AUTO-LUBRICATED FLOW AND PSEUDO-THIXOTROPY OF CONCENTRATED SUSPENSIONS AND PASTES

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Suspensions and pastes tend to yield stress and wall slip. The flow function of a plug flow is normally a power law function with a power law exponent much smaller than one, even if the matrix fluid is a Newtonian liquid.

Pure plug flow happens if the suspension has a yield shear stress and if the shear stress of the flow is lower than this yield stress. Exceeding the yield stress the material transport in a capillary is a superposition of two phenomena: Wall slip and shear deformation of the bulk. Separating shear and slip flow applying the Mooney method one can calculate the *relative slip velocity*: The ratio between slip velocity and the total volume rate. This relative slip velocity was found to be greater than one and sometimes even negative. The relative slip velocity of a plug flow is equal to one. Exceeding the yield stress, the relative slip becomes smaller. For many pastes the relative slip passes a minimum with increasing shear stress.

These phenomena can be described by a simple slip flow model, where the slip layer fluid is the matrix fluid itself (**auto-lubrication**) and where the slip layer thickness depends on the shear stress. The slip layer thickness is normally growing with increasing shear stress. This assumption explains why the apparent flow function of pure plug flows of suspensions with Newtonian matrix fluids normally increase very slowly with increasing shear rate. The slop is mostly much lower than one. E.g. the slop will be exactly equal to 0.5 if the slip layer thickness increases proportionally to the shear stress respectively the pressure drop.

Pastes often behave similar to Bingham or Hershel-Bulkley fluids. Exceeding the yield shear stress the relation between shear stress and slip layer thickness will change: The onset of the shear deformation of the bulk material entails an increase of the volume (porosity) of the bulk. Therefore the growing of the slip layer thickness with increasing shear stress is hindered.. In the mixed flow regime the relative slip becomes lower than one. If the slip layer thickness will further increase with the wall shear stress one gets a minimum of the shear stress - relative slip function. Depending on the slip layer function and the flow function of the matrix, the slop of the apparent flow function of the suspension is increasing or decreasing.

As a consequence of the stress dependent thickness of the slip layer, the auto-lubricated flow of suspensions and pastes show transient flow behaviour, which can easily be misunderstood as thixotropy. Therefore this phenomenon may be called as **pseudo-thixotropy**: Accelerating a shear flow suddenly to a higher steady state shear rate one observes a shear stress maximum followed by a fading shear stress towards lower steady state value. The reason for this transient behaviour is a time dependent increase of the slip layer thickness with growing shear stress. A shear stress minimum followed by a re-increase of the shear stress to steady state value is observed, if the shear flow is suddenly decelerated to lower shear rates.