The Optimum Design Analysis of the Small DC Electromagnetic Pump with Loop-Supported Type

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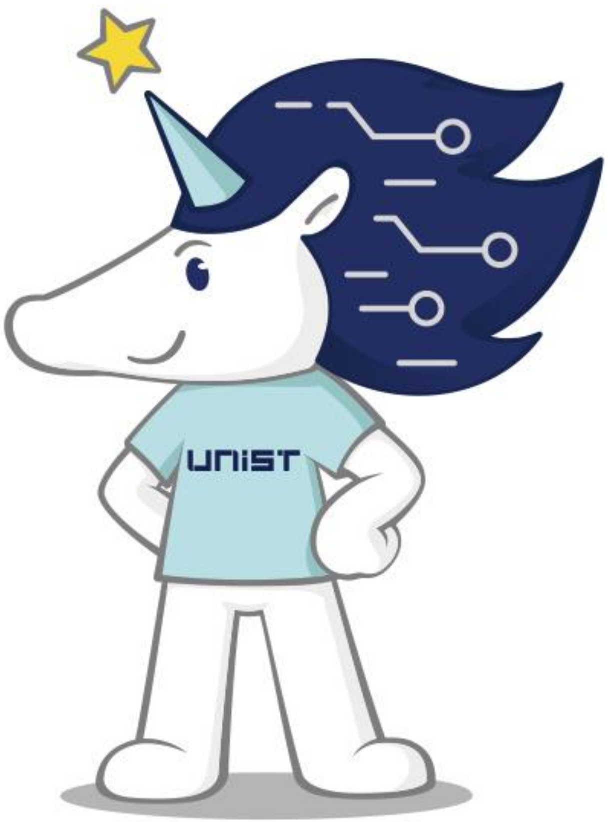

I. Introduction

Introduction

- Design of the DC EM (ElectroMagnetic) pump for the sodium-CO_2 reaction experimental loop in the SFR (Sodium Fast Reactor) at $3\ L/min, 0.05\ bar\ and\ 500\ ℃$

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Introduction

❖ Kinds of EM (ElectroMagnetic) Pump

Conduction pump

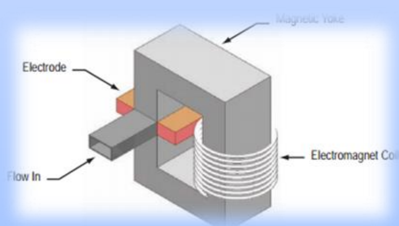
DC conduction

Pros

- ➢ Simple design
- ➢ Small size

Cons

- ➢ High current
- ➢ Heat loss



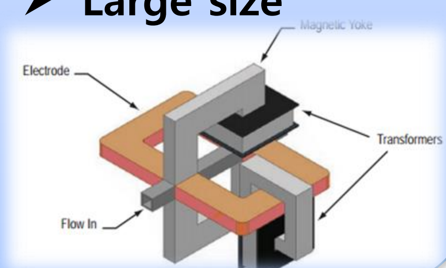
AC conduction

Pros

- ➢ Power control using transformer

Cons

- ➢ Relatively low efficiency
- ➢ Large size



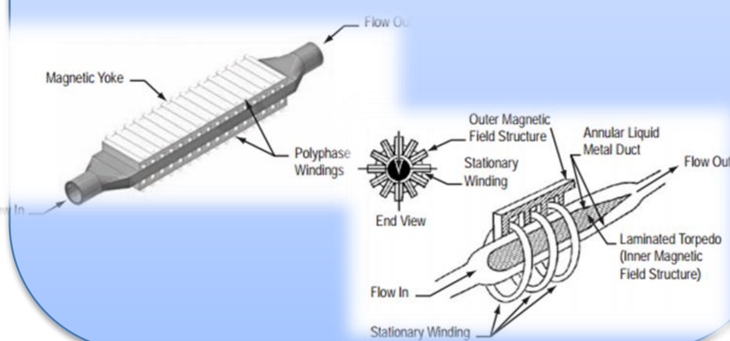
Induction pump

Pros

- ➢ Power control using transformer
- ➢ High capacity

Cons

- ➢ Complex design



❖ Reference : E.M Thomas, A.P Kurt, D. Amado, Electromagnetic Pumps for Conductive-Propellant Feed Systems, IEPC, 295, 2005.

Introduction

➢ The optimum design variables analysis of the DC EM pump

- Minimization of the input current

✓ $\leq 10\ kA$ Power supplies
→ have more than 3 m height.

❖ Reference : http://w3.siemens.com/powerdistribution/global/en/mv/medium-voltage-outdoor-devices/pages/vacuum-recloser-3ad.aspx

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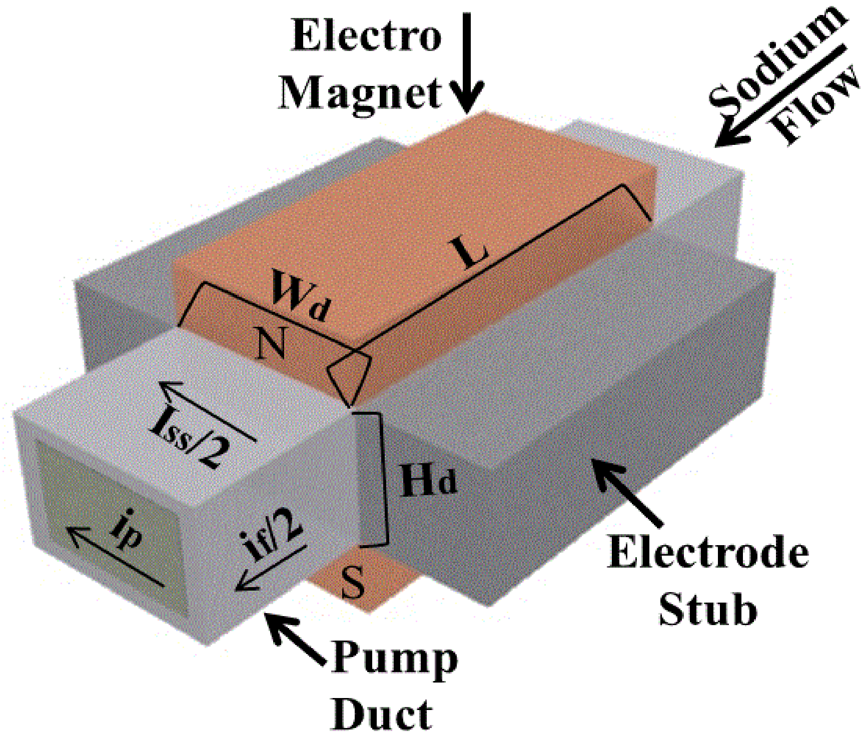
II. Analysis

Analysis

❖ Modeling & Principle of the DC EM Pump



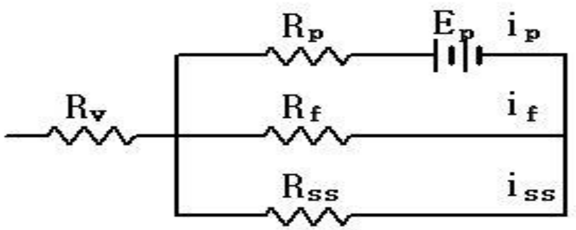
✓ Modeling of DC EM pump

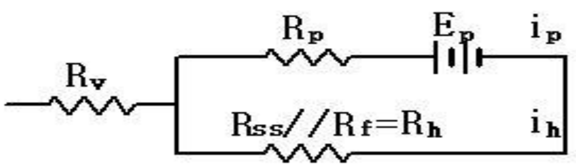
- Basic Principle :
  Fleming's Left hand rule
  $(F = B \times Il)$

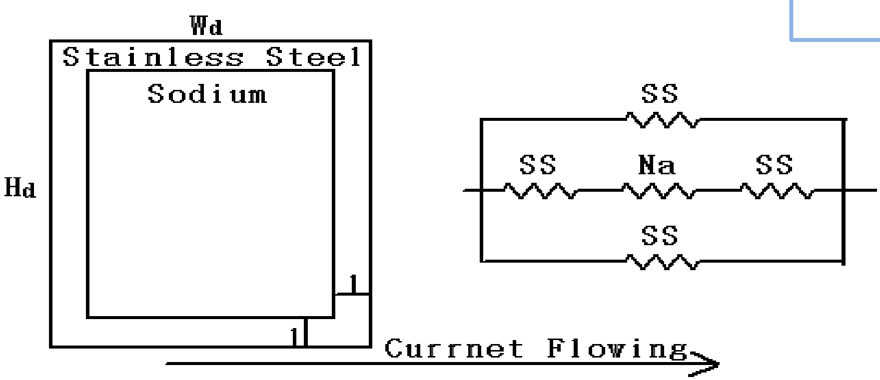
- Sodium get force by magnetic and current flow

Analysis

❖ Schematization of DC EM pump







✓ Overall & Cross sectional Schematization

$$i_t = \frac{\Delta P(R_h + R_p)(H_d - 2l)}{BR_h} + \frac{BQ}{R_h(H_d - 2l)}$$

Where,

$$R_p = \frac{\rho_{Na}(W_d - 2l) + 2\rho_{ss} l}{(H_d - 2l)L}$$

$$R_f = \frac{\rho_{ss}(\rho_{Na}(W_d - 2l) + 2\rho_{ss} l)}{k[(W_d)H_d\rho_{ss} + 2l\{\rho_{Na}(W_d - 2l) + 2\rho_{ss} l\}]}$$

$$R_{ss} = \frac{\rho_{ss}(W_d - 2l)}{2Ll}$$

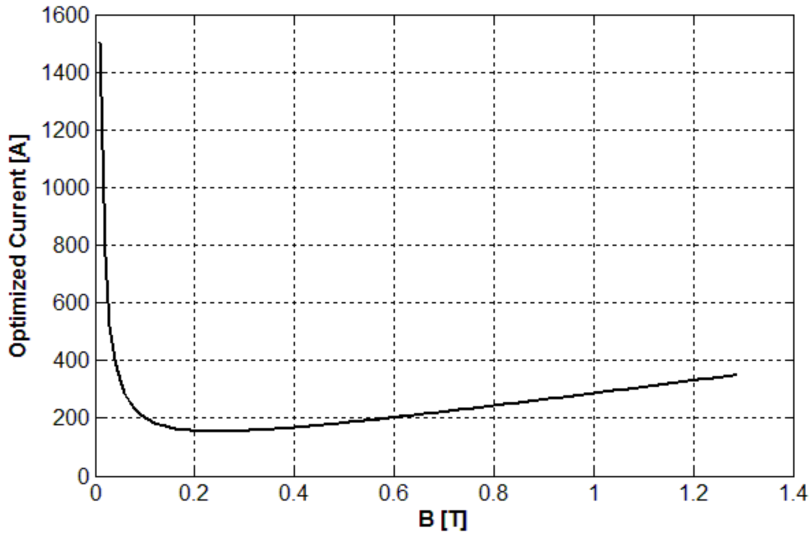
$$\frac{1}{R_h} = \frac{1}{R_f} + \frac{1}{R_{ss}}$$

III. Result

Result

With given data,
$Q\ (Volumetic\ flow\ rate)$: $3\ L/min$
$\Delta P\ (Pressure\ head)$: $0.05\ bar$
$T\ (Temperature)$: $500℃$

Relationship according to magnetic flux density is



✓ Optimized Current to change with magnetic flux density

- Analysis

$$i_t = \frac{\Delta P(R_h + R_p)(H_d - 2l)}{BR_h} + \frac{BQ}{R_h(H_d - 2l)}$$

✓ As magnetic flux density goes up until 0.1 T, left part (Force given by Fleming's left hand rule) is dominant so current is rapidly decreased

✓ As magnetic flux density goes down after 0.1 T, right part (electro motive force) is dominant so current is slowly increased

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Result

❖ Features of permanent magnet

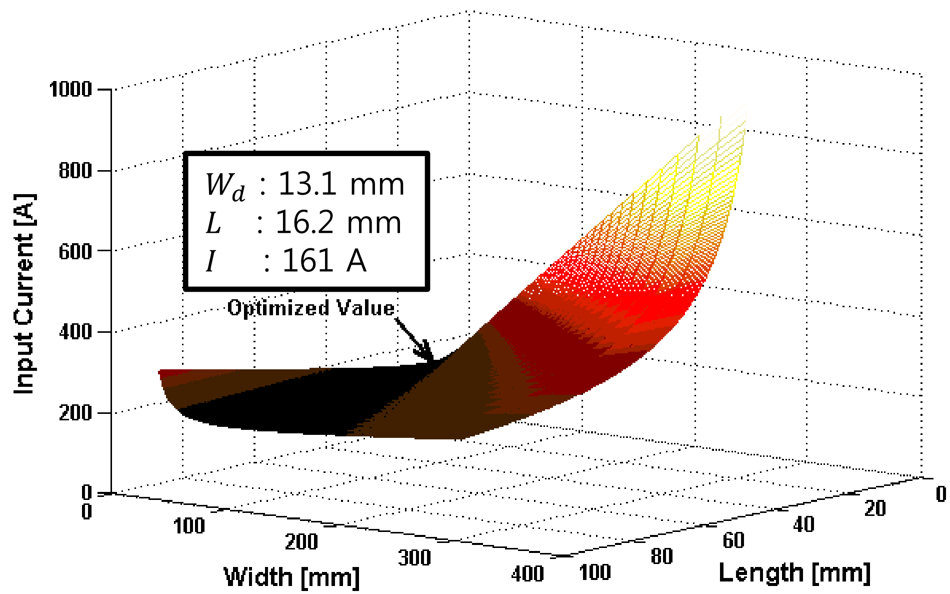
Properties	NdFeB	$SmCo_5$	Sm_2Co_{17}	Alnico	Ferrite
Curie temp. [℃]	320	750	825	860	450
Max. working temp. [℃]	80~200	260	350	550	250

✓ **Magnetic field strength at 6mm thickness: 0.4 T 0.05 T**

- In order to work at 500 ℃, Sm_2Co_{17}, Alnico is good to use.
- Sm_2Co_{17} is accepted
  because magnetic field strength is more adaptable than Alnico

Result

❖ Optimized value along the variables



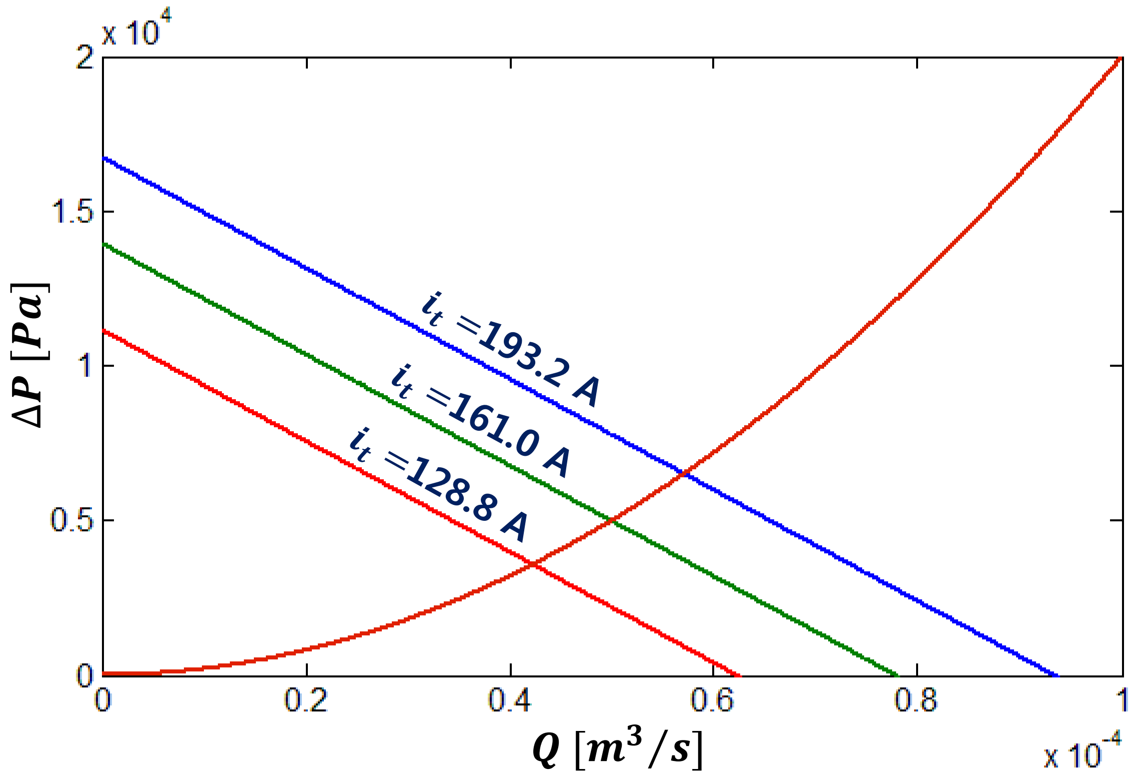
✓ Input current according to change of variables

W_d (Width) : 13.1 mm
H_d (Height) : 3.8 mm
L (Length) : 16.2 mm
I (Current) : 161 A

- H_d value is chosen by minimum value to adjust pump size.
- Black diagonal line has almost same value (max +7 %).
  Therefore this line values can be chosen according to variable situations.

Result

❖ P-Q characteristic analysis



✓ The characteristic curve of the pressure-flowrate

Slope is negative

- It works stably even if flow rate is fluctuated.

  - increased flow rate change causes reducing of developed pressure
  - decreased flow rate change causes increasing of developed pressure.

Result

❖ Viscous pressure drop & Power

$$\Delta \mathrm{P} = \mathrm{f_d} \cdot \frac{L}{D} \cdot \frac{\rho v^2}{2}$$

In turbulent flow,

- Viscous pressure drop is 44.4 Pa
- That affects only 0.9 % of total pressure ($0.05\ bar = 5000\ Pa$)

$$P = I^2 R$$

Power is 1.72 W

- Heat loss is small & hotness is safe

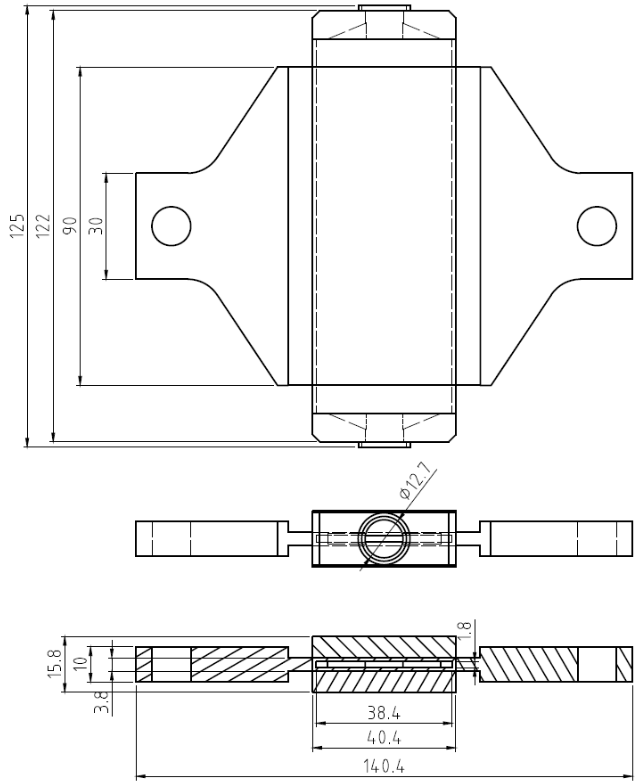
IV. Conclusion

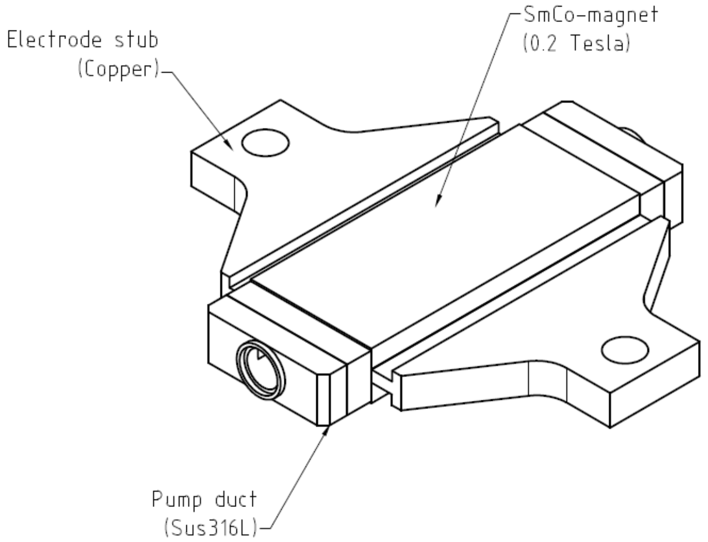
Conclusion

- Drawing optimized variables at $3\ L/\min, 0.05\ bar, 500\ ℃$
- This pump works stably.
- Viscous effect and Heat loss can be negligible.

Conclusion

➢ Manufacturing is ongoing now based on optimized values





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Thank you for your kind attention!

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