Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 27-28, 2016

The Pressure and Magnetic Flux Density Analysis of Helical-Type DC Electromagnetic Pump

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1. Introduction

The electromagnetic pump was used to develop pressure applying liquid metal which had high electric conductivity. The developed pressure was made by only electromagnetic force eliminating probability of impurities contact, therefore the high reactivity materials such as alkali were best match to electromagnetic pump. The heavy ion accelerator facility by Rare Isotope Science Project (RISP) in Korea is trying to construct accelerator using liquid lithium for high efficiency of acceleration by decreasing charge state. The helical-type DC electromagnetic pump was employed to make a charge stripper that decrease charge state of heavy ion. The specification of electromagnetic pump was developed pressure of 15 bar with flowrate of 6 cc/s in the condition of 200℃.

2. Analysis

The helical-type DC electromagnetic pump was divided into electrode stub part (copper), pump duct part (stainless steel 316L), and permanent magnets part (Sm_2Co_{17}) as shown in Fig. 1. The pressure was generated due to magnetic flux density and current density.

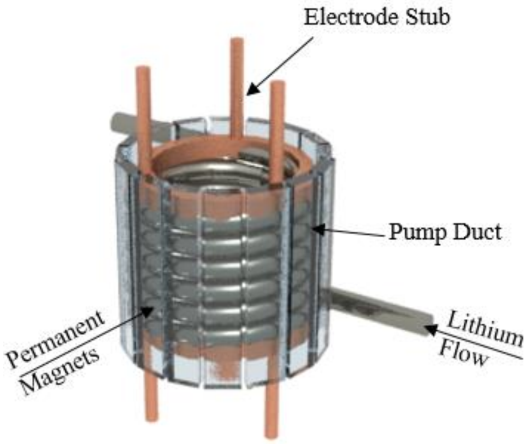

Fig. 1. Design modeling of helical-type DC electromagnetic pump

The pressure analysis[1] of helical-type DC electromagnetic pump was made up with equivalent circuit[2][3] method as shown in Fig. 2 including outer resistance, fringe resistance, stainless steel resistance, pump resistance, number of turns, number of electrode stub and electromotive force.

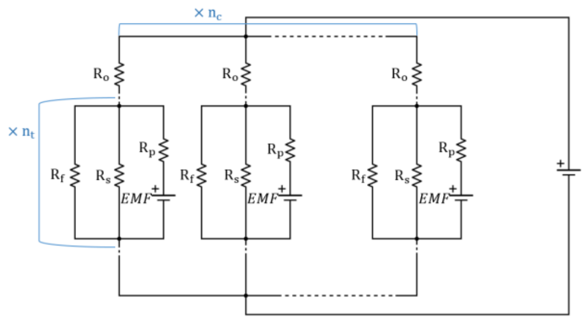

Fig. 2. The equivalent circuit of helical-type DC electromagnetic pump

The pressure was calculated with the combination of generated pressure of electromagnetic pump in Eq. (1) and pressure drop of loop system in Eq. (2).

$$\Delta P = n_t \left\{ \frac{4BR_{per}i_t}{\pi D_i(R_{ser}+R_{per})} - \frac{16 n_c B^2 Q}{\pi^2 D_i^2 (R_{ser}+R_{per})} \right\} - \left\{ f_D \frac{\pi \rho'_{lit} n_t D_R}{2} \frac{v^2}{D_i} + K_B \frac{\rho v^2}{2} \right\} \quad (1)$$

$$\Delta P = K_L v^2 \quad (2)$$

The magnetic flux density was also calculated to investigate effect of ferromagnet (1010steel) using a ANSYS code analysis.

3. Results

3.1 Pressure Analysis

The pressure of DC electromagnetic pump was analyzed in the aspects of current and number of duct turns.

The developed pressure was almost proportional to input current because relatively low flowrate made negligible of the electromotive force and hydraulic pressure drop as shown in Fig. 3 when number of duct turns was fixed as 14. The current was needed 1127 A to make a demanding specifications.

The developed pressure-flowrate curve had a characteristic of negative slopes in all current section which means stable even if small flowrate fluctuation was occurred as shown in Fig. 4.

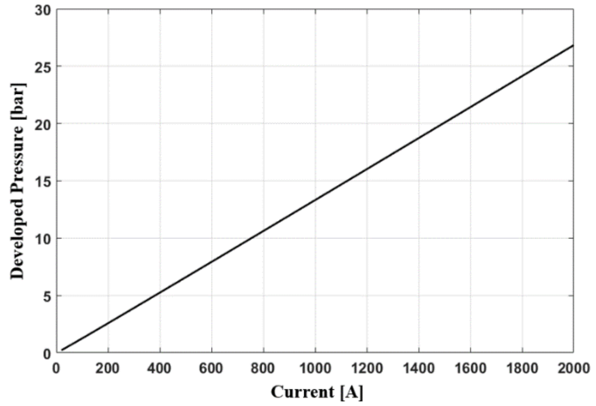

Fig. 3. Developed pressure of helical-type DC electromagnetic pump with changing of current

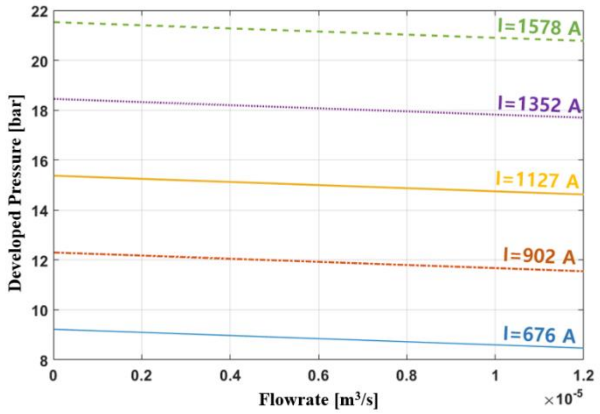

Fig. 4. Developed pressure-Flowrate characteristic of helical-type DC electromagnetic pump in the aspects of curent

The number of duct turns were affects to developed pressure proportionall because the pump duct got multiple force proportional to number of duct turns in spite of helical geometric as shown in Fig. 5.

The slope of developed pressure-flowrate curve was also negative value meaning a stable driving as shown Fig. 6.

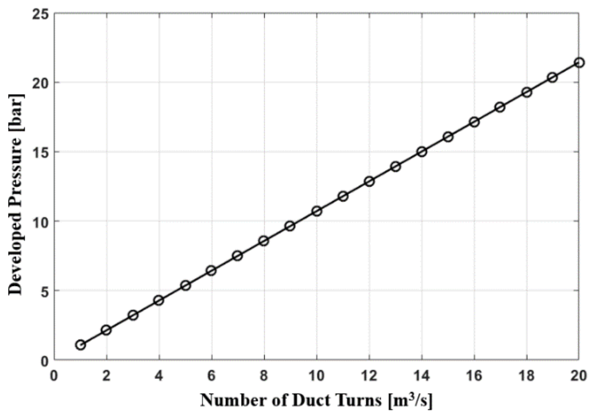

Fig. 5. Developed pressure of helical-type DC electromagnetic pump with changing of number of duct turns

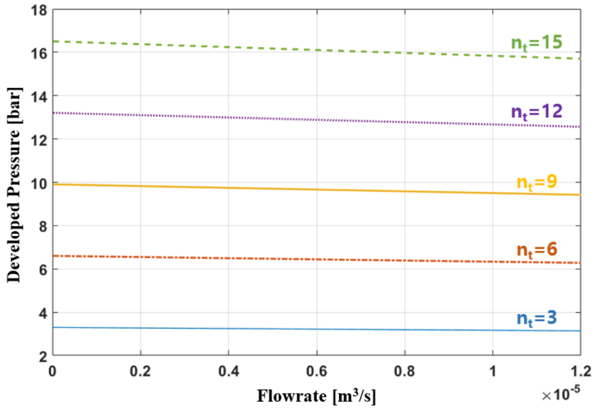

Fig. 6. Developed pressure-Flowrate characteristic of helical-type DC electromagnetic pump in the aspects of number of duct turns

3.2 Magnetic Flux Density Analysis

The magnetic flux density of helical-type DC electromagnetic pump was analyzed in the aspects of existence of ferromagnet.

The analytic region of the magnetic flux density was shown as Fig. 7.

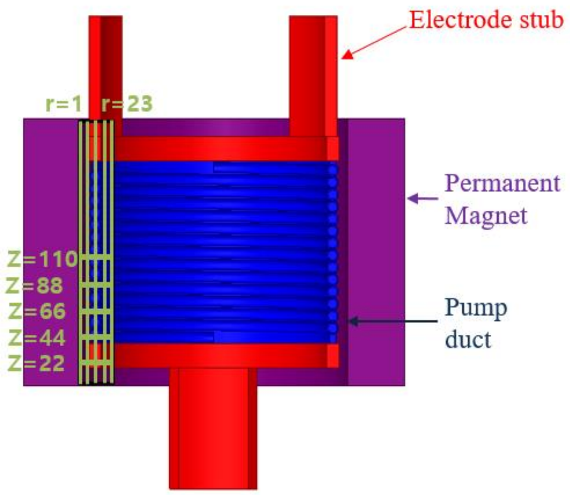

Fig. 7. Analytic region of magnetic flux density of non-ferromagnet helical-type DC electromagnetic pump.

The analytic results of radius direction magnetic flux density were shown as Fig. 8 and Fig. 9 when adjusting non-ferromagnet condition.

The magnetic flux density was increase as radius increase due to distance of permanent magnet, and it had peak point at end part of permanent magnet with having 0.07 ~ 0.1 T at pump duct.

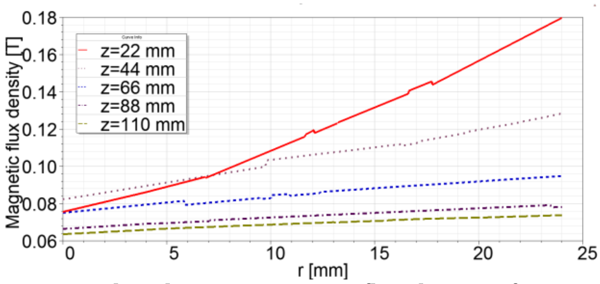

Fig. 8. Radius direction magnetic flux density of non-ferromagnet helical-type DC electromagnetic pump with changing of radius.

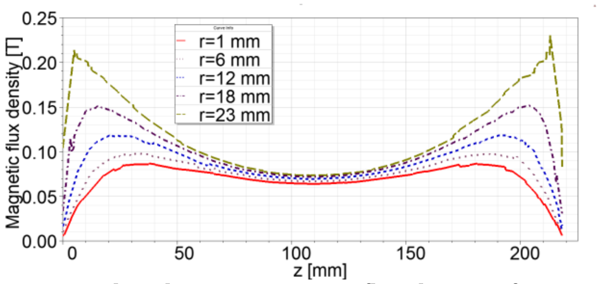

Fig. 9. Radius direction magnetic flux density of non-ferromagnet helical-type DC electromagnetic pump with changing of height.

The ferromagnet was added to helical-type DC electromagnetic pump in order to increase magnetic flux density as shown Fig. 10.

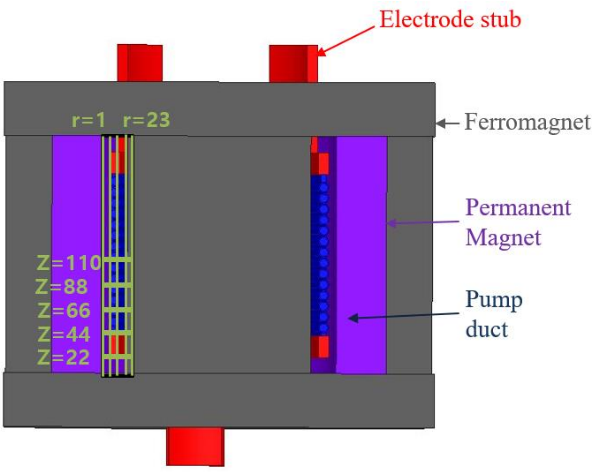

Fig. 10. Analytic region of magnetic flux density of ferromagnet helical-type DC electromagnetic pump.

The radius direction magnetic flux density results represented as Fig. 11 and Fig. 12 when adjusting ferromagnet condition.

The radius direction magnetic flux was decrease as radius increase and it had a peak point at middle point of height due to induce of magnetic field by ferromanget over increasing magnetic flux density by 0.7 ~ 0.8 T at pump duct.

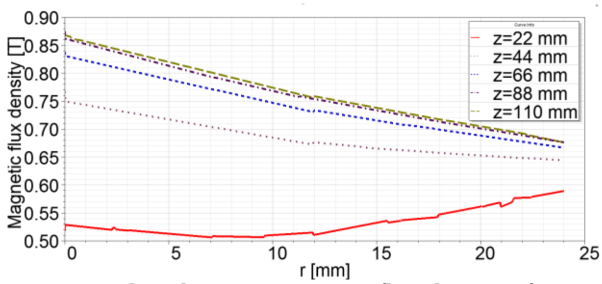

Fig. 11. Radius direction magnetic flux density of ferromagnet helical-type DC elctromagnetic pump with changing of radius.

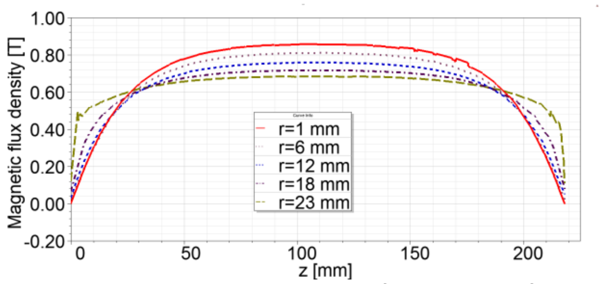

Fig. 12. Radius direction magnetic flux density of ferromagnet helical-type DC electromagnetic pump with changing of height.

3. Conclusions

The pressure and magnetic flux density of helical-type DC electromagnetic pump were analyzed. The pressure was proportion to input current and number of duct turns, and magnetic flux density was higher when ferromagnet was applied at electromagnetic pump. It seems that number of duct turns could be increase and ferromagnet could be applied in order to increase pressure of DC electromagnetic pump with constant input current.

REFERENCES

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