Development and Persistence of 'Static' or 'Dead' Zones in Flows of Certain Materials

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In the extrusion of metals, pastes, clays, and other materials (as well as the flow of granular materials) a 'static' or 'dead zone' can occur in a corner or side-region where a Newtonian fluid might have a slowly flowing recirculation zone. Different materials may be creating a static zone for different reasons, or there may be some relatively simple physics behind a variety of phenomena.

In this workshop we would like to develop "simple" models which show a static zone.

The motivation for this inquiry is a better understanding of the flow of ceramic pastes in the extrusion of cellular ceramic structures ([1] for review). Recently I became aware of the remarkable effect on extensional viscosity which thin rigid needles can have ([2],[3],[4]) – whereas bubbles will reduce the viscosity of a fluid, they stretch with the extensional flow, but rigid nano-needles do not stretch and have a intriguingly large effect on viscosity.

{QUESTION 1} So my initial question is whether the fluid with needle-like particles will show static zones.

The flow of ceramic pastes is typically described as a Bingham plastic (yield stress and then Newtonian fluid) or Herschel-Bulkley fluid (yield stress and then shear-thinning fluid). In addition, we find that ceramic pastes show a slip at the wall rather than a simple no-slip condition often used for Bingham plastics ([5] – "Benbow-Bridgewater" equation).
However, these fluids did not exhibit dead zones when I modeled flow through a contraction many years ago – the fluid just flows slowly in the corners.

{QUESTION 2} What is a simple way to augment the description of the fluid rheology to correctly capture 'static zones' or 'dead zones'.

Googling "dead zones" and 'static zones' will generate a large number of references.

{QUESTION 3} Is it possible that a steady state model of extrusion produces an erroneous result and that a transient model will show the flow in corners to be slowing down and stopping? {[6] – [8]; looking for more references}

References

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