The Effect of Nozzle Design in the Discharge Crucible Method

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Thermophysical properties such as density, viscosity and surface tension are fundamentally important for many high temperature metallurgical processes involving the melting of steels, slags and alloys. Although a large database of these properties is available, many alloys of commercial relevance do not have properties recorded. Making these property measurements, especially at high temperature (>1000°C), is difficult as the results are highly susceptible to errors caused by issues such as atmosphere contamination or temperature control, choice of ceramics used for melting, and data collection. A new technique permitting the measurement of these properties in a simple, robust, and cost-effective manner has been developed by the Advanced Materials and Processing Laboratory of the University of Alberta. This method, called the Discharge Crucible Method (DC), is unique since it simultaneously measures the density, viscosity and surface tension in a highly dynamic manner using only one experimental run. This method relies on formulations predicting the velocity of a stream draining from an orifice under the influence of gravity. The viscous losses are calculated with a discharge coefficient equation tested and developed using a numerical model that includes the influence of the interfacial surface tension between the liquid and the gas via the Young-Laplace overpressure induced in the jet. A laser sensor was used to record the evolution of the level of the fluid as it drains. The Levenberg-Marquardt nonlinear regression algorithm is then used to fit the theoretical model and the experimental data in order to calculate the density, surface tension and viscosity minimizing the least squares residuals. The model and experiments will be described along with the effect of different nozzle shapes on the distribution of forces in the DC method. The aim is to define the optimal nozzle design for a good distribution of forces throughout a draining experiment.