Surface Tension Measurements of Uranium Melts at High Temperatures

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During a severe accident in a nuclear reactor, uranium melts, or corium, can relocate into the reactor vessel lower plenum in case of core support plate failure. Corium composition may vary depending on the ability to stabilize it, either within the reactor pressure vessel, leading to so-called in-vessel retention, or outside the vessel if the latter fails, leading to so-called ex-vessel retention.

The success of both strategies highly depends on corium behavior at high temperatures, conditioning vessel integrity for in-vessel compositions, and spreading or fuel-coolant interaction for ex-vessel compositions. In order to feed the modelling tools allowing the numerical simulations of severe accidents scenarios, the thermophysical properties of uranium melts at high temperatures must be known. In particular, the surface tension of corium plays a significant role in fundamental mechanisms involved in both in-vessel and ex-vessel retention strategies. Such data are scarce (if existing) in the available literature.

Within the framework of corium characterization at high temperatures, the present work aims at filling the gap in surface tension data. A phenomenological review is first given, highlighting the impact of this particular property in the physical mechanisms governing the behavior of corium, when applied to both in-vessel and ex-vessel retention strategies. In order to accurately measure surface tension, the VITI facility has been designed to implement the Maximum Bubble Pressure (MBP) technique in refractory crucibles at high temperatures. Over the past few years, this technique has given access to original values (and related uncertainties) for the surface tension of uranium melts. These results are reviewed for some compositions of interest, highlighting the necessity of building a predictive approach for estimating the surface tension of other compositions and/or temperatures that remain inaccessible to experimental measurements. A related methodology, based on the Calphad approach and uranium thermodynamic databases, is unveiled as an outlook of the present work.