Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 10-11, 2007

Conceptual Design of Angular Position Detector for Control Element Drive Mechanism of Small and Medium Reactor

Je-Yong Yu, Hyung Huh, Ji-Ho Kim and Suhn Choi
Mechanical Engineering Division, Korea Atomic Energy Research Institute, P.O. BOX 105, Yuseong, Daejeon, 305-600, Korea, Phone: 82-42-868-2835, Fax: 82-42-868-8990, e-mail: yjy@kaeri.re.kr

1. Introduction

When the small and medium reactor is designed with a soluble boron free operation and nuclear heating for the reactor start-up, the design features require a Control Element Drive Mechanism (CEDM) to have a fine-step movement capability as well as a high reliability for a fine reactivity control. Also the reliability and accuracy of the information for the control rod position is important to the reactor safety as well as to design of the core protection system. The position signal of control rod is classified as a Class 1E because the rod position signal is used in the safety related systems. Therefore it will be separated from the control systems to the extent that a failure of any single control system component of a channel and shall have sufficient independence, redundancy, and testability to perform its safety functions assuming a single failure. The position indicator is composed of a permanent magnet, reed switches and a voltage divider. Four independent position indicators around the upper pressure housing provide an indication of the position of a control rod comprising of a permanent magnet with a magnetic field concentrator which moves with the extension shaft connected to the control rod. The zigzag arranged reed switches are positioned along a line parallel to the path of the movement of the permanent magnet and it is activated selectively when the permanent magnet passes by. A voltage divider electrically connected to the reed switches provides a signal commensurate with the position of the control rod. The signal may then be transmitted to a position indicating device. But position indicator can not recognize the malfunction of the rotary step motor of CEDM instantly because its signal output is changed after the control rod moves more than a distance of reed switch interval.

In order to monitor the operating condition of the rotary step motor of CEDM, the angular position detector is installed at the top of the rotary step motor by means of connecting between the planetary gear system and the rotating shaft of the rotary step motor. Therefore the angular position detector can measure one step angular increase of the rotary step motor by means of detecting the angular position of the permanent magnet using the reed switch assembly outside the pressure housing of the angular position detector. The angular position detector with planetary gear can measure precisely the control rod position by considering the gear ratio and the ball screw lead as well as can check the operating condition of the rotary step motor of CEDM at real time.

2. System Descriptions

In this section the system description and design feature of the major subsystems in CEDM are introduced. The CEDM consists of a Rotary Step Motor (RSM), four CEA Position Indicators (PIs), an Angular Position Detector (APD), an Extension Shaft Assembly (ESA) connecting CEDM and a Control Element Assembly (CEA). The general view of CEDM is shown in Fig. 1. Casing of RSM are made with the use of welded joints. The CEDM separate units are joined to each other by flanges with studs and nuts. Each part and subassembly of CEDM are located on the reactor central cover and connected to it by means of thread and omega seal weld. Communication line between CEDM and control hardware is provided by cables. [1-4]

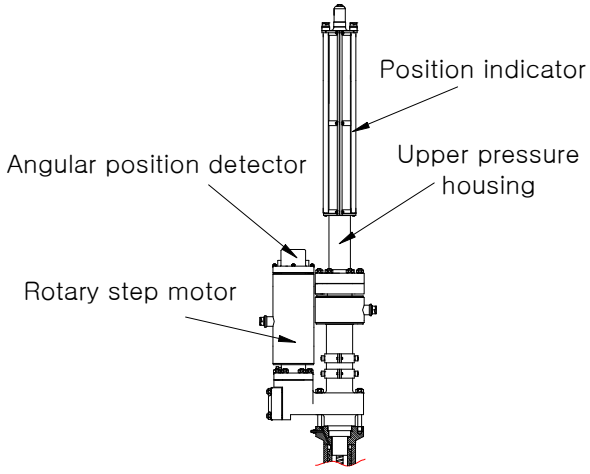

Fig. 1 Overall view of control element drive mechanism

3. Angular Position Detector

Fig. 2 shows a section view of the angular position detector and its major components are 2 pairs of planet and sun gear, a holder of planet gear, a magnet and reed switches around a housing of angular position detector. As the angular position change of rotor shaft of RSM comes to the spline of angular position detector, the planetary gear system magnifies the angular position of rotor shaft of RSM to help the reed switches to measure the angular position according to one step angular

increase of the rotary step motor. The detecting target of magnet to the reed switches is in the holder of planet gear.

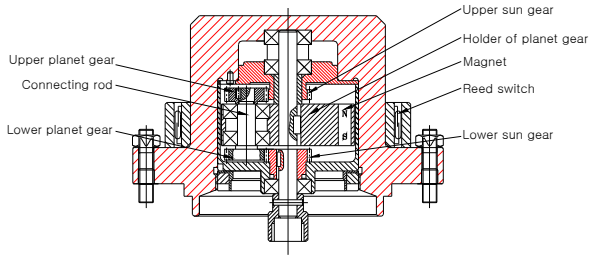

Fig. 2 Configuration of angular position detector

Fig. 3 shows the schematic diagram of planetary gear system having the role to magnify the angular position increase of the RSM.

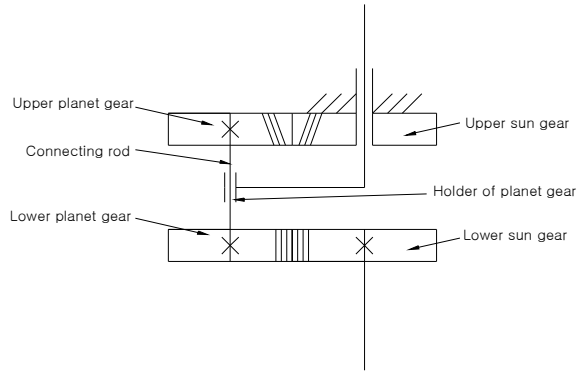

Fig. 3 Schematic diagram of planetary gear system

The principle of planetary gear system operation is as follows. The angular increment of magnet can be obtained by multiplying the original angular increment of RSM by the magnification ratio *i*. For example if we want to set the magnification ratio *i* 8 we only provide the planetary gear system having Z_1 of 30, Z_2 of 25, Z_3 of 30 and Z_4 of 32.

$$i = \frac{Z_2 \cdot Z_4}{Z_2 \cdot Z_4 - Z_1 \cdot Z_3} \qquad (1)$$

where

i : Magnification ratio
Z_1 : Number of tooth of upper sun gear
Z_2 : Number of tooth of upper planet gear
Z_3 : Number of tooth of lower planet gear
Z_4 : Number of tooth of lower sun gear

Fig. 4 shows the simplified shape of the reed switch holder around the pressure housing of the angular position detector. The design feature of reed switch holder is to provide the easy installation, maintenance and calibration for the angular position detector. Also the reed switches can be vertically mounted into reed switch holder. The permanent magnet positioned in the planetary gear holder which is designed to rotate of 60^O in corresponding to each step of the rotary step motor. The rotation angle of magnet can be surely detected by the reed switches around the pressure housing of angular position detector.

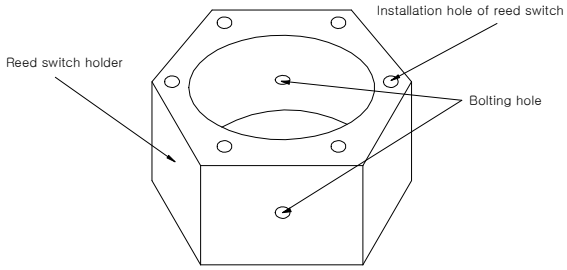

Fig. 4 Configuration of reed switch holder of angular position detector

4. Conclusion

In the design of the small and medium reactor, it is planned to develop CEDMs with fine-step movement capability as well as high reliability for fine reactivity control. A conceptual design of the angular position detector is proposed to enhance the accuracy of control rod position and to check the operating condition of the rotary step motor. The confirmation of performance of the angular position detector is fulfilled through ACAD model, analytic equations and reed switch tests. The results of this study have shown that the angular position detector will cooperate with the position indicator to measure the position of the control rod more reliably.

Acknowledgement

This work has been performed under the nuclear research and development program sponsored by the Ministry of Science and Technology, Korea.

References

[1] J. Y. Yu and et al (2001), “Development of Linear Pulse Motor Type Control Element Drive Mechanism for SMART”, ICONE-9, Nice, France.
[2] J. Y. Yu and et al (1999), “Review of Design Technology for Control Rod Position Indicators”, KAERI/AR-551/99, KAERI.
[3] J. Y. Yu and et al (2000), “Conceptual Design of RSPT Type Control Rod Position Indicator for SMART CEDM”, Korea Nuclear Society Spring Conference.
[4] J. Y. Yu and et al (2002), “Design of Magnetic Flux Concentrator of Permanent Magnet for Control Rod Position Indicator of SMART CEDM”, Korea Nuclear Society Spring Conference.