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Design and analysis of operation performance of parameters of the integrated valve under the high temperature condition

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ABSTRACT

Hydraulic Control Rod Drive Technology (HCRDT) is a newly invented patent and Institute of Nuclear and New Energy Technology Tsinghua University owns HCRDT's independent intellectual property rights. The integrated valve which is made up of three direct action solenoid valves is the key part of this technology, so the performance of the solenoid valve directly affects the function of the integrated valve and the HCRDT. First, based on the conditions occurring in the operation of the Control Rod Hydraulic Drive System, the coil of the direct action solenoid valve in high temperature is studied by the experiment and the temperature of coil under different temperature can be obtained. Second, the temperature field of the coil is analyzed by ANSYS in order that the thermal conductivity of coil under different temperature can be obtained. Third, the temperature field of the integrated valve is analyzed by CFX based on the thermal conductivity. The result shows that the current is the key point which affects the temperature of the valve most and the valve cannot work regularly if the current is too high. Finally, the working condition of the solenoid valve is optimized, especially the current, so that not only the temperature of the coil is under its decomposition temperature and but also the valve can work efficiently.

1. Introduction

The control rod (CR) driving mechanism is the crucial safety equipment, which plays an important part in the reactor startup, power adjustment and shut-down process (Bo et al., 2002). Combined with the fundamental research of the Hydraulic Control Rod Driving System (HCRDS) which is invented by Tsinghua University, and the advantage of the magnetic jack in pressurized water reactor (PWR), the control rod hydraulic drive mechanism (Bo et al., 2005) is developed as a new type of internal control rod drive technology. The integrated valve is the key equipment of control rod hydraulic drive mechanism, of which the outflow pulse regulates the step motion of the drive mechanism (Bo et al., 2000). The solenoid valve is the most important part of integrated valve.

The solenoid valve is a kind of actuator in automation instrument (Jiang and Zi, 1996; Brauer, 2006), with many advantages, such as fast and safe switching, high reliability, long service life, good medium compatibility of the materials used, low control power and compact design. It has already been widely used in industry, agriculture, transport, aerospace and aviation, tourism, living facilities. Especially, it is a critical control component in hydraulic control systems (Merritt, 1967; Trostmann, 1996; Blackburn et al., 1960). Based on the energy conversion methods (Jiang and Zi, 1996), the solenoid valve can be divided into two types: one is powered by electromagnetic energy directly and the other is by oil pressure which is driven by magnetic coil. The former is named direct action solenoid valve, while the latter is called pilot-operated solenoid valve. In the study, we do some research on direct action solenoid valve.

In detail, this type of solenoid valve is a newly invented valve with excellent dynamic characteristics to control the pulse outflow for CRHDM's good working performance (Liu et al., 2010a). In this study, there are four assignments to be finished. First, the temperature characteristic of the coil can be obtained by experiment. Second, the experiment results are analyzed by numerical method so as to gain the parameter of heat transfer of the coil. Third, the parameters of the integrated valve are analyzed. Forth, the working condition of the integrated valve is optimized.

In this paper, the optimization flow is shown in Fig. 1. Section 2 introduces the experimental study of the coil of the solenoid valve. Section 3 presents experiment analysis of the solenoid valve in order to obtain the coefficient of the thermal conductivity of the coil. Base on the coefficient, Section 4 presents parameters analysis of the integrated valve to gain the key parameter. Section 5 shows

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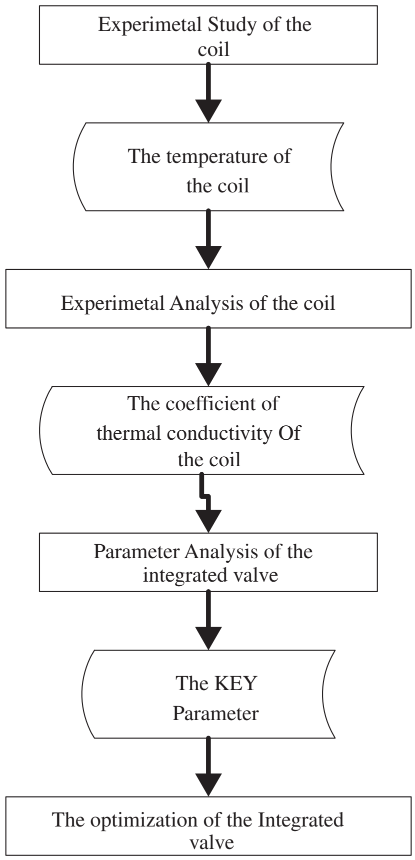


Fig. 1. The optimization flow.

the optimization of the operation performance of the integrated valve. In Section 6, the results are verified by experiment. The conclusion is shown in Section 7.

2. Experimental study of the coil

In the section, the temperature characteristic of the coil can be obtained, which can be used to gain the thermal conductivity of the coil in Section 3.

2.1. Model

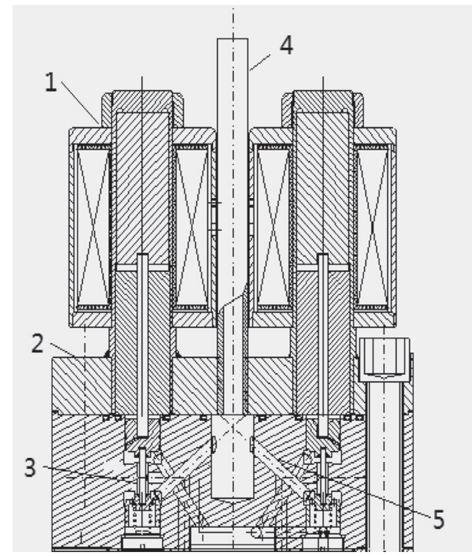
The structure of the integrated valve is shown in Fig. 2a, which contains the solenoid valve, the base, the spring, the inlet and the outlet. Fig. 2b shows the structure of the solenoid valve in the Control Rod Hydraulic Drive System. The solenoid valve is symmetrical and the components are list in Table 1. The thermal of the coil is the key of the study in the paper. What's more, the current input is from 0.05 to 0.35 A.

2.2. Facility and scheme

2.2.1. Facility

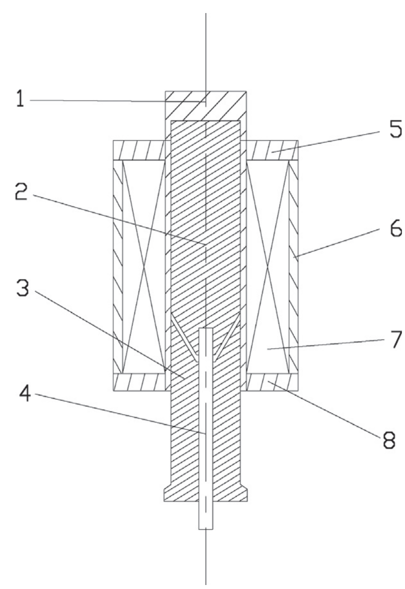
As seen in Fig. 3, the experiment system is made up of the coil, instrumentation system and data acquisition system.

The instrumentation system consists of the resistance thermometry, the current sensor and the power supply. Firstly, the temperature of the coil of the direct solenoid valve is measured by the resistance thermometry under different currents. Secondly, the coil current is measured by current sensor under different



(a) The structure diagram of the integrated valve

1-Solvnoid Valve;2-Valve base;3-Spring;4-Inlet;5-Outlet



(b) The structure diagram of the solenoid valve

1-top cover,2-action core,3-fixed core,4-pole

5-up cover board of coil,6-shell,7-coil,8-down cover board of coil

Fig. 2. The structure diagram of valve.

Table 1
The component of the solenoid valve.

No.	Name	Material
1	Top cover	1Cr18Ni9Ti
2	Action core	1J50
3	Fixed core	1J50
4	Pole	1Cr18Ni9Ti
5	Up cover board of coil	DT4C
6	Shell	No. 10 steel
7	Coil	Polyethyleneimine
8	Down cover board of coil	DT4C