VI
Conclusions

This thesis deals with viscoplastic materials, their rheological properties measurements, and their behavior in different kinds of flow. Moreover, a detailed analysis of flows such as viscometric, expansions-contractions, the displacements in capillary tubes, and the displacements inside oil wells was performed.

By the investigation of some viscometric flows of viscoplastic materials it was shown that if in one hand rather long times are needed in the low shear rate range so as to reach the steady flow from rest, on the other hand these times can be considerably shortened if the sample would have been previous sheared and no resting time was waited. This behavior was attributed to the fact that there is a minimum strain that needs to be attained so as to the steady flow can be reached. In addition, it was observed that apparent wall slip occurs mainly at lower shear rates as it was expected. However, the vane geometry performance in eliminating apparent wall slip was not as good as found in the literature. The grooved Couette obtained the best results in the rheological measurements realized in Carbopol dispersions without apparent slip.

The experimental and numerical analysis of expansions-contractions flows showed that this flow is governed by five dimensionless parameters. The displacement efficiency (volume of yielded material in the large-tube cavity / total volume of the cavity) was observed to increase with τ^*_R. Regarding rheological parameters, the displacement efficiency increases mildly with the jump number and decreases as the power-law exponent is increased. The dependence with the geometrical parameters was such that the displacement efficiency decreases with R_o/R and increases with L_o/R_o. A comparison between experimental observations and numerical predictions suggested that the stress intensity on the yield surface was actually higher than the yield stress ($\tau^* \simeq 1.5$), because at stresses below this value the viscosity value was still too high (Fig. III.4), and hence the velocity remains negligibly low.

By the results of chapter IV it was observed that, below a certain critical flow rate, the viscoplastic material is perfectly displaced by the pushing gas in capillary tubes. Just above this critical flow rate, which depends on the jump number, small lumps of unyielded material begin to deposit on the tube wall. As the flow rate was further increased, a smooth material layer of uniform thickness begins to form. The thickness of the layer was observed to increase with the dimensionless flow rate and to decrease as the jump number was increased.

And finally, the analysis of the displacements of viscoplastic materials inside oil wells showed that the upward displacement of a material by another in annular space regions becomes more efficient when the density and the viscosity ratio increases, and when the flow rate decreases. It means that the density and the viscosity of the displacing material needs to be higher than the displaced ones to perform a successful operation. This is true since the flow rate is higher enough to minimize the gravity effect in the downward displacement inside the inner tube, so as to avoid channeling due to the density ratio. In addition, the numerical results illustrated the prediction capability of numerical simulations of displacement operations. Simulating some operations before testing them in practice may save a lot of time and reduce costs dramatically. Therefore, computational non-Newtonian continuum mechanics can be a quite effective tool in the design of displacement operations inside oil wells.