# Development of the Methodology for the MHD Analysis in a Linear Induction Electro-Magnetic Pump

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## 1. Introduction

Generally, fast breeder reactors have adopted a liquid metal as a coolant for the heat transfer from the reactor to the heat exchangers. Since a liquid metal has an electrical conductivity, the pumping of the liquid metal may use an induction electro-magnetic (EM) pump which induces electrical current and body force on the metal flow. These linear induction pumps use a traveling magnetic field wave created by poly-phase currents and the induced currents and their associated magnetic field generate the Lorentz force whose effect can be actually the pumping of the liquid metal. [1] The flow behaviors in the pump are very complex such as the existence of a rotational force, pulsation and so on, because the induction EM pump has time-varying magnetic fields and the induced convective currents which originate form the flow of the liquid metal. These phenomena generate a stability problem in the pump and depend on the changes of the magnetic field and fluid flow field due to the induced currents and the fluid flow of the liquid metal with time and complex pump geometry. Therefore, an exact flow analysis is required for designing and evaluating the stability of a pump.

## 2. Numerical Analysis Method

We have developed the magneto-hydro-dynamics (MHD) analysis methodology based on the Maxwell equations and a simple fluid-dynamic flow model in an EM pump. [2][3] Firstly, we developed a magnetic field analysis method based on the Maxwell equation for solving the time-varying magnetic field with induced currents originating from the time-varying poly-phase currents and flow of the liquid metal. We have introduced the governing equations with a magnetic vector potential in order to analyze the time-varying magnetic field in an EM pump. The governing equations have the form of a mathematical vector curl equation. We developed the numerical code based on the finite volume method widely used in the numerical flow analysis. In the magnetic vector potential equation, the input current as well as the induced currents and convective current originating from the flow of the electrically conductive metal acts as a source of the magnetic field in the EM pump.

Secondly, we developed the fluid-dynamic analysis code for solving the metal flows in the pump. The fluid-dynamic analysis code is based on the finite volume method to maintain a consistency between the two numerical codes. In the fluid equation, the Lorentz force generated by the vector cross product of the magnetic field and the induced currents acts as the body forces in the momentum equation of the metal flows.

We have linked the two codes with a flow velocity of the liquid metal. The vector cross product of the magnetic field and flow velocity of the liquid metal is treated as the current sources with convective currents from the metal flows and the induced current originated from the time varying magnetic field. Also, the Lorentz force which is a vector cross product of the induced currents and magnetic field is treated as the body force for solving the fluid-dynamics in the pump. The linked code is solved by an iterative method because the flow velocity of the metal is affected to magnetic field and it is changed by Lorentz force. In the developed method, we have assumed that the Interaction number and the Hartman number are small and the magnetic Reynolds number is small. [2] Under these assumptions, the viscous and inertial effects may be confined to the very thin boundary layers adjacent to the walls. The governing equations are:

$$\nabla \times \frac{1}{\mu} \nabla \times A = J \qquad (1)$$

$$J = \sigma(u \times B - \frac{\partial A}{\partial t}) + J_0 \qquad (2)$$

$$B = \nabla \times A \qquad (3)$$

$$\nabla^2 p = \nabla \bullet (-\rho u \bullet \nabla u + \eta \times \nabla^2 u + J \times B) \qquad (4)$$

## 3. Analysis Results

Figure 1 shows the typical annular linear induction EM pump. We analyzed the characteristics of the EM pump such as the pressure and magnetic flux. Figure 2 shows the pressure field and Figure 3 shows the magnetic flux field with time. The input current density is assumed to be 4.66A/m2 and the parameters for the analysis are shown in table 1.

After this study, we will analyze the experimental pump and validate the developed methodology. Then, we will evaluate the instability of a large-scaled annular linear induction EM pump for a liquid metal reactor.

***Acknowledgements***

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## REFERENCES

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Table 1 Main specification of the linear induction pump

| | | |
|---|---|---|
| Flow rate | 2.7m3/min | |
| Developed pressure | | 0.32MPa |
| Frequency | 50Hz | |
| EMP height | | 0.1745m |
| Stator height | | 0.114m |
| Inner core height | | 0.0325m |
| Permeability of Na | | 1(relative) |
| Electrical Conductivity of Na | | 5.7E6 |
| Permeability of Stator and Core | 100 | |
| Electrical Conductivity of Stator and Core | 1.07E6 | |
| Density of Na (at 300 ℃) | 880Kg/m3 | |
| Kinematic Viscosity of Na (at 300 ℃) | | 3.9E-7m2/sec |

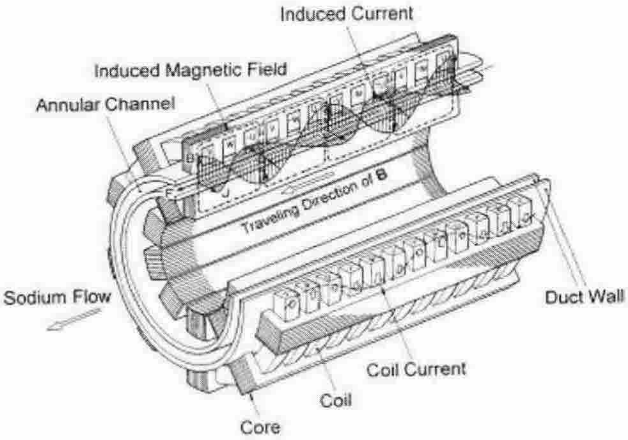

Fig. 1 Schematic drawing of the annular linear induction Electro-Magnetic pump

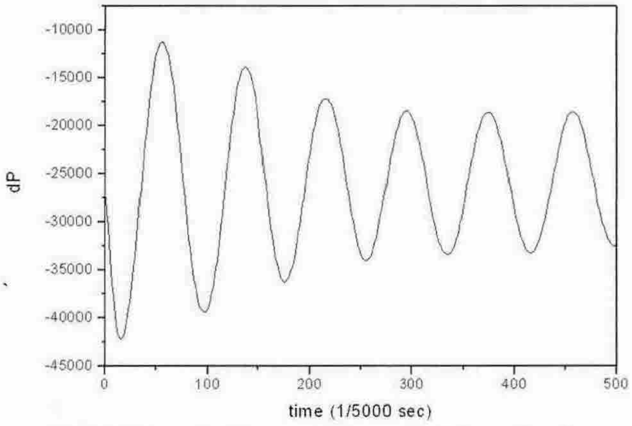

Fig.2 Differential Pressure between the inlet and outlet of the EM pump

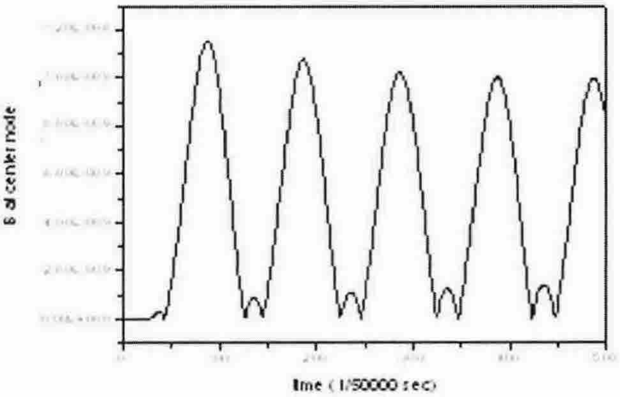

Fig.3 Magnetic Flux at fluid region in EM pump