Reduction of a Double Supply Frequency Pressure Pulsation in an Electro-Magnetic Pump

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1. Introduction

Fast breeder reactors using sodium coolant have adopted the AC induction electro-magnetic (EM) pump as a coolant pump for a liquid metal flow. Figure 1 shows the schematic diagram of an EM pump. The EM pumps have some disadvantages such as a double supply frequency (DSF) pressure pulsation and so on. The DSF pressure pulsation occurs in the induction EM pump, when an alternating current is supplied to the coils. The magnetic field produced by the coils reacts with the alternating current being passed through the sodium, and then the pressure developed pulsates at twice the input frequency.[1] The DSF pressure pulsation is dominantly affected by the disturbances of the electromagnetic force near the stator or core ends. The disturbance of the electromagnetic force can be derived the Lenz's Law which means that the opposite forces are generated when the magnetic field abruptly changed by the liquid metal flows near the stator ends. This phenomenon is called as the end effect.

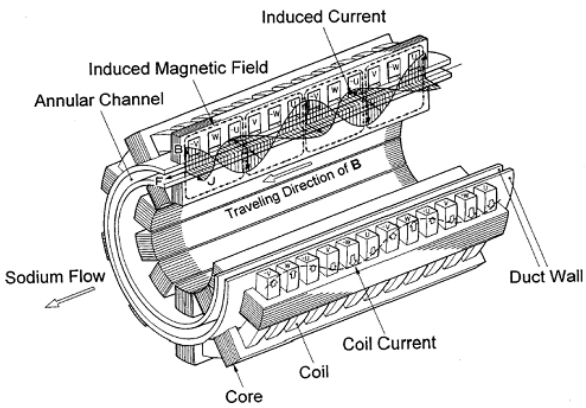

Fig.1 Schematic of EM pump

We have studied how to reduce the DSF pressure pulsation for designing the EM pumps used in a liquid metal reactor. The DSF can be reduced by suppressing the Lorentz's force disturbance (opposite force) near the stator ends. The Lorentz's Force is defined to the electromagnetic force which can be obtained by multiplying the magnetic field and the induced current in the sodium region in the EM pump. To suppress the opposite force, we have adopted a linear winding grading near the stator ends of the EM pump. [2] The method of linear grading is that the number of coil turns decreased gradually to the inlet/outlet of the EM pump. The magnetic fields at the inlet/outlet of the EM pump are depressed by a linear grading, and the change of the force disturbance can be reduced.

2. Analysis

For developing the methodology to decrease the DSF pressure pulsation in an EM pump, the magneto-hydro-dynamics (MHD) analysis is required. The MHD analysis consists of electromagnetic dynamics for analyzing the electromagnetic field and the flow dynamics for analyzing the sodium flow in the EM pump.

The electromagnetic dynamics are based on the Maxwell equations. For analyzing the MHD in the EM pump, the axisymmetry coordinate was adapted because the pump was symmetric along azimuthal direction. The governing equation is as follows including, the sodium flow.

$$\nabla \times \frac{1}{\mu} \nabla \times A + \sigma [\frac{\partial A}{\partial t} + u \times B_r] = J_0$$

Where,

$A = magnetic \cdot vector \cdot potential \cdot (B = \nabla \times A)$

$\mu = permeability$

$\sigma = conductivity$

$J_0 = current$

$B = magnetic \cdot field$

For simplifying the time behavior, we have adopted the time harmonic assumption widely used in analyzing for sinusoidal electromagnetic machines such as induction pumps. Also, the flow velocity U is nearly not changed in the pump. So, we could eliminate the time derivatives in the equation by replacing the time derivatives into the complex term; $\frac{\partial A}{\partial t} = i\omega A$. [3]

Then, we have developed the finite difference numerical scheme using Stokes theorem to simplify the interface boundary conditions.

3. DSF pressure pulsation

Using the analysis methodology, we have performed the DSF pressure pulsation with a linear grading. Table 1 shows the number of turns of winding coils according to the linear grading options (1T, 2T) in an EM pump.

Table1 linear grading options

Slot number	number of coil turns	
	Grading 1T	Grading 2 T
1/36	16	16
2/35	32	24
3/34	48	32
4/33	64	40
5/32	80	48
6/31	80	56
7/30	80	64
8/29	80	72
Others	80	80

Figure 2 shows the evaluated electromagnetic force distributions along the z-direction with each linear grading option in the EM pump. The forces were oscillating along with the time and the disturbance of the force near the stator ends was significantly reduced according to the linear grading options.

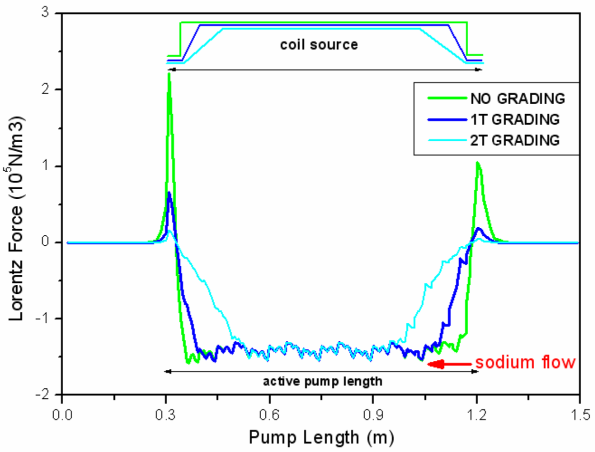

Fig.2 force distribution along z-direction

We analyzed the pressure pulsation with the CFX-5.7 code using the Lorentz's force shown in the Fig. 2. [4] For analyzing the flow dynamics, we put the transient Lorentz's force into the user specific body force for the sodium flow. Fig. 3 shows the relative DSF pressure pulsation according to the linear grading options. As shown in the Fig. 3, the DSF pressure pulsation was reduced by a linear grading option.

4. Conclusion

The DSF pressure pulsation is the intrinsic characteristics of an induction EM pump due to the end effect and sinusoidal features of the pump. The DSF pressure pulsation can result in a instable pump operation like a mechanical vibration. For a stable operation of the pump, the amplitude of the DSF pressure pulsation should be reduced. In this study, we proposed a linear grading option in order to reduce the DSF pressure pulsation.

The applied linear grading option could mitigate the disturbance of the electromagnetic force near the stator ends. Then, the amplitude of the DSF pressure pulsation was significantly reduced.

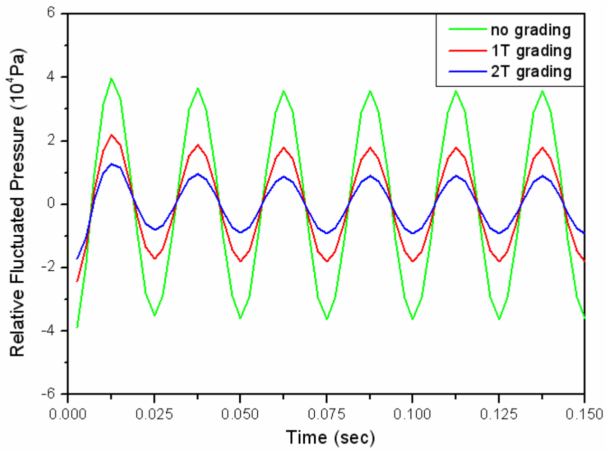

Fig.3 DSF pressure pulsation

Acknowledgments

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