Measuring the viscous flow behaviour of molten metals under shear

Title: Measuring the viscous flow behaviour of molten metals under shear

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Abstract: The flow behaviour of liquid metals (Sn, Pb and Sn-Pb eutectic) under different shearing conditions is investigated. Experiments were performed with two designs of concentric cylinder viscometers: rotating the inner cylinder (Searle) and rotating the outer cylinder (Couette). The latter technique is uncommon and the equipment was optimised with standard oils. The flow behaviour for the metals differs in the two systems. The curves of "apparent" viscosity versus shear rate may be divided into two regimes: I. At lower shear rates (<200 s⁻¹): a reduction of "apparent" viscosity with shear was observed with both viscometers. It is suggested that the high density and high surface tension of the metals and eccentricity between the cylinders at low shear rates, leads to instabilities. Results at low shear rates were therefore discarded and further detailed analysis would be required for a fuller understanding of this behaviour. II. At higher shear rates: a steady, shear-independent behaviour of "apparent" viscosity with shear rate is observed in the Couette system (upto 600 s⁻¹) whereas in the Searle system the "apparent" viscosity increases with shear rate (upto 2600 s⁻¹). From hydrodynamic theory about Newtonian fluids, it is suggested that in the Searle type viscometer, the fluid is unstable and Taylor vortices are expected at low shear rates (~80 s⁻¹). This gives rise to an increase in the "apparent" viscosity with shear rate. Whereas, in the Couette type, the flow is more stable, resulting in a steady "apparent" viscosity. This interpretation is consistent with liquid metals behaving as Newtonian fluids, but further research is required to confirm this. The author suggests further experiments, with the prime one being the investigation of the fluid with counter and co-rotation of the cylinders in order to observe more complex flows. The results are expected to have implications in the modelling of flow for liquid metal processes, especially the initiation of Taylor vortices under the unstable flow conditions produced by rotating the inner cylinder.

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Viscous shear is a diffusive process, in that the rate of momentum transfer by viscous shear is proportional to the momentum gradient. In this way, it is similar to solute diffusion and thermal diffusion, with which you are by now very familiar. This section will begin with a brief review of solute and thermal diffusion, and introduce the concepts of momentum diffusion, the shear stress tensor convention, and the role of pressure. The shear strain is dimensionless, but the shear strain rate dimension is inverse time, so the viscosity has dimensions of molten metal flow using water and measure velocities very close to what one would expect in the molten metal. Even the kinematic viscosity of molten oxides is one of the most important physical properties. Only limited viscosity data of complex molten oxides in literature are available. The agreement between different investigations is not satisfactory. The present studies are to enhance our fundamental understanding on the viscous behavior of borate and borosilicate melts.

Experimental studies! Viscosity measurements on the systems: Na-B, Na-Si, and Na-Si-B! Investigation on rheological behavior of Na-Si-B melts! Preparation of samples and Experiment description! 4.