Development of Advanced Loop-Type Fast Reactor in Japan (5): Adoption of Self-Actuated Shutdown System to JSFR

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A self-actuated shutdown system (SASS) is a passive safety feature which inserts control rods into the core by passive actuation accompanied by abnormal coolant temperature rise within the reactor core in anticipated transient without scram (ATWS) events. JAEA selected the Curie point electromagnet SASS, which is a simple structure and has flexibility of detaching method, as the most promising concept for use in a JAEA sodium-cooled fast reactor (JSFR). This paper shows the effectiveness of SASS by describing the design condition, related R&D activities and their major results, and results of some preliminary safety analysis.

In the Curie point electromagnet SASS, the control rod is held by the electromagnetic force. When the temperature of the sensing alloy embedded in the armature of the electromagnet excesses above the normal operation level in a certain extent, the holding force is rapidly lost due to significant diminishment of the magnetic flux. In a reactor case, when the temperature of the sensing alloy heated by the coolant flowed out from the core exceeds the actuation temperature in ATWS events, SASS drops the control rod into the core without any external driving force and actuation signal. In addition, the JSFR is designed to assure the insertion performance of control rod by taking preventive measures against excessive reactor core deformation and a control rod stuck; therefore, the probability of failure of the control rod insertion is considered negligible small.

Various out-of-pile tests have already conducted to investigate the basic characteristics of SASS: durability of SASS components against thermal aging and corrosion in sodium, holding force characteristic and transient response characteristic. In order to confirm the impact on SASS under the irradiation; a demonstration test of holding stability of SASS under the reactor operation condition, a function test of the driving system to re-connect and pull out the control rod, and the element irradiation test were conducted in the experimental reactor JOYO. These tests have almost completed and variable data concerning transient response and reliability of SASS was obtained.

In order to see the feasibility of SASS for a reference core design in the large-scale JSFR, some preliminary safety analyses were conducted against three typical ATWS events: unprotected transient overpower (UTOP), unprotected loss-of-flow (ULOF), unprotected loss-of-heat-sink (ULOHS). The analytical results showed that the maximum temperatures of coolant in all cases were less than safety criterion under ATWS condition; thus, the feasibility of SASS in the JSFR was confirmed.

The above-mentioned activities for the development of SASS ensured the applicability to JSFR as a passive reactor shutdown system. To improve the flexibility of rod detaching temperature for various core designs, development activities will be continued by minor modifications of material components.