The Preliminary Test of the Annular Linear Induction EM Pump

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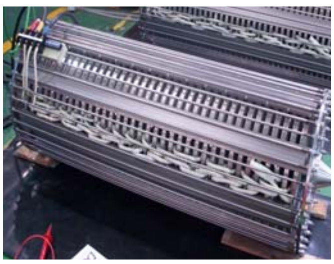
1. Introduction

Annular linear induction electromagnetic (EM) pumps have been widely investigated for the circulation of molten metal with high electrical conductivity [1-2]. Advantages such as having no moving mechanical parts which minimize the corrosion produced by the liquid metal on mechanical components and the fact that usually no maintenance is needed for a long period of time, have enabled the EM pump to be the only option in the area of the development of pumps for a nuclear Liquid Metal Reactor (LMR). The basic design concept of conventional linear induction motors is generally employed as the design method of an EM pump. Practically, an electrical equivalent circuit, which consists of equivalent resistances and reactances which are given by the pump geometrical and operational variables, is used for the EM pump design. In 2010, an electromagnetic pump with a nominal flowrate of 2,265 L/min and a nominal developed pressure of 4 bar (0.4 MPa) was designed and manufactured by taking into consideration the requirements of materials able to operate in a high temperature sodium environment [3]. In the present study, the preliminary operation tests for the pump were carried out by changing the electrical input before installing it in the sodium loop for verifying the elements of the sodium-thermo-hydraulic experimental system.

2. Method and Results

2.1 The Fabricated EM Pump and Test Preparation

Fig. 1 shows the completed three-phase annular linear induction electromagnetic pump with a flowrate of 2,265 L/min and a developed pressure of 4 bar [3]. The fabricated pump was installed into a test system as seen in Fig. 2 to verify the fundamental operation of the pump where a three-phase variable AC power supply was used.


(a) The front view


(b) The side view

Fig. 1. The fabricated annular linear induction EM pump

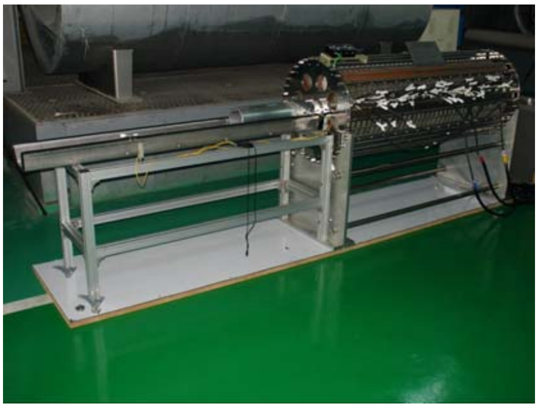


Fig. 2. The fundamental operation test system of the EM pump

The solid aluminum pipe with an outer diameter of 130 mm and an inner diameter of 122 mm was used to measure the developed force and velocity basically at the annular channel of the pump in room temperature, where the developed force and velocity corresponds to the developed pressure and flow velocity of the liquid sodium loop system, respectively.

2.2 The Function Test of the EM Pump

The input current of the pump was proportional to the input voltage as represented in Fig. 3.

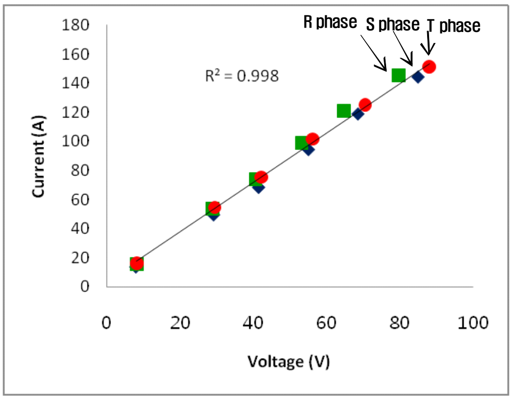
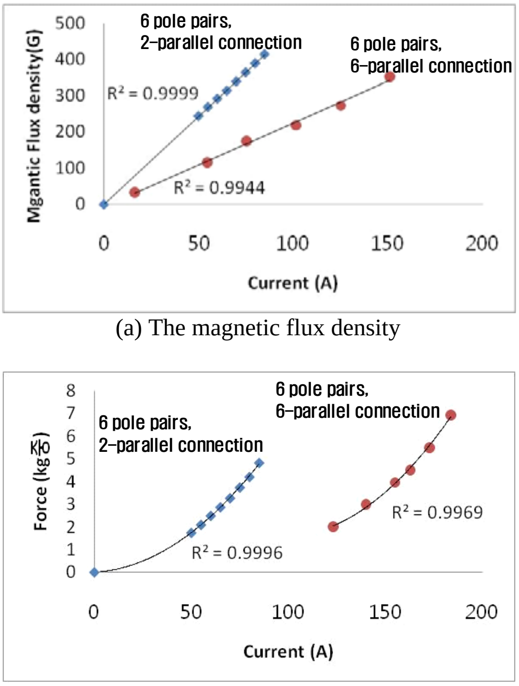


Fig. 3 The input voltage on the change of the input current driven to the EM pump

In Fig. 4 (a), the magnetic flux density was proportional to the input current as the Ampere's law indicated [4]. It was twice higher at the 2–parallel connection than at the 6-parallel connection when the number of pole pairs was 6. In Fig. 4 (b), the stand-still force, which corresponds to the developed pressure (ΔP), was increased in proportion to the square of the input current. Actually, in Eqn. (1) giving a function expression between the EM pump variables, the developed pressure has the relationship proportional to the square of the current from the fact the value of $R_2/(X_m s)$ of the present pump is much less than unity where $s = 1 - Q/Q_s$.

$$\Delta P = \frac{3I^2}{Q}\frac{R_2(1-s)}{s(R_2^{\,2}/X_m^{\,2}s^2+1)} = \frac{36\sigma s^2 f\tau^2(\mu_0 k_w NI)^2}{pg_e^{\,2}\{\pi^2+(2\mu_0\sigma sf\tau^2)^2\}} \qquad (1)$$



(a) The magnetic flux density

(b) Stand-still force

Fig. 4 (a) The magnetic flux density and (b) stand-still force of the EM pump

Also, the force at a 2–parallel connection was much higher than that at a 6-parallel connection. From Fig. 4 (a) and (b), it was understood the 2–parallel connection would be more efficient than the 6-parallel connection for the pumping.

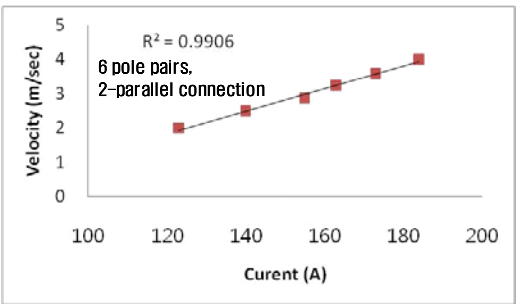


Fig. 5. The measurement of velocity of the aluminum pipe in the annular channel of the EM pump

The velocity of the aluminum pipe was measured when the pump was 2-parallel connected. In Fig. 5, it was proportionally increased as the input current was increased. The numerical value of the denominator, $(2\mu_0\sigma sf\tau^2)^2$ in Eqn. (1) is much less than unity when it is calculated on the case of the present EM pump. Also, the slip (s) is proportional to the velocity. Accordingly, the velocity is approximately proportional to the input current at the fixed developed pressure from the Eqn. (1). On the other hand, when the pump is actually installed and operated in the liquid sodium loop, the developed pressure is thought to decrease by the head loss which is given by $\Delta P_L = \rho K v^2/2$ [5] in the annular channel of the pump.

3. Conclusion

The EM pump with a flowrate of 2,265 L/min and developed pressure of 4 bar of the externally-supported-in-pipe type has been tested by using solid aluminum pipe. It was verified that the tendency of the fundamental characteristic was in good agreement with the theory from the test results where the numerical comparison between experiment and prediction was needed.

Nomenclature

f	electrical frequency
g_e	effective inter-core gap
I	input current
K	a loss coefficient
k_w	winding factor
N	turns of coils
R_2	secondary equivalent resistance
Q	flowrate of the fluid
Q_s	synchronized flowrate
s	slip
X_m	magnetizing reactance
ΔP	developed pressure of the EM pump
ΔP_L	head loss in piping system
μ_0	magnetic permeability in vacuum
τ	pole pitch
ρ	density of the fluid
σ	electrical conductivity of the fluid

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