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Advanced Integrated Head Assembly Design for APR+ Nuclear Power Plants

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1. Introduction

An Integrated Head Assembly (IHA) installed on the Reactor Vessel Closure Head (RVCH) is designed with functions of lifting the RVCH, supporting a seismic excitation, cooling the CEDM coils, protecting missiles and routing/supporting the head area cables. The design of the IHA was introduced in the previous research [1]. After the first application of APR1400 IHA at Shin-Kori 3&4, there was modification of the IHA to be suitable for APR+. The APR+ IHA maintained the similar design concept and configuration with APR1400 IHA. With the design experience, innovative design improvement of the IHA has been requested in a view of reduction of seismic loads and time to access CEDM weld for in-service inspection.

This paper shows the design features and experience for APR1400 and APR+ IHA, and proposes an advanced IHA design applicable to APR+, which is different from existing APR+ IHA. In addition, it provides expected benefits of the advanced IHA with respect to the maintenance and loads.

2. APR1400 and APR+ IHA

2.1. Design Features of APR1400 and APR+ IHA

The APR1400 and APR+ IHA consist of the cooling shroud assembly, lifting assembly, air plenum assembly, seismic support assembly, cable support assembly.

The cooling shroud assembly provides the cooling air path and consists of three sub-assemblies as lower, middle, upper cooling shroud assembly. The shell was used for the cooling shroud assembly as main structure.

The lifting assembly consists of the main columns, tripod assembly and shackle. The function of the lifting assembly is to form load path and support lifting loads of entire weight of RVCH and IHA.

The air plenum assembly provides a room to ensure uniform pressure and speed of uneven cooling air passing through the baffle. The uniformed cooling air is drawn into the inlet of CEDM cooling fans and maximizes the efficiency of the CEDM cooling fan.

The purposes of the seismic support assembly are to restraint the behavior of CEDM and transfer the seismic loads of the CEDMs and IHA caused by the earthquake excitation. The seismic support plate is a circular perforated plate enveloping all CEDMs and the seismic restraints can support only tensile loads.

The cable support assembly is made up of the messenger wires, messenger wire support beams, holders, cable bridges to route and support CEDM cables.

2.2. Experience of Designing and Operating the IHA

At Shin-Kori 3&4, it was discovered that the IHA should be disassembled for CEDM weld inspection prior to plant operation. Since the IHA encloses all the CEDMs, in order to access the weld zone of the CEDM, the components of the IHA needs to be disassembled. Based on the site information, it took about a month to complete the CEDM weld inspection including the IHA disassembling and reassembling. As a result it was requested to improve the procedures and reduce working hours.

It is a trend to increase the seismic capacity for the nuclear power plants (NPPs). For the APR+ IHA, increasing the diameter of the reactor vessel, the size of the IHA was also increased. It caused the weight increase of the IHA. The combination of the increase of seismic demands and the weight developed the large seismic loads on the IHA and caused design margin to be reduced. So it needs the large scale design modification of the IHA ensuring the enough structural margins against an earthquake.

3. Design of Advanced IHA

Generally, a structure is reinforced by increasing the size of members or adding extra members as external loads increase. However, in case of the IHA, it was revealed that the IHA member loads were increased along with the increase of the IHA weight due to increasing member sizes. So the design approach of the advanced IHA is focused on reducing the weight of the IHA. In addition, it has been modified to consider operational efficiency. The configuration of sub-assemblies and components of the advanced IHA is shown on Fig. 1.

3.1. Advanced Design Features

To reduce the weight of IHA and improve the maintenance work, the structural frame of the cooling shroud assembly has been changed from shell to support columns. The comparison between the support column type and shell type structure is shown in Table I.

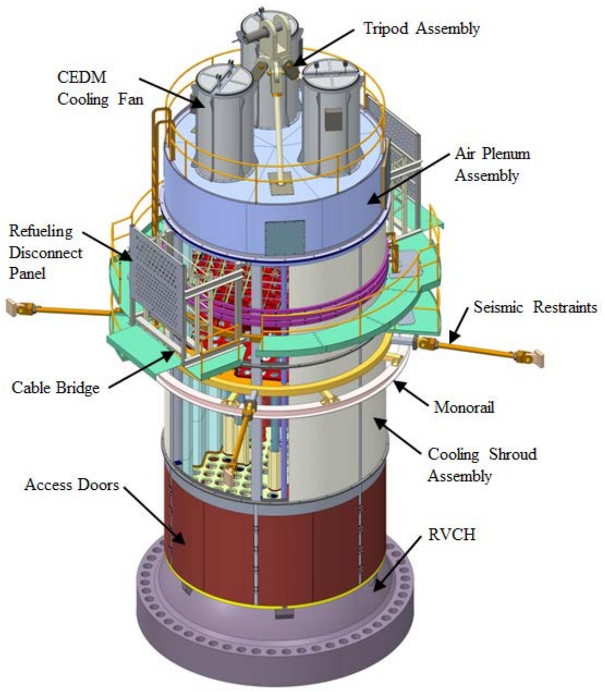

Fig. 1. Advanced Integrated Head Assembly

Table I: Comparison of Support Column and Shell

Items	Shell Type	Support Column Type
Weight	Heavy	Light
Extension of Air Inlet Opening	Difficult	Easy
Seismic Load Reduction	Average	Excellent
Design	Simple	Complicated
Maintenance	Average	Excellent

The support columns are enclosed by the shroud plates and baffles providing cooling air passage but certain region between support columns is utilized for air inlet opening for CEDM cooling air. The opening is also used for access route for the Heated Junction Thermocouple (HJTC) and Reactor Coolant Gas Vent System (RCGVS) valve. The double sided doors in the lower cooling shroud assembly (LCSA) are adapted to easily access to the CEDM nozzles and RV head area for maintenance and inspection.

The lift blocks of the lifting assembly are installed on the missile shield and provide the connection point between the main columns and tripod rods. The missile shield is designed to protect the missile and also used as a spreader to support horizontal loads due to RVCH lifting. By changing the design of the lifting assembly, the height of the advanced IHA is lowered.

The seismic support assembly is designed to support the CEDMs at two different heights and the individual seismic support plates and cap plates are designed. The individual seismic support plate and cap plate is installed on the CEDM upper shroud. The elevation of the lower seismic support assembly is determined to be around 0.75 of H/L (Support height/Total CEDM length) [2]. This height is the optimal location to minimize the displacements and loads of the CEDMs. The upper seismic support assembly is located at the top of the CEDMs to limit the displacement of the CEDM cables. In addition to the above support elevation, tension and compression concept has been reflected to the seismic restraints in order to reduce the loads of the members and embedment as well as to enhance the IHA seismic capability.

In order to reduce the weight, members for the messenger wire support beam are changed from solid type to tubes. In addition, locations of the cable bridges are rotated about 20 degrees to minimize the interference with the RV guide stud installation.

Those design features of the advanced IHA contribute to reduce its own weight by 30% compared to the APR+ IHA. It is expected that the diminution of the IHA weight will lead to the effect of reducing the seismic loads.

3.2. Simplified Disassembly/Reassembly Procedure

The development of the advanced IHA is started to improve the operating convenience and reduce the work steps of maintenance. The simplified process of disassembling and reassembling contributes to reduction the refueling outage period and radiation exposures to personnel.

To compare the time of disassembling and reassembling between the APR1400 IHA and the advanced IHA, the procedures of the pre-service inspection (PSI) of the CEDMs at Shin-Kori 3&4 were analyzed. It was surveyed that almost 26 days were required to disassemble and reassemble the APR1400 IHA. However, in the advanced IHA, the processes of removing the seismic support plate and RV head insulation are not required, and the LCSA does not need to be detached and lifted from RVCH. It is expected that overall time for disassembling and reassembling of the advanced IHA will be reduced as much as 7 days.

4. Conclusions

The advanced IHA reflects the past APR1400 and APR+ IHA design and operating experience. Upgrading the IHA design, it is expected that the hours spent for the CEDM weld inspection will be reduced and the seismic loads on the IHA will be also decreased.

The completeness of the advanced IHA design will be verified through the structural analysis and computational fluid analysis in the future. The design of the advanced IHA is applicable to domestic and overseas nuclear power plants.

Acknowledgment

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