Experimental investigation and modelling of the influence of crystallization on the flow behavior of oxide slags

Sören Seebold

Institute of Energy and Climate Research, IEK-2, Forschungszentrum Jülich, Germany

Numerous technical applications in the energy and metallurgical industries demand a fundamental knowledge of the flow of slags. In particular, the operation of an entrained flow gasifier is challenging as the slag has to be reliably discharged. The slag consists of unburned inorganic matter, usually oxides. Crystallization in this oxide melt influences the flow behavior of the slag drastically because of the occurring precipitates. In this study the mechanisms and impact of crystallization on the flow of oxide slags were investigated. For this purpose, isothermal viscosity measurements were conducted on fossil fuel slags in order to examine the rheological evolution over time caused by the crystallization. It has been demonstrated that the evolution of viscosity of a sub-liquidus melt depends strongly on time, as well as on temperature and composition. Using a rotational high-temperature viscometer, it was found that the crystallization during flow could be separated into three time regimes: a lag-time, in which the undercooled melt behaved as an Arrhenius-liquid; the kinetic-driven crystallization accompanied by an increase of the viscosity; and, finally, the rheological equilibrium that is represented by a constant viscosity. Furthermore, an increase of viscosity caused by crystallization was accompanied by a shift from Newtonian to non-Newtonian flow; here, shear thinning flow indicated the existence of precipitates. The conclusions from the experimental results regarding the influence of crystallization on the flow of oxide melts were transferred to an empirical model based on thermodynamic modelling, using FactSage and the database developed by GTT and FZJ. The model considers the physical influence of the crystals and the chemical change of the bulk composition caused by the crystallization. Therefore, the concept of the resulting relative viscosity was introduced in order to describe the physical and chemical effects of crystallization. The evolution of viscosity from the metastable to the equilibrium state was described by a kinetic theory. The results of the model correlate well with the experimental observations.