Computational Modelling of Fluid Dynamics in Electropolishing of Radiofrequency Accelerating Cavities

H. Rana¹, L. Ferreira²

¹Loughborough University, Loughborough, Leicestershire, UK
²CERN, CH-1211, Geneva 23, Switzerland

Abstract

The work hereafter investigates into the use of COMSOL Multiphysics® to simulate the electropolishing process performed on radiofrequency accelerating cavities in order to improve their inner metal surface finishing. The physics studied in COMSOL Multiphysics® is the fluid dynamics of the process, and the use of exported velocity data is made to transpose into current density to determine the effectiveness of the existing electropolishing process currently undertaken.

Introduction

Superconducting radiofrequency (RF) cavities are accelerating cavities that enable the propelling of charged particles to high energy in particle accelerators. Electropolishing is the electrochemical process that RF cavities undergo in order to improve their inner metal surface finishing. This is performed prior to their installation into the accelerators, to enhance their accelerating properties. Using COMSOL Multiphysics® it is possible to model the electropolishing process of the cavities and study the fluid dynamics of the setup.

Theory

Levich equation:

\[
I_F = 0.62 nFAD_0 \sqrt[3]{\frac{1}{\nu}} \frac{1}{C_0} \omega^2
\]

Hydrodynamic relationships [1]:

\[
\omega = 0.545 \frac{V^2}{r} \quad \nu = 0.023 \frac{V^2}{r}
\]

Results

Using an initial relationship for current density and electrode angular velocity obtained via laboratory runs with an RDE setup, a current density distribution was created for the pentacell, giving an average current density of ~53 A/m².

Conclusions

COMSOL Multiphysics® was found to be a vital tool in shedding light on what occurs during electropolishing of RF cavities at CERN. Using the initial relationship that accounts solely for electrode rotation, the pentacell average current density was found to be ~ 53 A/m². Through the modelling of the RDE, it was possible to re-establish a relationship between current density and angular velocity that further incorporates fluid dynamics (bath speed of the system). With the bath speed relation, the average value is ~122 A/m², which is very close to 130 A/m² as found in the workshop.

References