2018 ASME/KEPIC Joint Workshop

Status of Repair Technology Development for Damaged Clad in RPV

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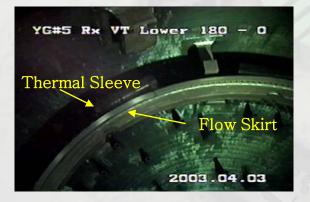
- I. Backgrounds
- **II. Technical Reviews**
- III. Technology Developments
- **IV. Future Works**

I. Backgrounds (1)

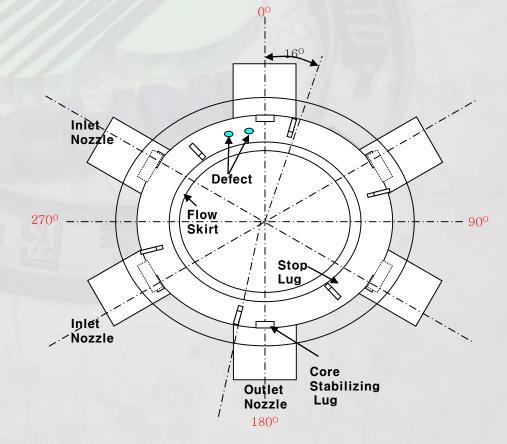
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***** Current Status and Problems

> Confirm the damaged clad of RPV for Hanbit unit 5 by falling Thermal Sleeve ('03. 4)

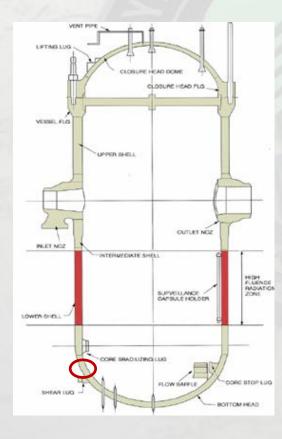


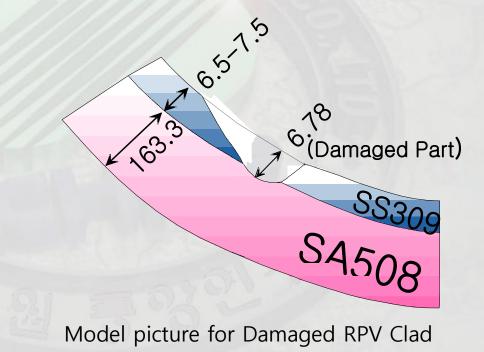




I. Backgrounds (2)







Base metal exposed to cooling water

* Average corrosion rate : 0.1 mm/year

I. Backgrounds (3)



- ***** Current Status and Problems
 - > Replica analysis for damaged part by every OH by removing CSB(Core Support Barrel)
 - ✓ Concerns about falling accident during CSB handling
 - Detailed damaged part



Designed SA 508 thickness = 163.3mm

Minimum thickness for safety = 103.5mm

Margin for corrosion = 59.8mm

 \checkmark Needs to consider corrosion issues for base metal (SA508) such as

SCC, galvanic corrosion, crevice corrosion

I. Backgrounds (4)



- * Technical Challenges
 - Remote works under high radiation area
 - Underwater welding for repair
 - ASME Section XI IWA 4661 : P-3 base metal shall not be welded underwater conditions
 - Effects for base metal of RPV should be minimal
 - > No other specific repair codes in ASME Section XI
 - > No repair practices for RPV clad

Alternative or Relief request through Mockup tests

Irradiated Materials Welding Guidelines [EPRI, MRP-379]

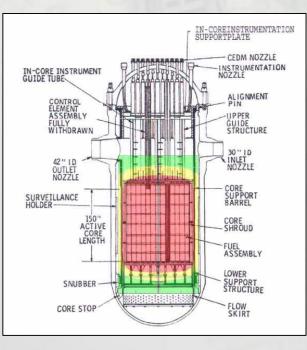
Main contents : welding heat input(0.1~10 KJ/cm),He concentration(0.01~10 appm), irradiated metal(SUS304, 316L, Low alloy steel)

< Summary of results >

He concentration	Contents
0.01 appm	Below 0.01 appm, Both of GTAW and LBW is possible
0.1 appm	For 0.1 appm, GTAW is available , safety margin is lower than 0.01appm
1.0 appm	Above 1.0 appm, LBW(Laser Beam Welding) is suggested
Above 10 appm	Effective heat-input should be limited below 0.1KJ/cm . No available data to prove the integrity of HIC from neutron dose



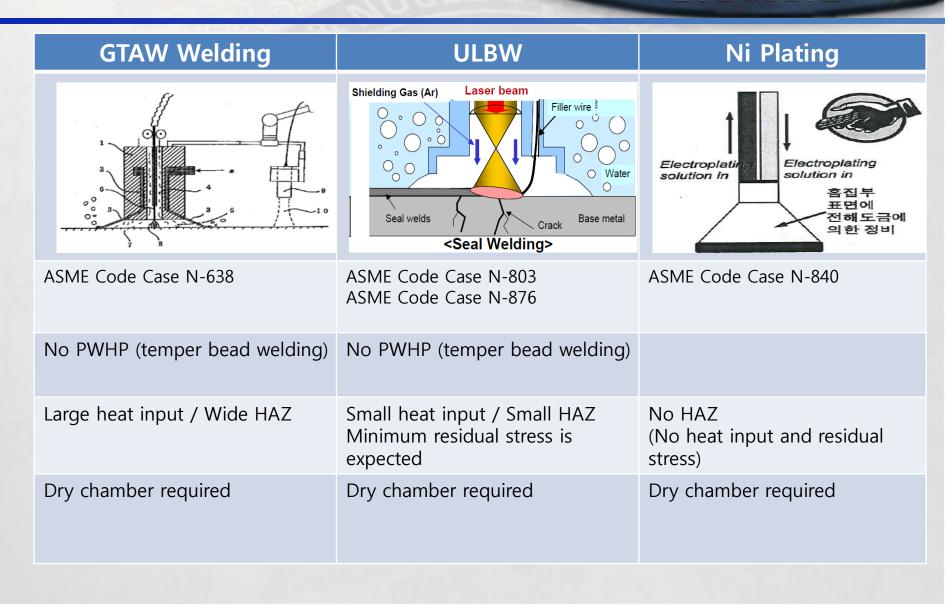
- Computation of Neutron doses for RPV clad [EPRI, MRP-346]
 - Computation Code : RAPTOR-M3G / ALPAN-VII.0
 - Considered values : operation duration(20, 40, 60 EFPY), initial Boron concentration(1, 10, 50, 75 wppm), Ni contents 12%



- Red -Zone-He generation greater than 10 appm (not weldable with current welding processes)
- Yellow- Zone-He generation greater than 0.1 appm and less than 10 appm (weldable with heat input control)
- Green -Zone-He generation less than 0.1 appm (No special process control is needed)

He concentrations around damaged area : 0.01 appm * Welding is available regardless of heat input effects (No He embrittlement)

Candidate Technology



- ✤ ASME Code Case N-803
 - This code is about ULBW for Similar and Dissimilar Metal Welding Using Ambient Temperature.

ASME Code Case

- Recently accepted by NRC(RG 1.147, rev.18 2017).
- ✤ ASME Code Case N-876
 - This code is about ULBW for clad repair approved by ASME(2017)
 - Not accepted by NRC
 - Final clad repairs require surface examination only
 - The depth of the repair cavity shall not be greater than 1/4 in.

* ASME Code Case N-876 is more close to clad repair condition

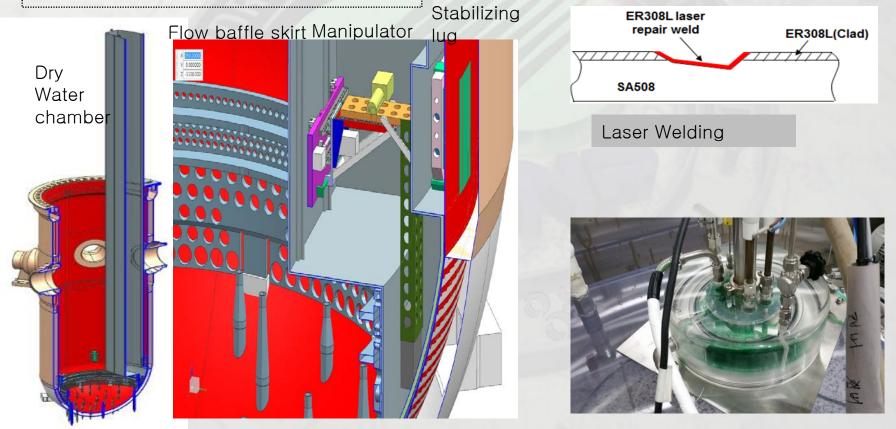
- ✤ ASME Code Case N-840
 - This code is about Cladding Repair by underwater Electrochemical Deposition(ECD) in Class 1 and 2.

ASME Code Case

- Enable clad restoration by depositing a corrosion resistant material on the exposed surface.
- The ECD layer is highly resistant to corrosive attack.
- The benefit is negligible residual stress and visual examination
- Minimum deposit thickness required (No specified in Code Case)



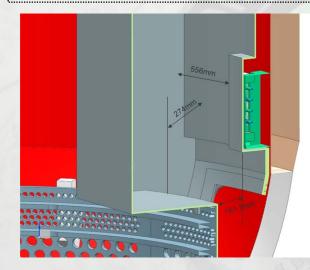
Concept of repair system (1)

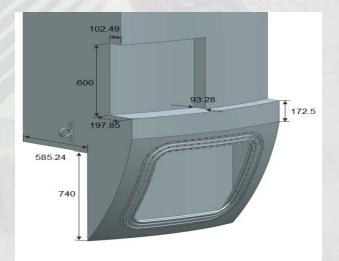


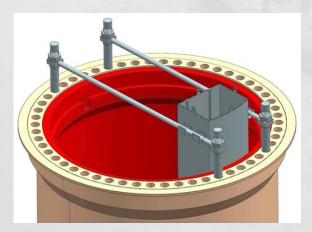
Ni-plating cell



Concept of repair system (2)

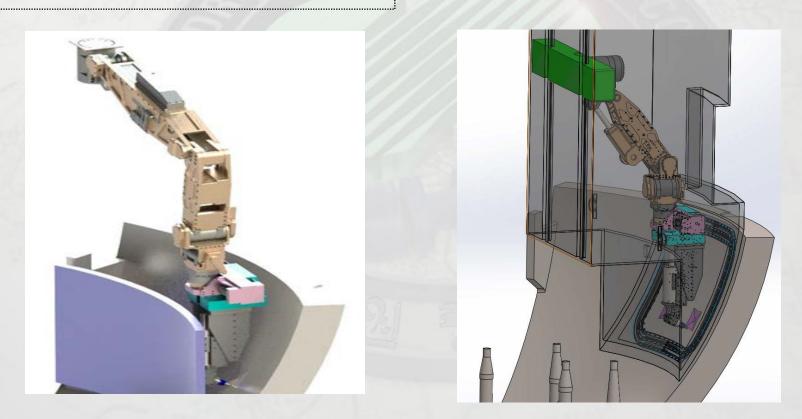








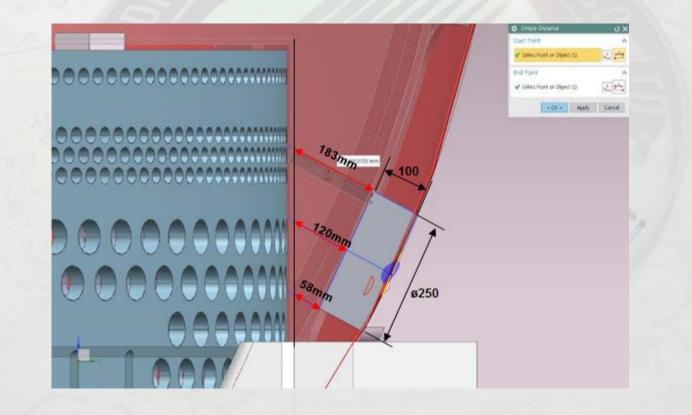
Concept of repair system (3)



Articulated robot arm inside of dry water chamber

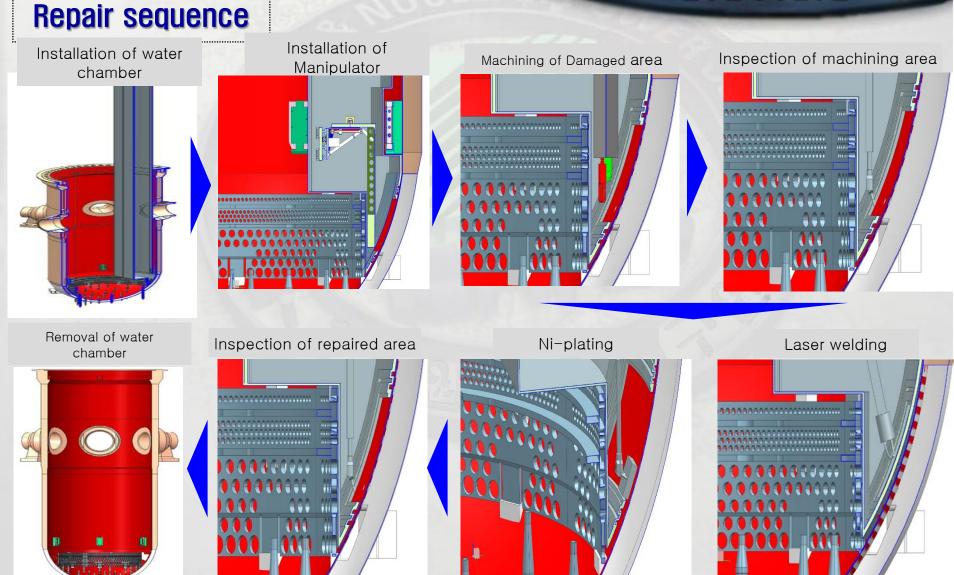


Concept of repair system (4)



Ni plating chamber will be installed around damaged area

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Basic design of repair systems

- Function tests for Small scale mockup equipment of dry water chamber
- * Manipulator
 - Delivery System / Robot Arm attached
- * Machining equipment
 - Robot arm with End-mill or grinding tool
- * Laser welding preliminary tests
 - Test variables : welding speed, supply of filler metal, welding heat input
- ✤ Remote NDE equipment
 - Surface examination : PT / Volume examination : UT
- Integrated control system will be applied for repair



Ni-plating

- Correlation analysis among Ni plating factors
 - Pre-Ni plating thickness(5 μm) , current density(100 mA/cm²), Niplating temp.(60 ° C)
- Ni plating tests (Laboratory scale, 30 hours continuous test)







Ni-plating

✤ Test results

- The initial tests have not been satisfied as below figure. There was a few pits happened.
- Currently, we have changed Ni plating chamber structure to improve the circulation of Ni liquid solution.



✤ Future assignment

• Need to find optimal deposit thickness to protect base metal of RPV.

IV. Future Works



- ✤ Manufacture of full scale mockup for repair [2018.10 2019. 5]
 - Dry water chamber, Manipulator, Welding head, Ni plating chamber, Monitoring system, Non-destructive equipment
- ✤ Full scale Demonstration test (2019)
 - LBW test / Ni plating test
 - Developments of Equipment operating procedures(2019. 6)
- Integrity evaluation : Structural, Thermal, Fatigue, Welding residual stress(2018.12)
- ***** Final decision of repair technology for LBW and Ni–plating (2019. 3)
- ***** Preparing licensing documents for alternative request

Thanks for Your Attention

