Control rod drive for high temperature gas cooled reactor*

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Abstract This control rod drive is developed for HTR-10 high temperature gas cooled test reactor. The stepmotor is prefered to improve positioning of the control rod and the scram behavior. The preliminary test in 160°C ambient temperature shows that the selected stepmotor and transmission system can meet the main operation function requirements of HTR-10.

Keywords HTR reactor, Control rod drive, Performance testing

1 Introduction

In normal operation the control rod drive mechanism (CRDM) drives the control rods up or down at a certain speed to control the reactivity and stop at certain position. But for safe shutdown, the control rods should be inserted by its own weight at a certain speed. The control rod position indicator and the terminal switch are usually installed. The object of this project is to develop CRDM which is suitable for the HTR-10 high temperature gas cooled test reactor operated at 160°C ambient temperature.

The new CRDM we set up in this study is mainly based on the facility working in cold condition we set up in 1990-1992, which originated from the THTR (Thorium high temperature reactor) first shutdown facility.[1,2] The rods and the drive of THTR CRDM are connected by a link chain, driven by a two phase AC motor through the gear transmission consisting of planetary gear, bevel gear, the chain wheel and gear wheel reducer. During operation the THTR rod can be held at a position or automatically moved to the required one. For safe shutdown the rods can be inserted into the lowest position rapidly by themselves gravity as deenergizing the motor, the traveling speed is limited by an eddy-current brake, and the end of the link chain is equipped with a shock buffer to absorb the kinetic energy. The two phase AC motor used in CRDM is the simplest and gear design is also, but a sophisticated control is needed and its positioning property is not ideal.

The stepmotor is selected in this study for more accurate positioning of the control rods in the HTR-100 and HTR-M. In result, the scram behaviour is improved much because inertia moments of this motor and gear are both smaller.

The compositions of the CRDM with stepmotor are basically similar to those with two phase motor. But the former torque moment is so large that the planetary gear reducer can be omitted; additionally, the permanent magnet of the stepmotor has the function of the eddy-current brake so the brake can also be neglected. The CRDM in this project consists of the bevel gear and the gear wheel reducer, the chain and the chain wheel, the spring buffer, and the reed position indicator. In addition the safety plug is provided for dismantling the drive from the rods in the pressurized reactor and for limiting the gas flow during the operation of normal condition. In order to satisfy requirement of the ambient temperature the special electrical heater and insulation cover are installed. And a special controller is also developed.

2 R & D of CRDM

2.1 Design requirements of CRDM

In normal operation control rods are moved to the required position at 10 mm/s, the speed of rapid insertion is 500 mm/s, the traveling path of the control rods is 2.6 m, the ambient temperature is 160°C, the rod weight is 40 kg.

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2.2 Developing of stepmotor

According to requirements, the stepmotor should possess the following qualities: the torque moment in normal load is 5 Nm, the torque moment in the maximum load is 12.5 Nm, the rotation speed is lower than 300 rpm, the normal speed is 30.7 rpm, in full load condition the motor can run in positive and negative directions, the motor has the lock function when it is powered , the control rods could descend to its lowest position by gravity when deenergized , the motor has the shaft extended in both ends.

The commercially available 130 BYG 301 stepmotor was selected for the test in normal ambient temperature. Due to its insulator is of grade B it can only be used in the ambient temperature of 40°C. Therefore better insulator materials of grade C were selected in order that it can be used in 160°C ambient temperature.

First, based on electric parameters of stepmotor high temperature stepmotor was designed, and all the electric materials were replaced into grade C; then, tested and improved step by step upto it can satisfy the requirement.

Test results show that the static torque moment was 12.8 Nm; after it was operated at frequency of 300 pps in the oven of 160°C for 3 h its static torque moment and characteristics of torque versus frequency were both not changed.

2.3 Mechanical transmission

As mentioned above, the mechanical transmission of the CRDM consists of the bevel gear and gear wheel reducer, the chain wheel and chain, the spring shock buffer, the reed position indicator and the safety plug. Through two stage retard the reduction gear ratio is 1:12. In the transmission design the tolerance and the grease which are both suitable for the high temperature condition are selected.

2.4 Electrical heater

In order to engender an ambient temperature of 160°C a set of special heating device[3] is installed in CRDM. In the device there are 4 heating sleeves in which there are heating elements and special liquid, the diameter of the sleeve is about 40 mm. Outside the sleeves there is an integral heat insulation cover. The power of the heater is 3.5 kW. The temperature of the heater can be controlled automatically.

2.5 CRDM controller

A special controller is developed for HTR-10 CRDM to control the movement of the control rods and indicate the position of the control rods. The controller is operated in multinode automatically and manually. The controller consists of 5 parts, the rod position luminous diode indication, the rod position numeral indication, the rapid descension, the automatical mode and the manual mode, the motor rotation speed setter and power switch.

2.6 The overall test

First, 110 BYG 401 stepmotor is used to determine the torque moment of the CRDM; then, 130 BYG 301 stepmotor is used in normal ambient temperature to determine design parameters; finally, a new special developed 130 BYG 301 stepmotor is used in 160°C by heating device to test the lifting ability with the load of 120 kg (2.4 times of the normal load) and with the load of 50 kg, and to test the scram behaviour with the normal load of 50 kg.

Results show that when the motor was deenergized the load descending for 2.6 m takes 4 s. The pin for connecting the chain and the spring shock buffer was broken, then replacing it with an enlarging diameter pin. Finally the overall test is quite well after some improvements were made.

3 Conclusions

It is observed that the stepmotor, the controller and the mechanical transmission part are good enough to meet the requirements of working at 160°C high ambient temperature for HTR 10.

The further R&D work should be done to solve the seal and lubrication problem in high temperature pressurized helium condition by careful design and material selection.

References

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