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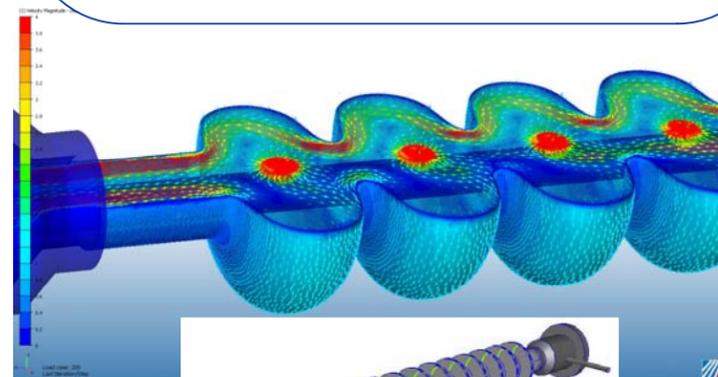
Abstract:

A system for modeling the thermal and hydrodynamic flow conditions internal to an electropolishing niobium cavity has been developed using the commercial code CFDesign™.

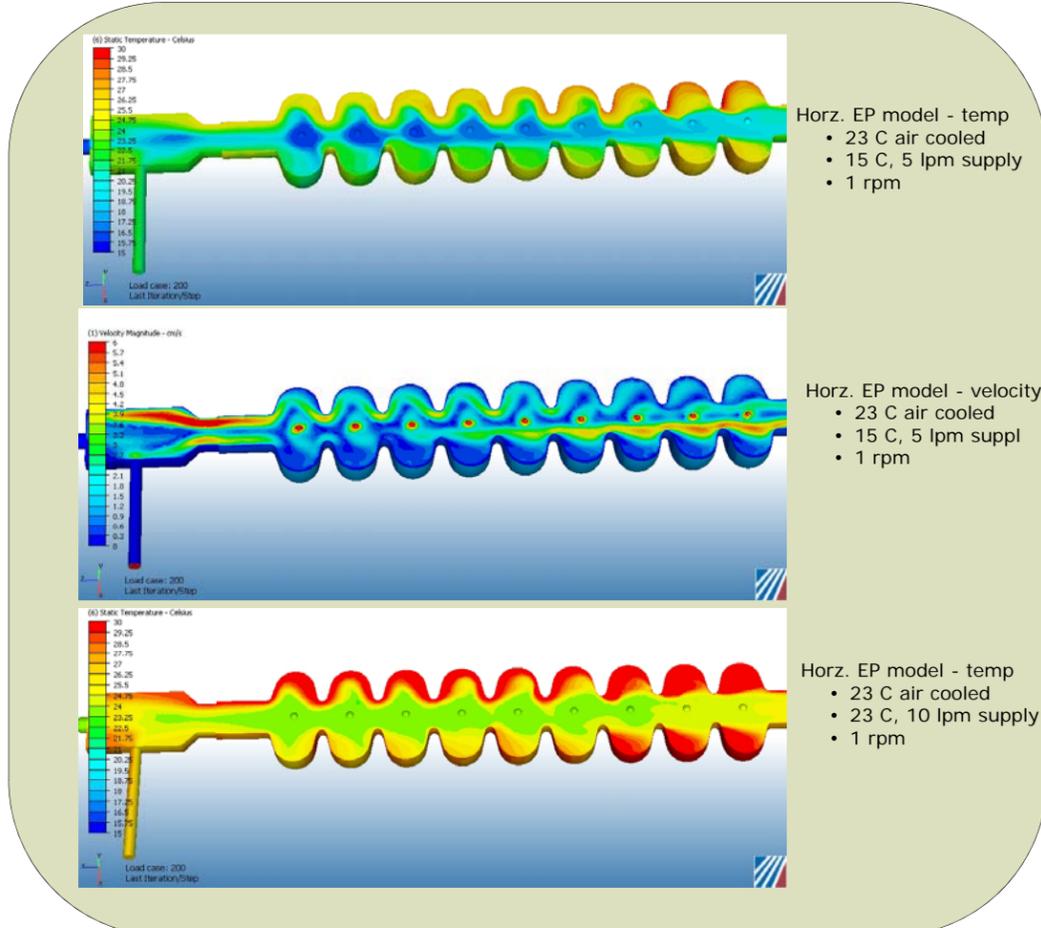
Building upon parametric studies with small niobium samples that highlighted the process sensitivity to both local temperature and fluid flow conditions, we seek to gain predictive insight into processing methods which assure uniform controlled polishing – in both the traditional rotating horizontal configuration as well as the potentially more convenient vertical orientation.

For present modeling runs, the experimentally measured temperature-dependent viscosity of the standard HF/H₂SO₄ electrolyte has been included. For the horizontal configuration, we have modeled the recent JLab-adopted reduced temperature and flow conditions used for ILC cavity processing and find corroboration of improved thermal control and uniformity.

For vertical EP, the amplitude and pattern of nominally steady-state internal convective flow under conditions of external wall cooling and no electrolyte circulation has been observed for vertical EP for both single-cell and 9-cell cavities.



Modeled horizontal system

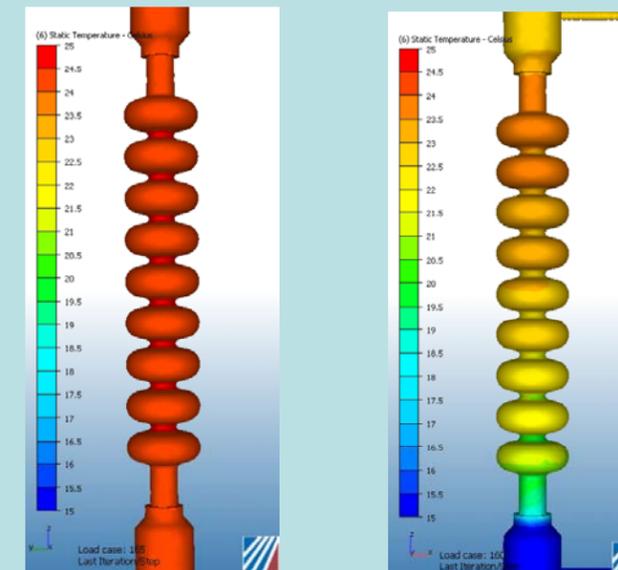


The models incorporate new temperature-dependent viscosity data

Vertical Electropolishing

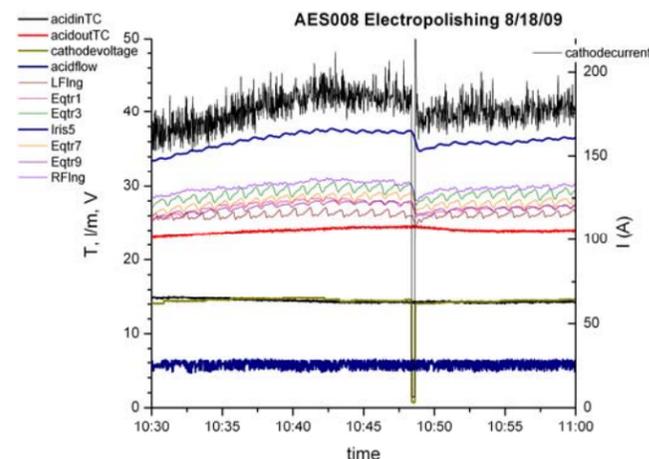
Using the same material parameters as used for the horizontal models, we reoriented gravity, filled the cavity with electrolyte, centered the cathode on the cavity axis, and eliminated the supply of electrolyte via a hollow cathode.

To provide stabilization of the process temperature, the boundary condition on the outside surface of the cavity was set to simulate the presence of a 20°C water cooling bath by using a film coefficient of 467 W/(m²-K). The figures below show the thermal solutions with no flow or stirring of the electrolyte and with a simple 2 liter/min bottom-to-top flow of electrolyte supplied at 15°C. In both models, the heat flux is a constant 0.2 W/cm² on the inside surface of the niobium.

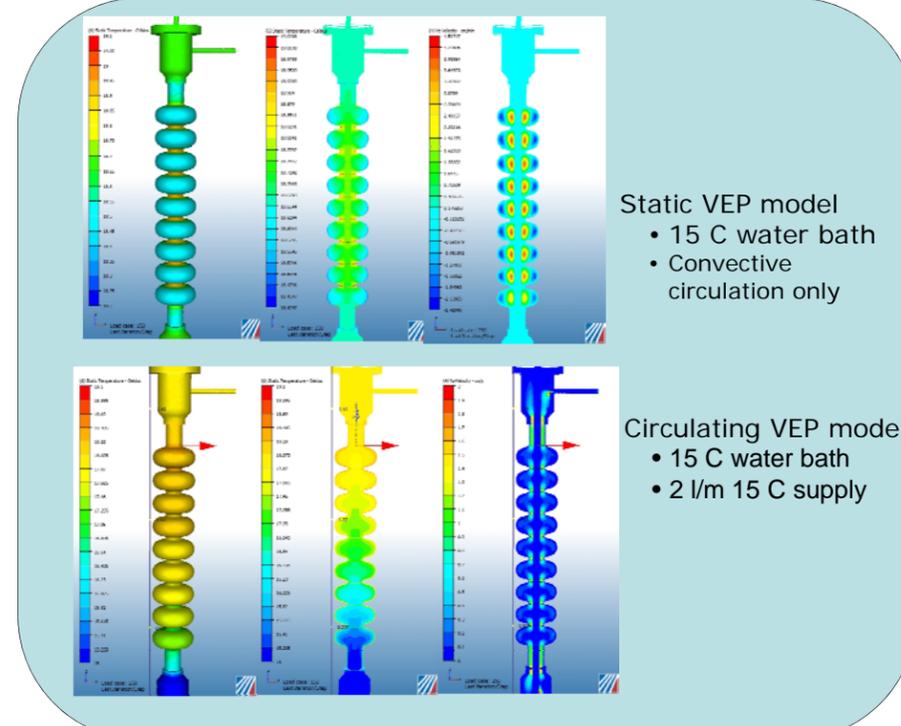


Steady-state cavity/electrolyte interface temperature

9-cell cavity with 20°C external water bath boundary conditions, a) static electrolyte, and b) 2 lpm vertical flow supplied at 15°C.



Logged process conditions during EP of cavity AES8 at JLab, used for reference.



Summary:

Initial hydrodynamic models have been developed to simulate the thermal and electrolyte flow conditions in the ILC 9-cell cavity electropolish processing system at Jefferson Lab and also in a potential vertical electropolishing configuration.

Using approximate material parameters for the electrolyte and averaged heat flux conditions relevant the cavity EP process, solutions are obtained which correspond reasonably well with measured data.

The lowered supply temperature and reduced flow rate, compared with former process conditions, yield improved temperature control and process uniformity across the cavity. Significant variations in local temperature and flow conditions yet remain. The model also indicates that providing external water cooling to the cavity during EP processing dramatically stabilizes the thermal conditions and eliminates the need for the circulating electrolyte solution to serve as heat sink, which in turn reduces the internal flow rate variations.

We are encouraged to pursue water bath cooling during vertical electropolishing of niobium cavities in our future integrated cavity processing (ICP) systems.

ACKNOWLEDGEMENT

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