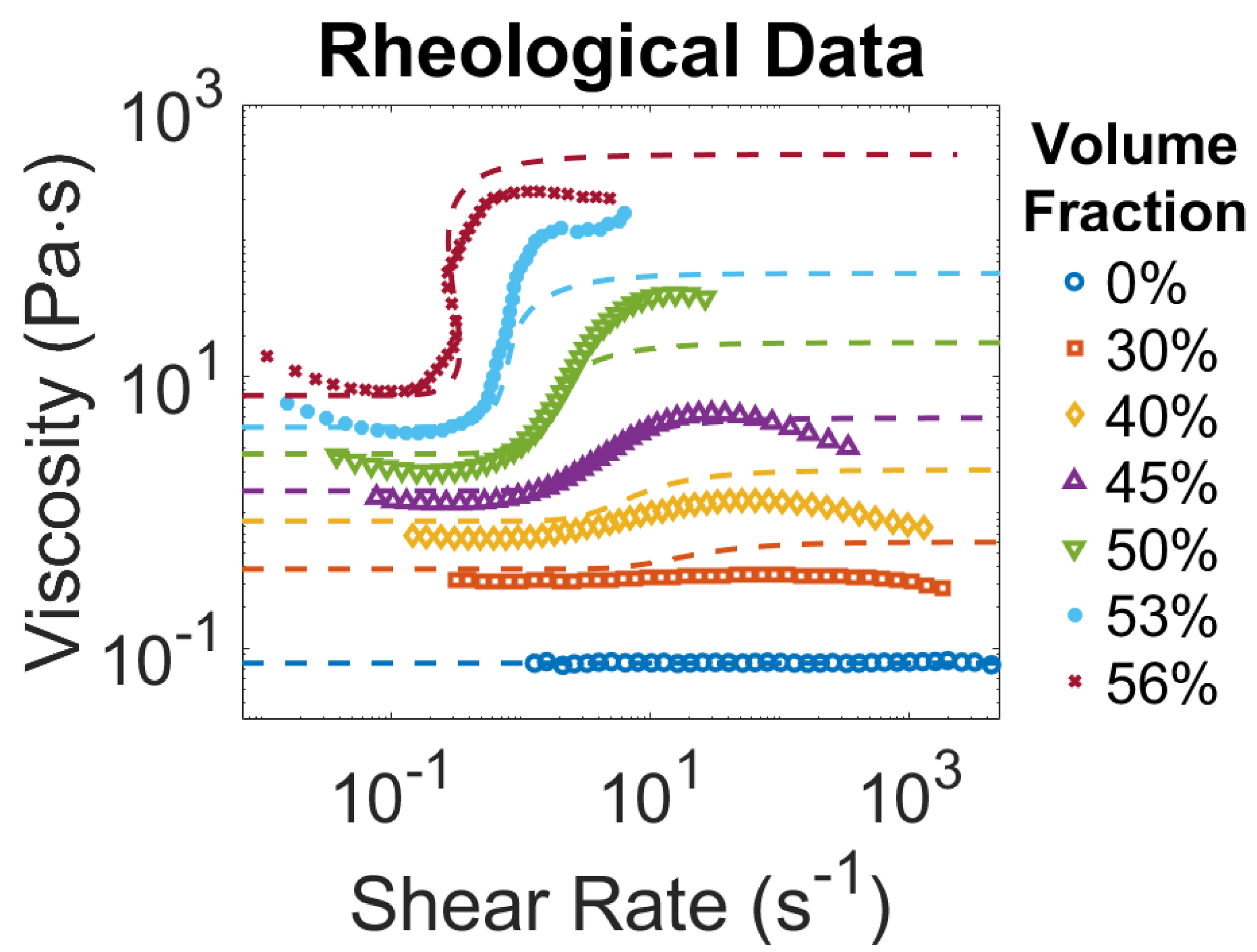


Fig. 1: Shear rheology of cornstarch in glycerol-water mixture at various volume fractions [1]. Dashed lines show model fits [2].

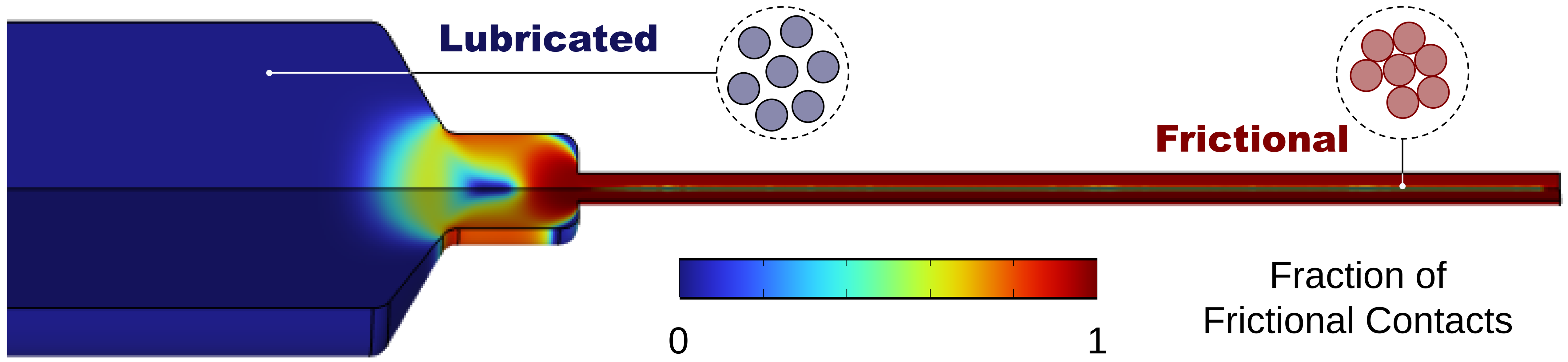


Fig. 2: CFD simulation of a particulate suspension through a syringe needle (volume fraction of 50%, particle diameter of 10 μm). Contours show transition from lubricated to frictional particle contacts, which leads to shear thickening and clogging.

References

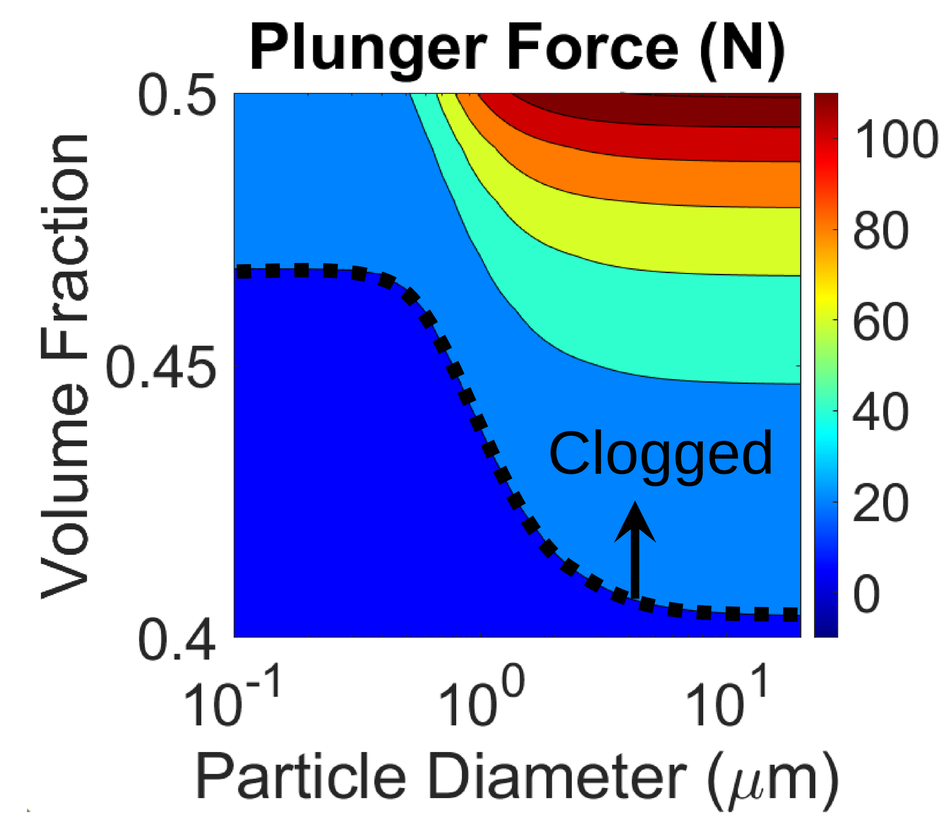
[1] E. Brown & H. M. Jaeger (2012) *J. Rheol.* 56.4, 875-923

[2] M. Wyart & M. E. Cates (2014) *Phys. Rev. Lett.* 112.9, 098302

Discussion

Simulations of suspension flow through needle at various particle diameters and volume fractions enable prediction of the 20 N threshold for clogging (Fig. 3, dashed line). Smaller particle diameters (< 1 μm) clog above a volume fraction of 47%, whereas larger particles (> 1 μm) clog above around 40%.

Fig. 3: Contours of plunger force as a function of suspension properties. Dashed line shows the 20 N clogging threshold.



Conclusion

Veryst employed CFD simulations to predict clogging of a particulate suspension flowing through a syringe needle. An operating diagram based on a maximum allowable plunger force predicts higher risk of clogging for larger, more densely packed particles. The onset of clogging was correlated to the transition from lubricated to frictional particle contacts as the suspension enters the needle. Simulations such as these can help predict and remediate clogging in prefilled syringes, which ultimately lead to savings in development time and cost and reduced risk.