Reactor Coolant Loop and Reactor Internals Concurrent Installation of APR1400: a feasibility study

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1. Introduction

As part of efforts to reduce construction time and cost of Advanced Power Reactor 1400 (APR1400), we investigate the validity of reactor coolant loop (RCL) and reactor internals (RI) concurrent installation. RCL welding causes thermal expansion of piping and reactor vessel (RV) deformations, therefore RI is typically installed after RCL welding procedure.

To evaluate the validity of RCL and RI concurrent installation, we conduct finite element analyses (FEA) and calculate the RV deformation during concurrent installation period. The analyses results are compared with RV/RI gap requirements.

2. Methods and Results

In this section, the concept of concurrent installation is described. The procedure and result of RCL/RV FEA are also described.

2.1 Concept of concurrent installation

The concept of concurrent installation is RCL and RI installation starts at the same time during construction. The considered RCL is the cross-over leg which connects Steam Generator and Reactor Coolant Pump. The concurrent installation will be applied to the Shin Ulchin nuclear power plant, and it is expected to reduce installation period of about 2 months. The traditional sequential installation and concurrent installation time schedules are compared in Fig. 1.

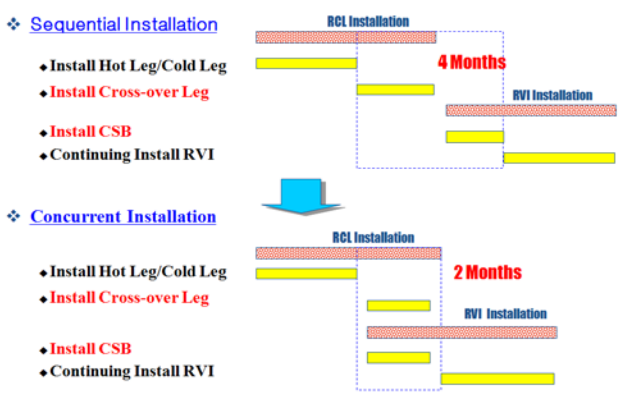

Fig. 1. Sequential installation and concurrent installation time schedule

The major RI installation processes during concurrent installation are installing the core support barrel (CSB) and the core stabilizing lug shim, measuring RV/RI interface dimensions and core stabilizing lug gaps, and machining CSB snubber shims.

2.2 RCL finite element analysis

The hot leg and cold leg welding may cause a large deformation to the RV because these pipes are directly connected to the RV. Therefore, we only consider cross-over leg weld in the RCL/RI concurrent installation to minimize reactor vessel deformation. The cross-over legs are installed by 8-point welding in the order of 1A, 1B, 2A and 2B as shown in Fig. 2.

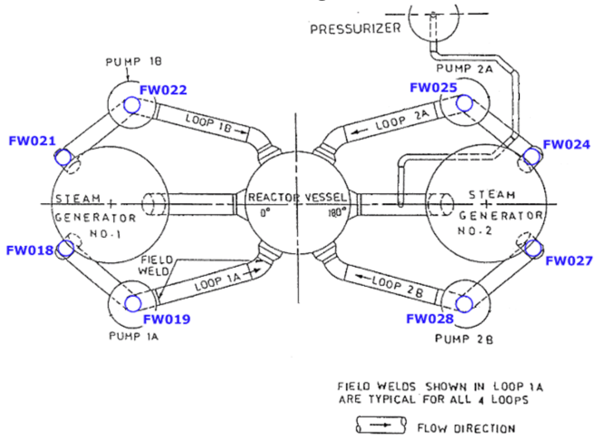

Fig. 2. RCS arrangement and cross-over leg welding points

To simulate cross-over leg installation, weight of the cold leg, weld shrinkage and post weld heat treatment (PWHT) temperature distribution are used as input loads, and the weld procedure is applied to this analysis. These individual input loads are combined to reflect various potential situations in the real cross-over leg installation process. The force and moment of the RV main nozzles (inlet and outlet nozzle) are calculated for each load combination case from this analysis. These results are used in the subsequent RV FEA as input loads to calculate RV deformations. The maximum force and moment occur at the load combination case of 4 cross-over leg installation, non-uniform weld shrinkage and PWHT. The RCS FE model and deformation shape are presented in Fig. 3.

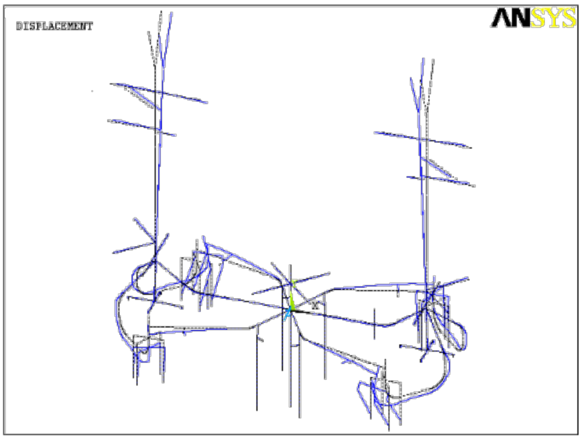

Fig. 3. RCS FE model and deformation shape

2.3 RV finite element analysis

The RV FE model is built using the 3-D solid element of ANSYS. According to RV installation conditions, fixed boundary conditions are applied to the RV support bottom vertical direction, the RV support upper lateral direction, and the RV shear key circumferential direction. The maximum force and moment are applied to the RV inlet and outlet nozzle among previous RCL analysis results to maximize RV deformations. The RV deformation shape is presented in Fig. 4.

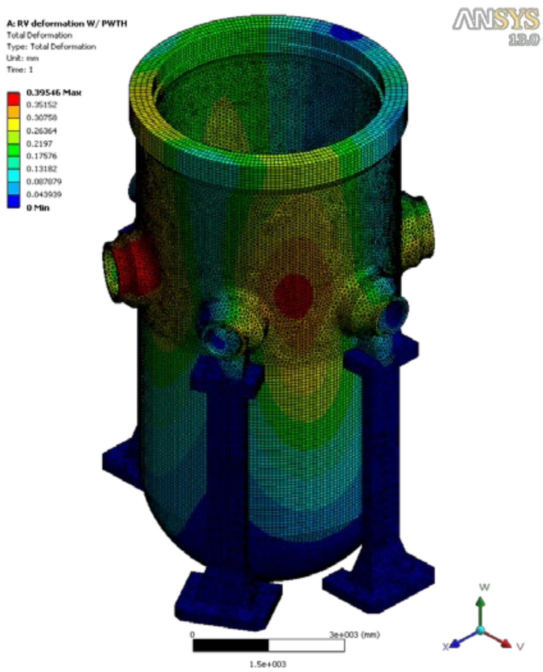

Fig. 4. RV deformation due to cross-over leg welding

2.4 Results and evaluation

The RV deformation analysis results caused by concurrent installation are compared to RV/RI installation requirements in Table I. The circumferential displacements of the RV Flange Keyway and the Core Stabilizing Lug and the hot leg directional displacement of the RV Outlet Nozzle are compared with the requirements. Though the effect of PWHT is more dominant than other loads, all results are satisfied with the installation requirements.

Table I: RV deformation and installation requirement

Location	Displacement (mm)	
	FEA result	Setting limit
RV Flange Keyway	0.0180	0.0254
RV Outlet Nozzle	0.2619	0.3429
Core Stabilizing Lug	0.0220	0.0635

3. Conclusions

From the result of the RCL/RI concurrent installation feasibility study, it is concluded as follows:

1. The structural analysis results show that the RV deformations during the cross-over leg welding are acceptable compared to the installation requirements.
2. From this study, we can confirm that the concurrent installation of APR1400 is feasible, and it will be able to reduce the duration of installation by about two months.
3. However, we conservatively recommend that the constructor avoids the RI installation during post welding heat treatment of the cross-over leg.

REFERENCES

[1] ANSYS, Version 13.0, “Finite Element Program”, ANSYS Inc., 2010

[2] K-W Park, J-H Bae and S-H Park, The application of concurrent installation of the RCS cross over leg and the reactor vessel internals, ASME PVP conference, July.18-22, 2010, Bellevue, Washington.