Summary

In many geophysical situations and in all industrial applications, turbulent flows are wall-bounded. Many of these flows are multi-phase, i.e. flows consisting of one or multiple inclusions. The current understanding of these flows is still limited and this makes it important to study them. In this thesis we study these wall-bounded multi-phase flows in two canonical systems: Taylor-Couette flow and Rayleigh-Bénard convection.

First, we used rigid spherical neutrally-buoyant particles to investigate if we have reduced skin friction similar to bubbly drag reduction. The global torque measurements showed that these particles barely alter the drag, even at very large particle volume fractions. One would expect that adding particles increases the apparent viscosity and therefore, expect an increase in drag. This is however not found and we hypothesize that the drag reducing effect is competing with the drag increase from the increased apparent viscosity.

In real life, actual bubbles can have any shape, and this might be a key element in the drag reducing effect. To test this hypothesis we introduced cylindrical neutrally-buoyant particles into the system. While the drag response of the system was very similar to the spherical particles, we found that these rods show a preferential alignment with respect to the inner cylinder wall. This is very surprising as it was often hypothesized that a systematic alignment in such highly turbulent flows is not possible. We model the orientation of the fibers using the Jeffery equations which give a fair estimate of the shape of the alignment probability density distributions.

Using an immiscible fluid we are able to create deformable inclusions. We selected silicon oil with a viscosity similar to that of water and varied the oil volume fraction between 0% and 100%. We found two regimes: first we have oil droplets in water, that gradually increase the apparent viscosity until the inversion point. The second regime starts after the inversion where we have water droplets in oil. In this regime we find drag reduction and we think that this is due to much larger water droplets. Using an in-situ microscope we were able to confirm this hypothesis as the water droplets are more than 14× larger than their oil droplet counterparts.

To investigate the effect of non-perfect boundaries, we used another canonical system: Rayleigh Bénard Convection (RBC). Using direct numerical simulations, the boundaries were divided into equal stripes of conducting and insulating regions. While keeping the area identical and varying the amount of divisions we were able to get almost the same heat transfer as a fully conducting system. This means that small temperature imperfections are not visible by the bulk flow.

In the same spirit, we applied sand grain roughness onto the inner cylinder of the Taylor-Couette apparatus, thereby also creating inhomogeneous boundary conditions. By varying the periodicity of the rough/smooth patches, we were able to control the secondary flows. When the width of the roughness patches are similar to the gap size, we find an optimum in angular momentum transport. For the largest patches, we can reduce the secondary flows to only two individual rolls. This shows that different configurations of roughness can alter the flow structure tremendously.