Design of DC Conduction Pump for PGSFR Active Decay Heat Removal System

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1. Introduction

A Direct Current (DC) conduction Electromagnetic Pump (EMP) has been designed for Active Decay Heat Removal System (ADHRS) of PGSFR. The PGSFR has active as well as passive systems for the DHRS. The passive DHRS (PDHRS) works by natural circulation head and the ADHRS is driven by an EMP for the DHRS sodium loop and a blower for the finned-tube sodium-to-air heat exchanger (FHX). An Annular Linear Induction Pump (ALIP) can be also considered for the ADHRS, but DC conduction pump has been chosen. Selection basis of DHRS EMP is addressed and EMP design for single ADHRS loop with 1MWt heat removal capacity is introduced.

2. Methods and Results

2.1 Characteristics of ALIP and DC conduction pump

To meet the DHRS design requirements, ALIP and DC conduction pump can be appropriate candidates [1, 2]. The two types of EMP are different in characteristics. In Table 1, the characteristics of each pump are summarized.

Table 1. Characteristics of EMP

	ALIP	DC conduction pump
Pros	- Potentially better efficiency (~20 to 40+ %) - Lower current requirement	- Lower voltage requirement (< ~few volts) - All metal construction - Simple construction - Simpler power supply (could be driven by a battery stack)
Cons	- Higher voltage requirement (> ~100 to ~1000 volts) - Need of good electrical insulator - Complex construction - Complex power supply (variable frequency drive or VFD) for efficient operation	- Inherently lower efficiency (< ~10%) - Very large current requirement(>~1000A)

For the DHRS in a nuclear reactor system, the reliability of the pump is the prime consideration and the pump efficiency is not an important factor. Although, a DC conduction pump tends to be able to develop low pump head and to have low efficiency, a DC conduction pump still remains a good candidate due to its simple construction and no need of high temperature electrical insulator. Therefore, a DC conduction pump has been chosen as a pump of the ADHRS of PGSFR [3]. An image showing a typical DC conduction pump is illustrated in Fig. 1.

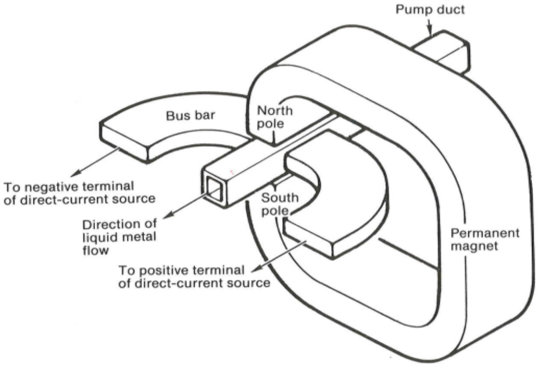

Fig. 1 Typical DC conduction pump

2.2 Design of DC conduction pump

Based on the design requirements, the set of the DC conduction pump parameters were calculated using an ANL developed Visual Basic for Application (VBA) code [3]. The code calculated the pump duct design including the electrodes attached to the pump duct with the design criterion to minimize the drive current need. The required magnetic field strength and the area of the pole face were also calculated.

Input parameters for designing pump are summarized in Table 2.

Table 2. Input parameters for designing pump

Parameter	Value
Temperature	468.75 K
Net pressure head	10 kPa
Flow rate	0.005 m^3/s
Maximum allowed flow velocity	5 m/s
System duct inner diameter	0.1 m
Duct wall thickness	4 mm
Contraction coefficient	0.36
Relative roughness	1.00E-07

In this work, during the design calculations, the pump geometry dependent parameters were optimized to minimize the total current to develop the required flow rate and the pressure head. The logic diagram is elucidated in Fig. 2. From the input parameters and the thermo physical properties, the following pump geometry dependent parameters are calculated and listed in Table 3.

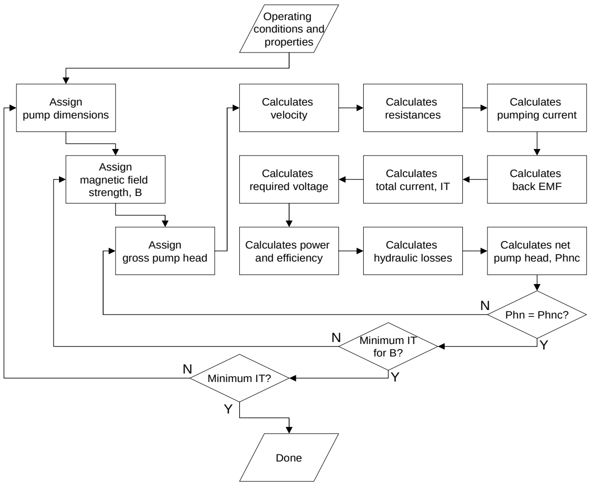

Fig. 2 Logic diagram for designing pump

Table 3. Designed parameters of the pump

Parameter	Value
Pump width	0.15 m
Pump length	0.0748 m
Pump height	0.0208 m
Magnetic field strength	0.134 T
Required voltage across pump	0.106 V
Actual current through pump	1378.6 A
Total current	5671.0 A
Current density at the electrode	3.64E+06 A/m^2
Total input power	601.8 W
Pumping power	50.0 W
Efficiency	8.31 %
Gross pressure head	14341 Pa
Calculated net pressure head	10000 Pa
Fluid velocity	2.742 m/s
Hydraulic diameter	0.024 m
Reynolds number	127359.71
Hydraulic loss	4341 Pa

Using the fixed pump geometry dependent parameters, described in the above, the performance curve of the pump is calculated by changing the flow rate. As the flow rate changes, the electric parameters of the pump change while keeping the total current constant, providing the new pump pressure head for that flow rate. Keeping changing the flow rate and plotting the corresponding pressure head forms the pump performance (flow rate-pressure head) curve as seen in Fig. 3.

2.3 Dipole Design

With the calculated required magnetic field strength, a dipole that would produce the magnetic field to cover the pump section of the duct was designed [3]. The dipole employs a double-C style and the field strength can be easily adjusted by changing the cross sectional area of the magnet as well as the thickness of the magnet, while minimizing the leakage of the magnetic field (Fig. 4).

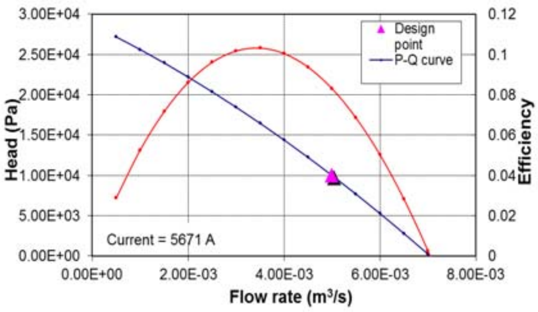

Fig. 3 Pump performance curve at 5671 A

Because of the relatively low pressure head requirement, the required magnetic field strength is ~0.1 to 0.2 Tesla, which can easily be achieved using a conventional magnetic material (soft iron) and magnet (Samarium Cobalt).

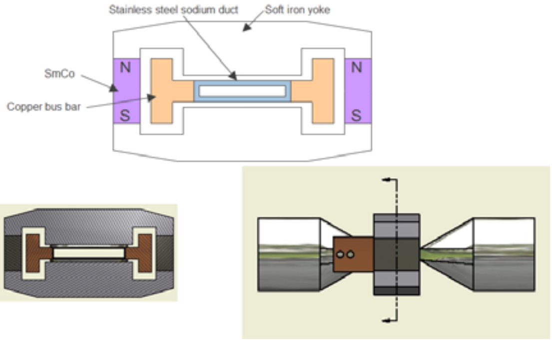

Fig. 4 Double-C style dipole design

3. Conclusions

A DC conduction pump has been designed for the ADHRS of PGSFR. A VBA code developed by ANL was utilized to design and optimize the pump. The pump geometry dependent parameters were optimized to minimize the total current while meeting the design requirements. A double-C type dipole was employed to produce the calculated magnetic strength. Numerical simulations for the magnetic field strength and its distribution around the dipole and for the turbulent flow under magnetic force will be carried out.

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