Numerical Quasi Stationary and Transient Analysis of Annular Linear Electromagnetic Induction Pump

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Abstract

Electromagnetic (EM) induction pumps are used for liquid metal transportation in variety of technological processes. The main advantage of such device is contactless pumping of liquid metal using electromagnetic force, therefore hermetic construction can be designed with significant safety improvements over mechanical pumps. Use of annular linear electromagnetic induction pumps (ALIP) is foreseen in Gen IV sodium-cooled fast reactors (SFR) therefore posing interest of this topic.

In present work mainly numerical approaches are used to study and analyze electromagnetic and magnetohydrodynamic (MHD) effects in ALIP (Figure 1). Reynolds averaged Navier-Stokes (RANS) and Induction eq. where solved using COMSOL Multiphysics® with some modifications in each particular case.

Problem was solved using 4 approaches of different complexity:
1. Quasi-stationary solid body (QS SB)
2. Transient solid body (TD SB)
3. Quasi-stationary MHD (QS MHD)
4. Transient MHD (TD MHD)

All results are presented in dimensionless form. In (Figure 2) characteristics of developed EM pressure numerically obtained with QS SB approach (points) using five frequencies are compared with analytical solution considering only main harmonic of height averaged magnetic field. Apparently, analytical results correlate better with numerical solution in case of low flowrate (f' = 3, 4, 5) as well as high flowrate (f' = 1, 2). It could be explained by multi-harmonic structure of magnetic field not considered in analytic solution. This is confirmed by analyzing axial force along channel, where strong, periodic negative force is observed (Figure 3) near wall 1 (Figure 1).

Developed pressure of QS and transient approaches was compared only in case f' = 4. In the case of QS MHD was possible to estimate difference between EM and developed pressure to calculate pressure losses in channel due to friction which correlates rather well with analytic

estimation (Figure 4 secondary axis). Also transient pressure development was compared in SB and MHD cases where double supply frequency (DSF) pulsations were observed (Figure 4 error bars).

Performed analysis revealed that influence of higher harmonics cannot be negligible and have significant impact on integral characteristics (Figure 2,3). It was estimated that time averaged p - Q characteristic of ALIP in all 4 approaches were quite the same, therefore simple QS SB approach can be used (Figure 4).

It was shown that TD SB approach can be successfully used to estimate amplitude of DSF pulsations. QS MHD approach can be used to analyze axial force and velocity profiles (not shown in this abstract) more precisely and to calculate pressure losses, which correspond quite well with analytic estimations (Figure 4). By using QS MHD and TD SB approaches TD MHD calculation can be successfully substituted.

Reference

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Figures used in the abstract

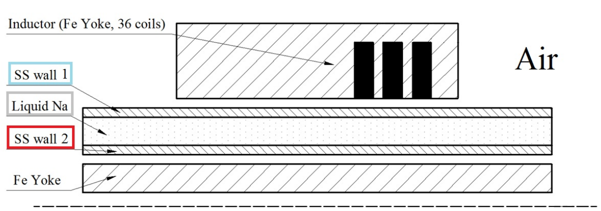

Figure 1: Principal sketch of axisymmetric ALIP geometry and different zones.

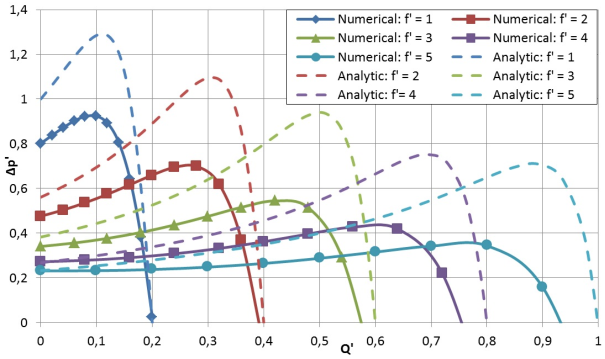

Figure 2: Numerical and analytic p – Q curves of SB approximation.

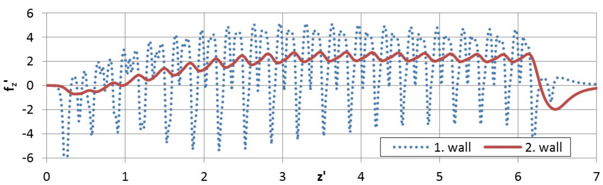

Figure 3: Distribution of axial EM force near walls: f' = 4; Q = 0.8; QS MHD.

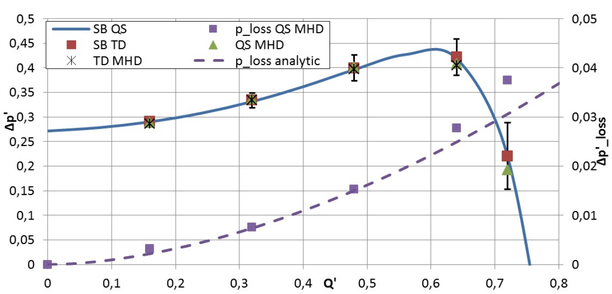

Figure 4: Comparison of time averaged developed pressure and pressure losses: f' = 4; Q = 0.2.