Task 32

Modeling and Design Algorithms for Electromagnetic Pumps

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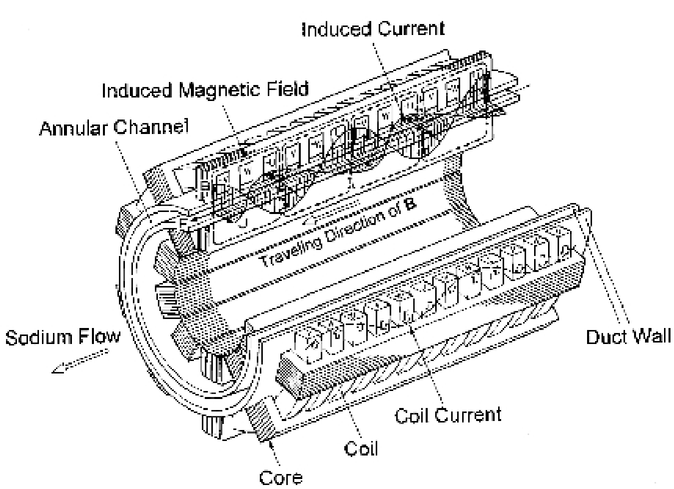
BACKGROUND

Electromagnetic (EM) induction pumps are used extensively in current and proposed nuclear power systems and industrial molten metal transfer operations. Although the Magnetohydrodynamic (MHD) theory that underlies the operation of these types of pumps has been studied extensively in the past few decades, the design of specific EM pumping systems for specific flow cases requires computational tools and expertise, which is lacking in the U.S. In recent years, the majority of research done on these systems has been done in Japan, Korea, France, and the former Soviet-bloc countries. However, for the past two years, researchers at UNLV have been utilizing the TC-1 liquid metal loop system at UNLV and an Annular Linear Induction Pump (ALIP) to drive the liquid metal and to develop such computational tools that will allow the accurate and efficient optimization of EM pump systems for nuclear applications.

A cut-away picture of an ALIP such as has been used in prototype Sodium Fast Reactors and the TC-1 loop at UNLV is illustrated below. These ALIPs consist of three main parts:

- An inner cylindrical core fabricated from a ferromagnetic material
- An annular channel through which the liquid sodium flows
- An outer ferromagnetic core in which a set of inductor coils are embedded

During operation, a 3-phase, alternating current travels through the inductor coils. This current produces a magnetic field which, in turn induces a current in the liquid sodium in the pump annulus and inner core. Pumping forces develop in the liquid sodium due to the interaction of the magnetic field and the induced current, causing the liquid sodium to flow down the length of the annulus. The magnitude of these pumping forces, and the operational efficiency of the pump, is dependent on a large number of design parameters including coil current and position, material selection for the inner and outer cores, and size of the annular gap.



Cut-away picture of an annular, linear induction pump (ALIP).

TC-1 Loop laboratory located at UNLV.

RESEARCH OBJECTIVES AND METHODS

The research objectives of this task are:

- A literature review of topics pertinent to EM pump design. These topics include the equations governing the physical phenomena occurring in EM pumps and mathematical algorithms used in modeling these physical phenomena, different EM pump configurations, and the effects of materials properties on pump performance.
- Development of computational models of the TC-1 loop at UNLV.
- Evaluation of the computational models through comparison with experimental data taken on the TC-1 loop.
- A parametric study of the TC-1 loop investigating the pumping efficiency as a function of operating conditions, materials properties, and geometric parameters.

RESEARCH ACCOMPLISHMENTS

<u>On-line EM pump literature database</u>

The on-line literature database has been available for over a year and now contains over 140 entries. New entries are added on a regular basis by the various researchers working on the project. Currently, this database can be found at:

http://nstg.nevada.edu/mmrg/research/LitSurvey/EMP-Literature.html.

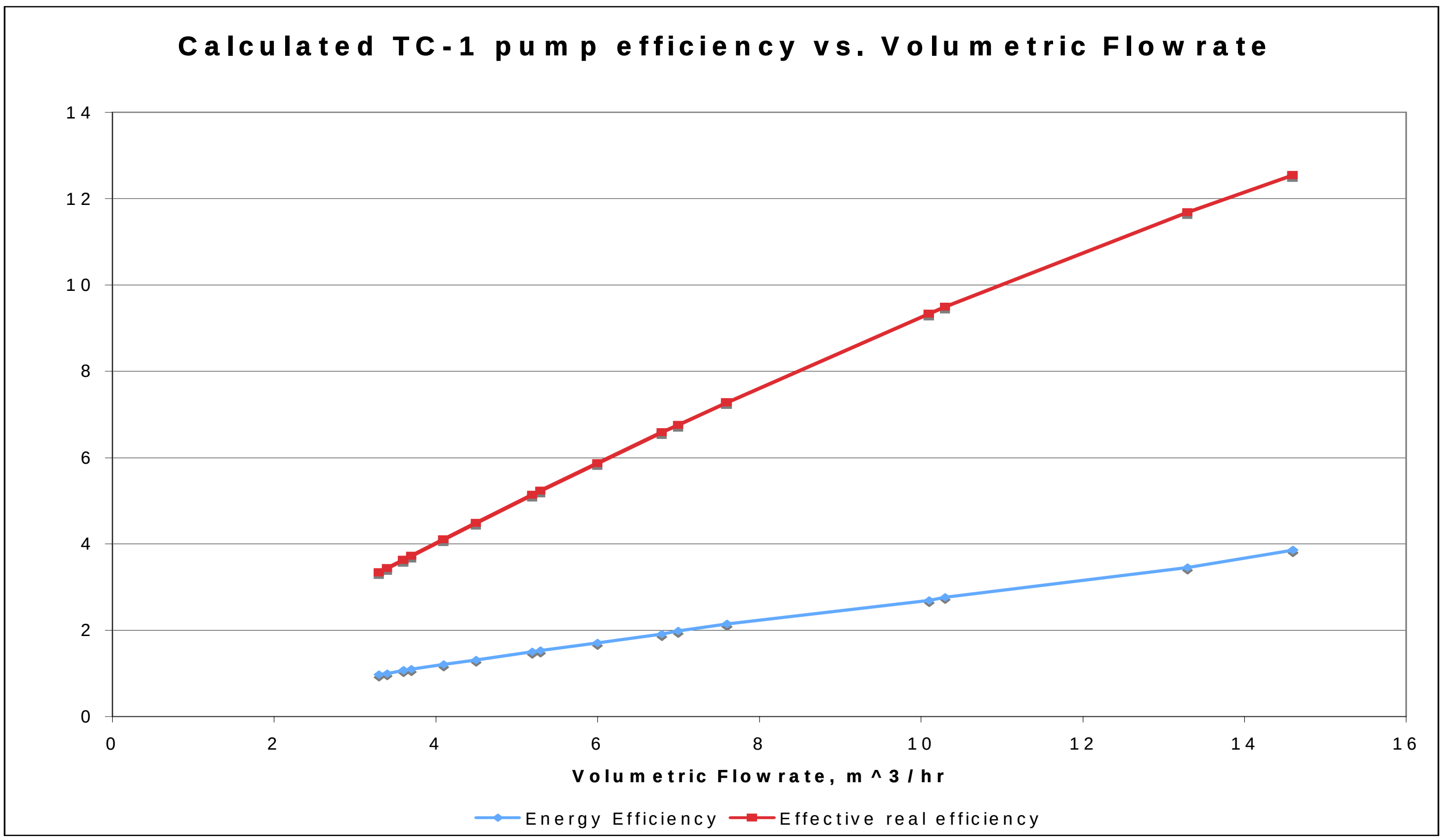
Calculations of EM phenomena and pump efficiency

An analytic model of the EM phenomena in a generic ALIP has been developed using the method of separation of variables and Fourier transforms applied to the magnetic vector potential form of the induction equation. The model is written in Fortran and consists of a library of functions that calculate the various EM phenomena (magnetic vector potential, magnetic field components, Lorentz forces, induced current density distribution, etc.).

While working through these results, some of the earlier results from this project were revisited, in particular, the calculated values for the TC-1 pump efficiency. There are several ways to calculate the efficiency for an EM pump. One way, often referred to as the energy efficiency of the pump, is to divide the energy of the flowing fluid, i.e., pressure times flow-rate, by the energy it takes to run the pump, i.e., voltage times current. A second way to calculate the efficiency of an EM pump, often termed the effective real efficiency, basically relates the speed of the fluid to the speed of the traveling magnetic field. Both of these types of efficiency are illustrated below as a function of mass flow rate through the TC-1 loop. It should be noted that previously calculated efficiencies were always less than 1%, whereas the new calculations are all significantly above 1%. This discrepancy needs to be explored further and clarified.

FUTURE WORK

The next phase of the project involves development of a fully-coupled MHD solver for calculating both the EM and fluid flow phenomena in the EM pump. For this model, the EM field phenomena will be calculated using an integral formulation of the Maxwell's equations, and the fluid flow phenomena will be calculated using a finite volume formulation of the Navier-Stokes equations.



Calculated efficiencies for TC-1 loop pump.

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