Appendix A

Inferred torque for zero shear rate

Depending on the loading fraction and density ratio, the best curve fit for the measured torques as a function of shear rate does not always go through the origin. Figure A.1 shows the inferred value of the liquid-solid flow's torque at $\dot{\gamma} = 0$ for density ratio of 1 and 1.05. The value was inferred considering the best fit for the lowest Stokes numbers measurements. For the case of $\rho_p/\rho = 1$, the curve fit considers all the points and for $\phi \leq 30\%$, the intercept torque is zero since the data is best fitted by a power law. For the case of $\rho_p/\rho = 1.05$, a linear fit is considered for the first three points. The intercept torque increases with loading fraction for the case with settling particles, indicating a presence of a yield stress for these flows. For the case with density ratio equal to one the intercept torque is equal or close to zero for all the loading fractions tested.

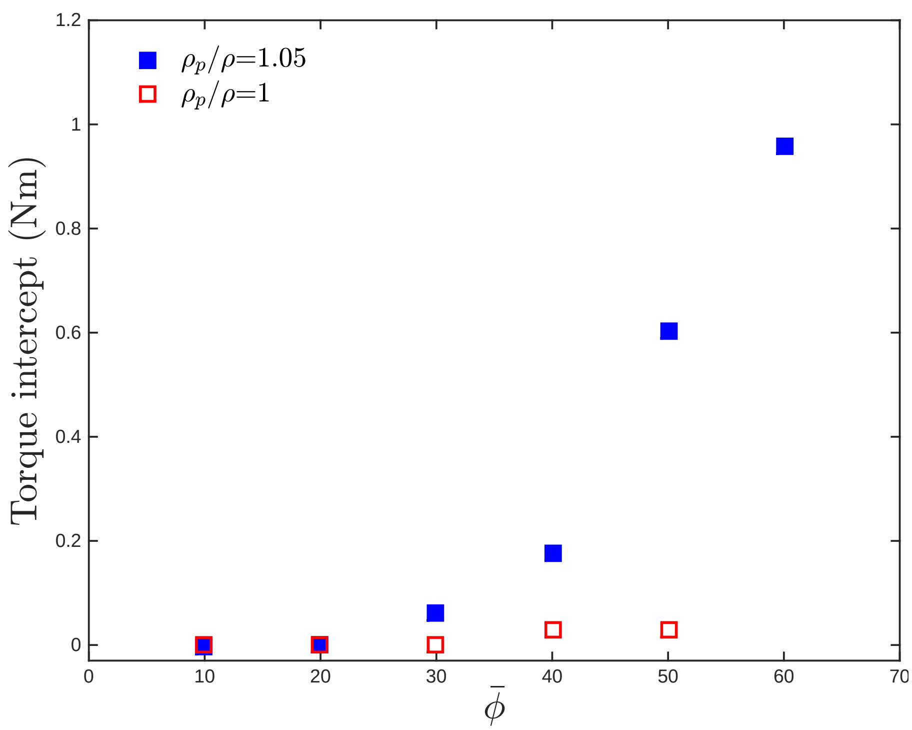

Figure A.1: inferred torque at the origin for $\rho_p/\rho = 1$ and $\rho_p/\rho = 1.05$.

For the experiments with flow over a porous medium, a linear fit for the first three points was considered. Figure A.2 shows the intercept torques for this case. There is more than one intercept torque for each loading fraction and it corresponds to the experiments with increasing and decreasing shear rates. The intercept torques exhibits a linear behavior with respect of the loading fraction, which is different from the behavior observed for the case without porous medium.

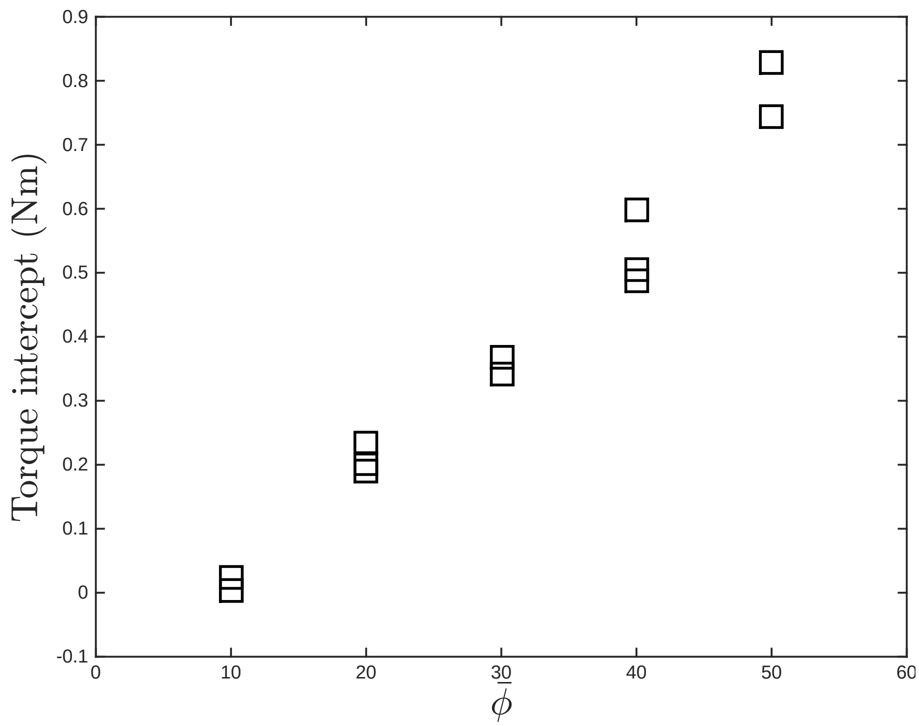

Figure A.2: inferred torque at the origin for flow over porous medium as a function of the loading fraction.$\rho_p/\rho = 1.05$.

Comparison between the intercept torques corresponding to flow with and without porous medium is presented in Figure A.3 as a function of the loading fraction. The intercept torque increases with loading fraction for the cases with settling particles. However, the intercept torque dependance on loading fraction is different for the case with a porous medium. The effective volume fraction for the two cases is significantly different than the loading fraction and these differences lead to differences in the intercept torque, which seems to depend on the particles' column height. For this reason the intercept torques are plotted against the normalized particles' column height in Figure A.4. The intercept torques for the experiments without a porous medium are closer to the intercept torques with a porous medium; however it does not exactly coincide for normalized heights. The reason for this discrepancy might be due to the topology of the particles' top surface. For the case with h_s/h_t between 0.5 and 0.8, the intercept torques show the largest differences. This seems to indicate that the presence of a porous medium increases the yield stress of the flow. The reason for this is not clear.

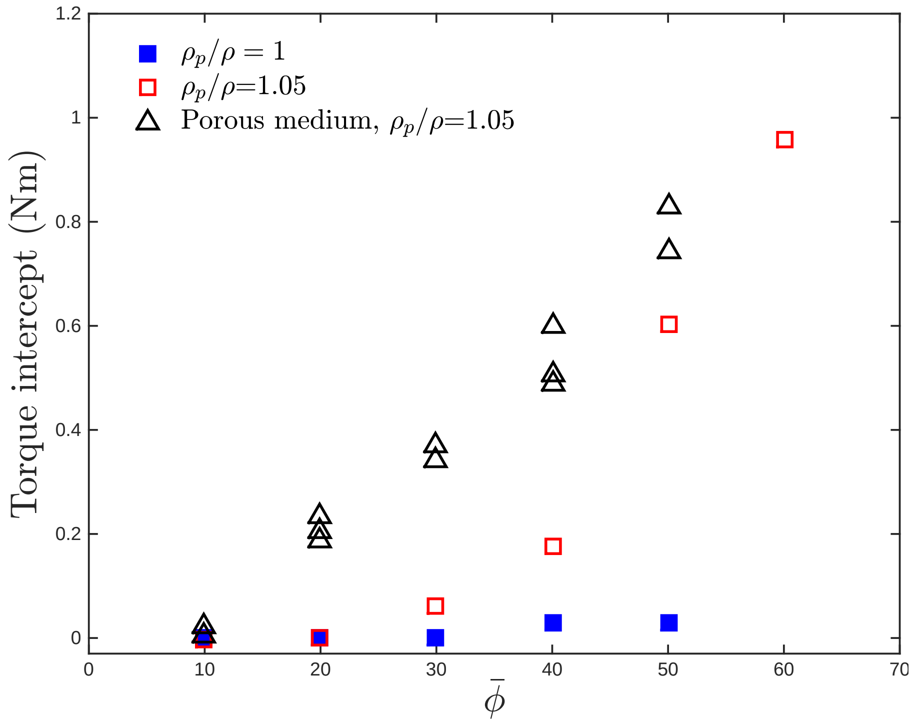

Figure A.3: inferred torque at the origin for flow with and without porous medium and $\rho_p/\rho = 1.05$, and $\rho_p/\rho = 1.05$ as a function of $\bar{\phi}$.

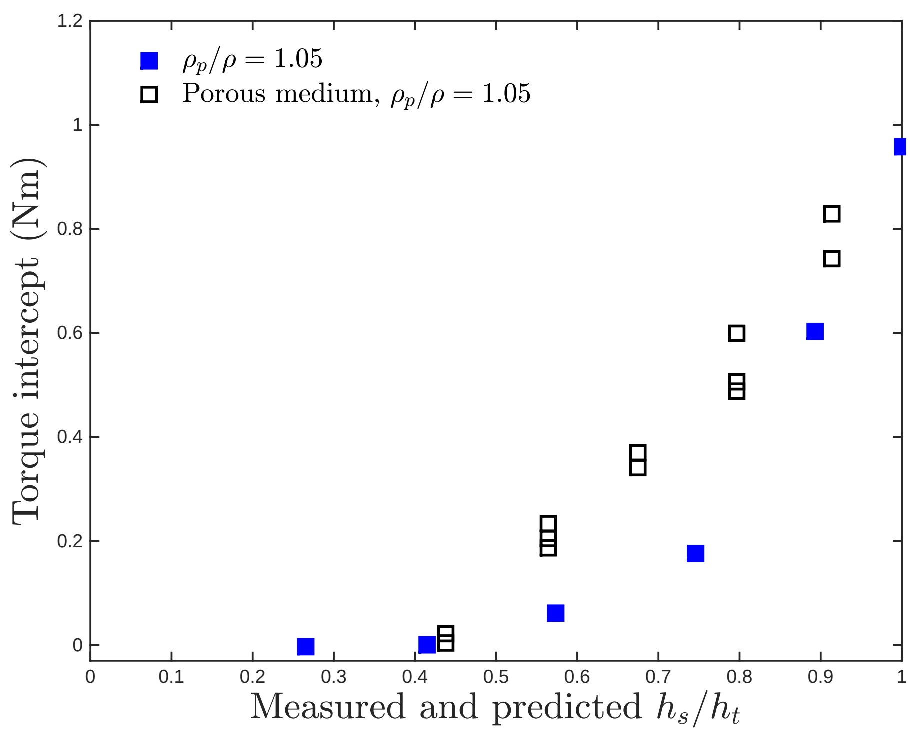

Figure A.4: inferred torque at the origin for flow with and without porous medium as a function of normalized settling height. $\rho_p/\rho = 1.05$.