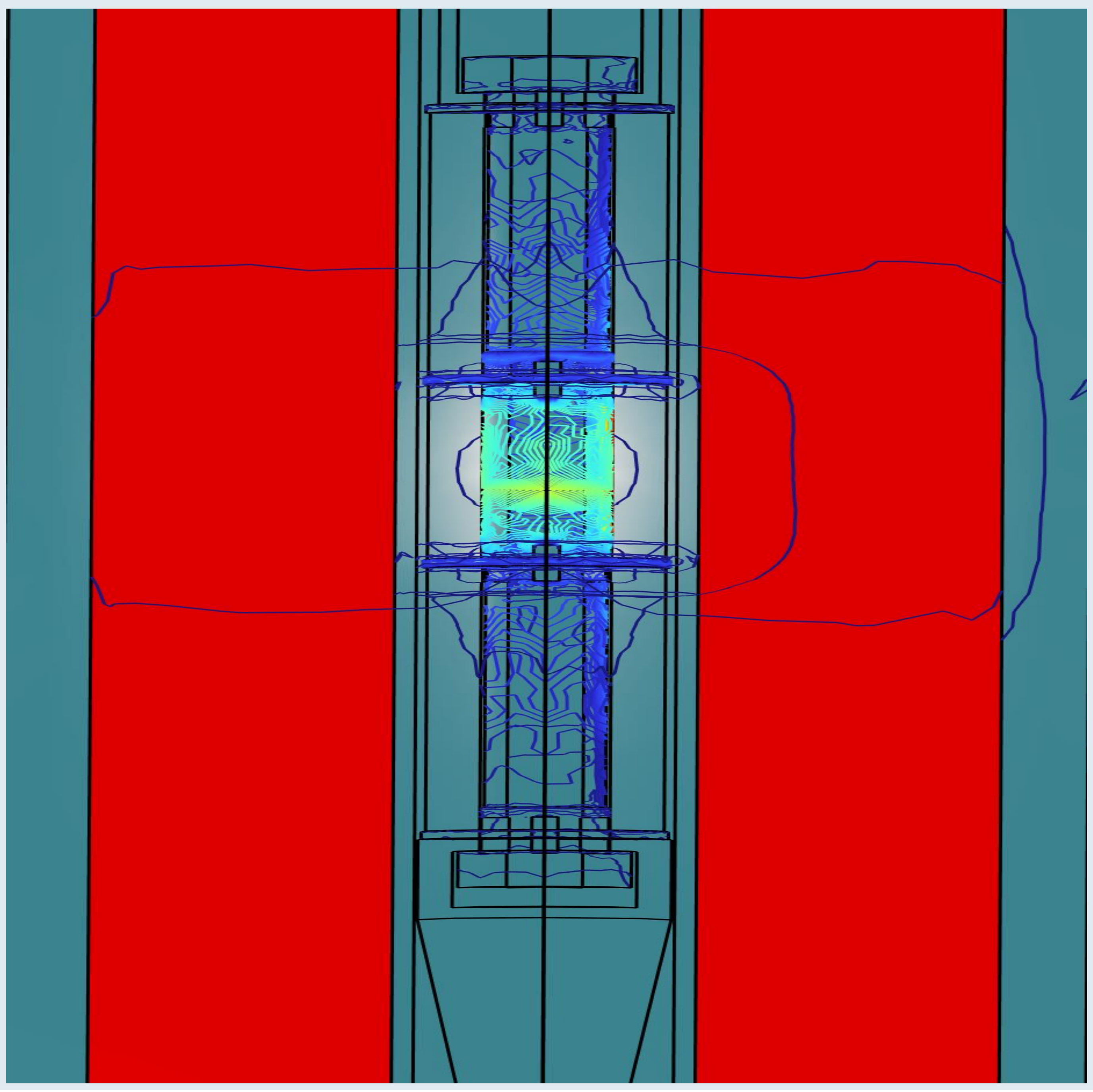

Three Dimensional Numerical Analysis of an Eddy Current Flow Meter

Effect of mechanical position and tilt of the bobbin on the output of an Eddy Current Flow Meter.

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Abstract

Liquid Metal Fast Breeder Reactor (LMFBR) employs molten sodium as coolant due to its suitable neutronic and thermal properties. Measurement of coolant flow rate is a very important factor both from operational and safety aspects of a fast reactor. Good electrical conductivity of liquid sodium is often exploited to deploy different electromagnetic devices for instrumentation purposes. For measurement of sodium flow rate, Eddy Current Flow Meter (ECFM) is also used in some applications. The output of such ECFM depends on a number of factors. An accurate assessment of the output requires solution of both Maxwell's and Navier Stokes Equations, which is computationally a very challenging task. The ECFM consists of three coils- one primary and two identical secondary coils. The primary winding is excited by alternating current supply which creates a magnetic field which in turn induces voltages in the two secondaries. Under static condition both the secondaries give equal voltages whereas, when liquid metal is under motion, difference of the two secondary voltages is proportional to the flow rate of liquid metal around the sensor. The output of the flow meter depends on a number of design factors. The output also gets affected by mechanical position and tilt of the sensor. To analyze the impact of these factors, a three-dimensional numerical modeling of the ECFM was carried out using multi-physics based COMSOL software. The details of the 3-D numerical model of ECFM are described here. Effect of position and tilt of the sensor on the output is also presented.

FIGURE 1 (not to scale). Left: Bobbin at Centre. Middle: Bobbin Tilted by maximum extent. Right: Bobbin Laterally Displaced by maximum extent.

Methodology

Tilt and radial displacement of an ECFM (Fig. 1) require a three-dimensional computational model. Therefore, a three-dimensional 1:1 model of an ECFM was developed. The coils have been modelled using helix geometry feature. AC-DC module was used for the computation of magnetic field and k-ε turbulence model for evaluation of sodium flow profile. A steady state analysis was carried out with the primary excited by constant amplitude alternating current. An accurate assessment of ECFM output requires solution of both Maxwell's and Navier Stokes Equations:

$$\rho\,(V\nabla)\,V = -\nabla p + J \times B + \mu_f \nabla^2 V + \rho\, g$$

$$J = \sigma(E + V \times B)$$

Results

The flow signal is the difference between the two secondary coil voltages and the same was calculated for different amounts of tilt and radial displacement. Magnetic field profiles (Fig. 2) and induced voltages were calculated under different conditions.

At 400 °C, the maximum deviation in measurement of flow rate due to the shift and tilt of bobbin was estimated to be 0.33 m^3/h at no flow condition. For a flow rate of 20.20 m^3/h, the maximum deviation in flow rate measurement was estimated to be 0.37 m^3/h (i.e., 1.83%). Thus, the performance of given ECFM will not be significantly affected by the shift and tilt of bobbin inside the guide tube.

The developed numerical model can be utilized for evaluation of other ECFMs with different configurations also.

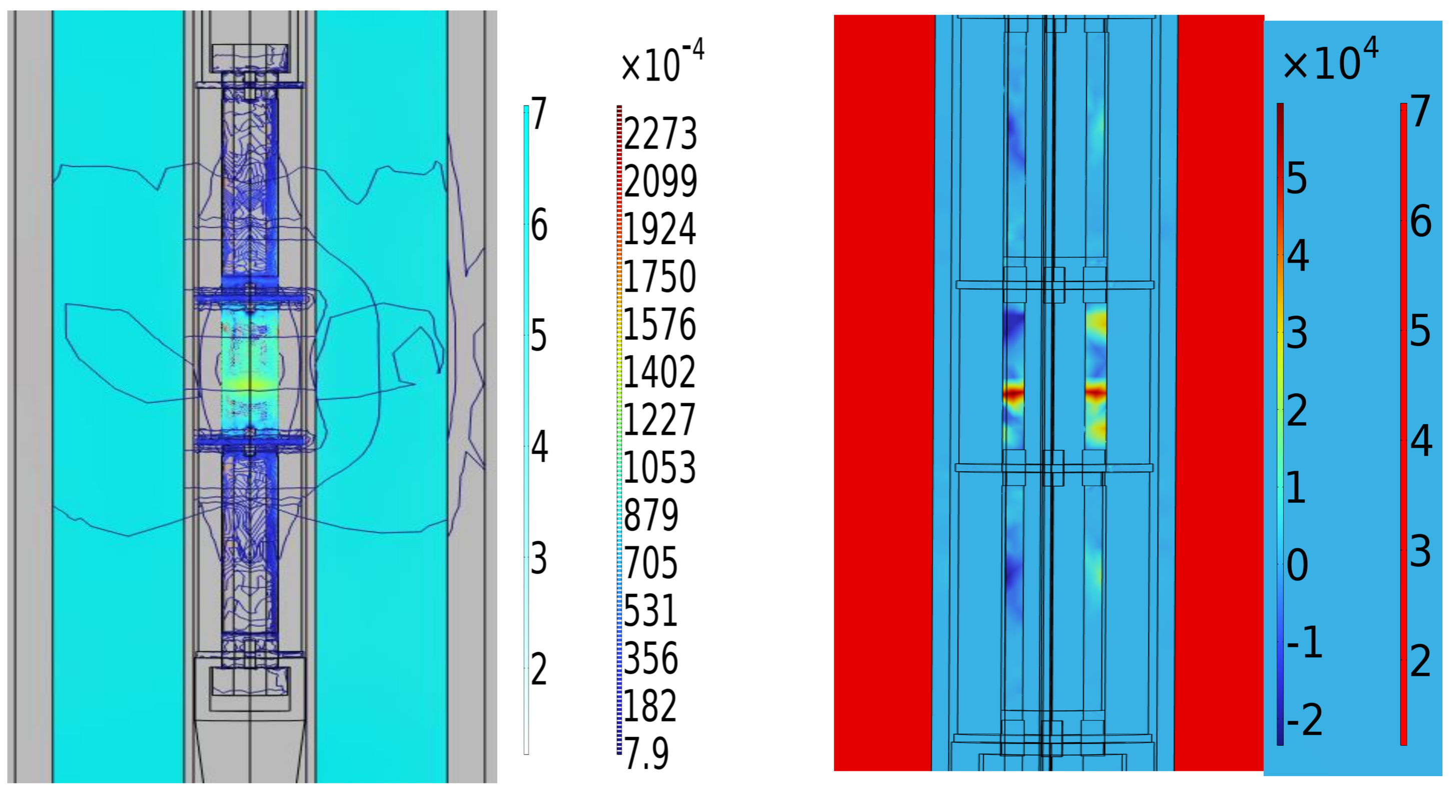

FIGURE 2. Left: Magnetic flux density in ECFM and sodium. Right: Induced current density in ECFM and sodium

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