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Simulation of Residual Stress due to Welding in Core Shroud of Boiling Water Reactor

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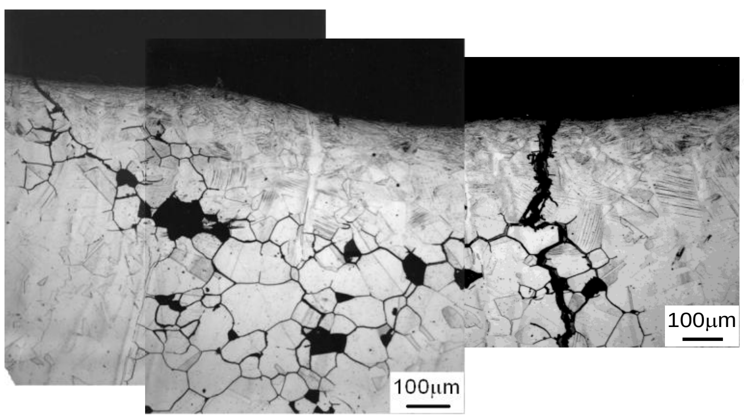
Outlines

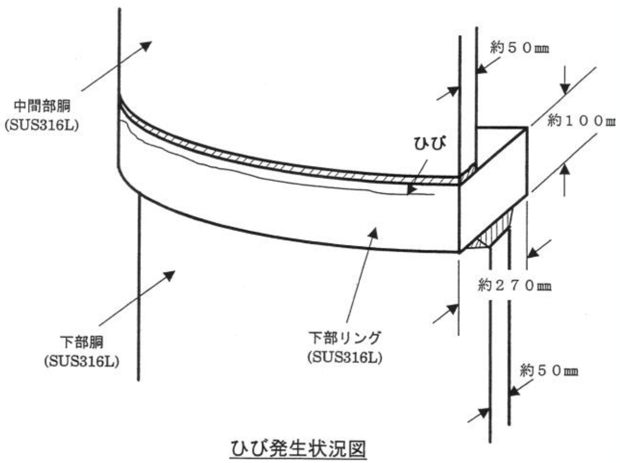
- Background and objective;
- Analytical method;
- Composition and properties of Type 316L stainless steel;
- Heat histories of beads in SGA and FCTDA;
- Comparison of SGA and FCTDA;
- Simulation results by FCTDAs comparing with experimental results;
- Summary and Future Work

Background and objective

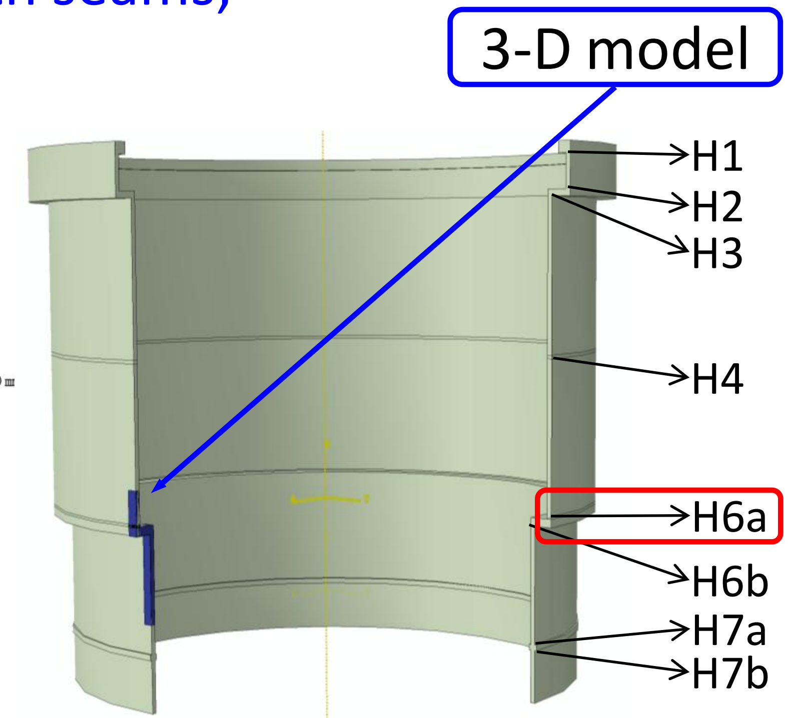
■ Stress corrosion cracking (SCC)

Weld residual stress (WRS) around horizontal girth seams;
Corrosion;
Neutron irradiation (fission in nuclear reactor).





SCC in lower HAZ of H6a



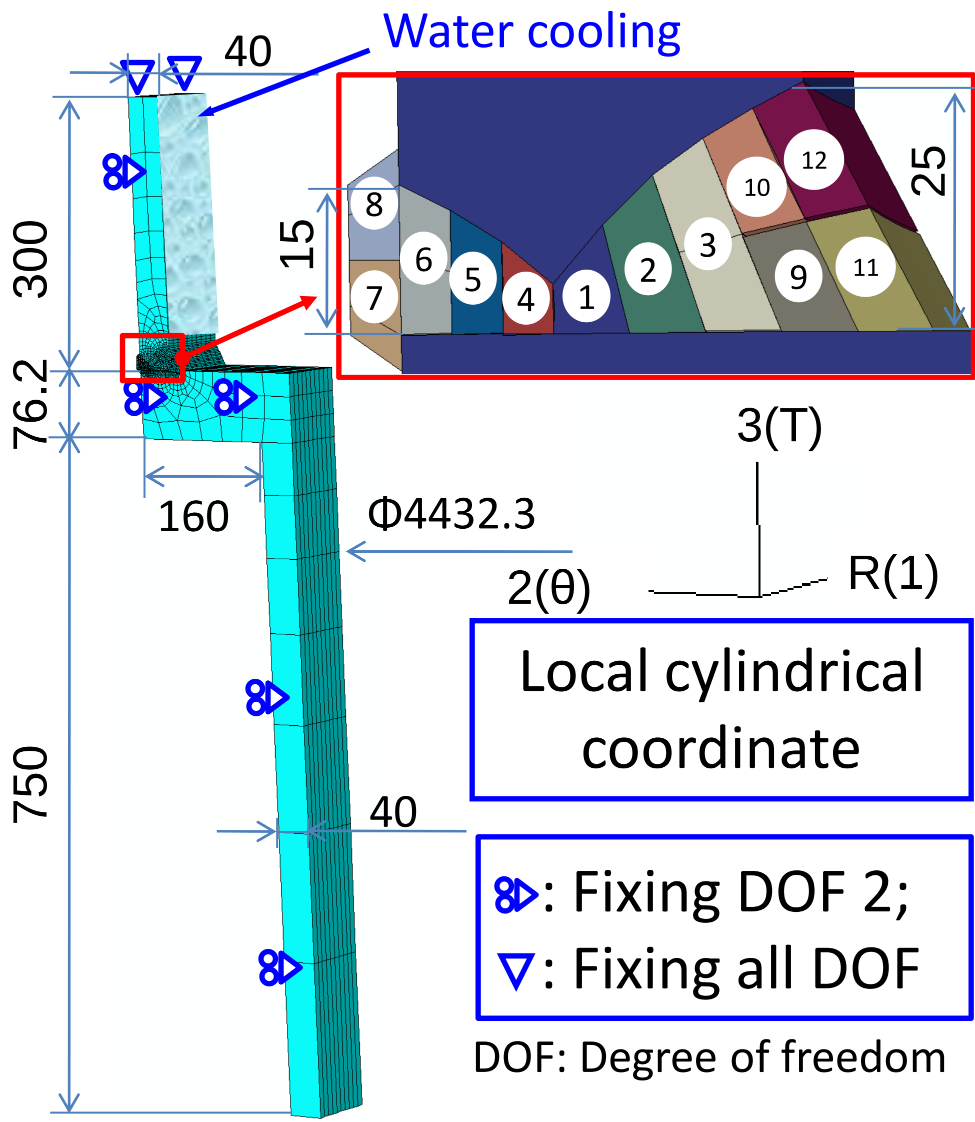
Core shroud model in present study

■Objectives

Studying the Fields of WRS in the girth seam H6a of the core shroud model

Reference: 2004, JAERI-Tech, 2004-044.

Analytical method



3D model π/180 degree (units: mm)

Method： FEM ABQUS Version 6.9

- **Static general analysis (SGA):**
  - ✓No heat transfer;
  - ✓9187 8-node linear brick element
- **Fully coupled temp-displacement analysis (FCTDA):**
  - ✓With heat transfer;
  - ✓9207 8-node trilinear displacement and temperature element;
  - ✓Thermal boundary conditions

Three analysises

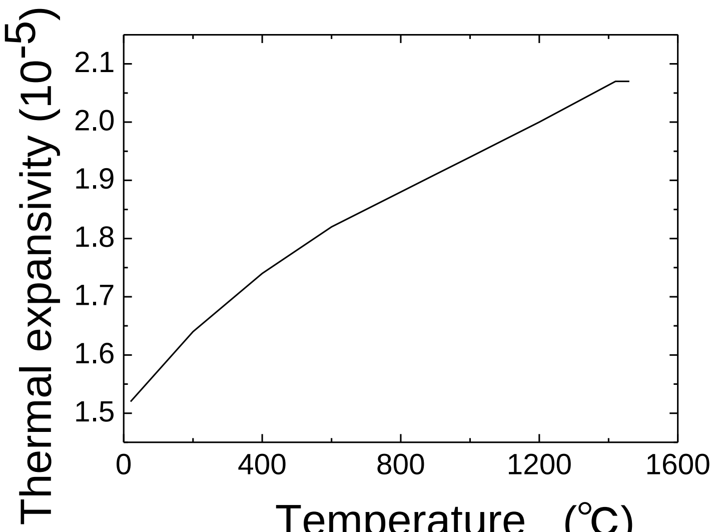
SGA	FCTDA1	FCTDA2
No heat transfer	Heat transter	Heat transfer
—	Cooled in air	Cooled with water at inner upper face

Composition and properties of Type 316L stainless steel

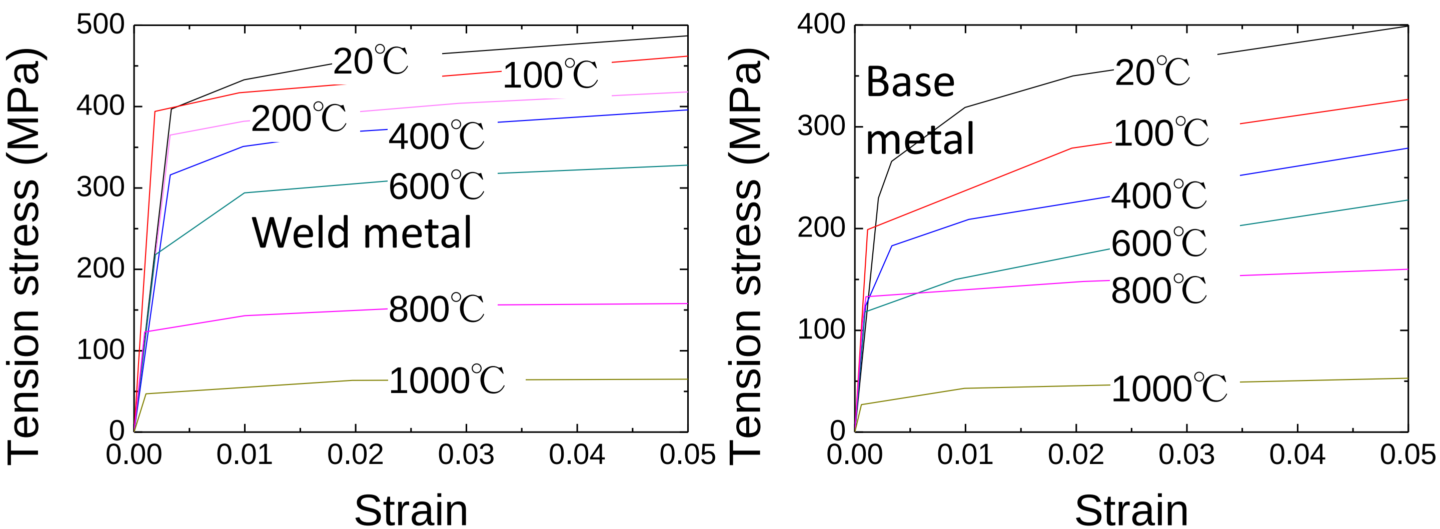
Chemical composition (in mass.%)		
C	Si	Mn
≤0.03	≤1.00	≤2.00
P	S	Ni
≤0.045	≤0.030	12-15
Cr	Fe	Mo
16-18	Bal.	2-3

Thermal conductivity, specific gravity and heat, and emission coefficient

Temperature ℃	20	100	200	400	600	1000	1500
Thermal conductivity kJ/mms℃	1.46E−05	1.56E−05	1.70E−05	1.97E−05	2.24E−05	2.76E−05	3.43E−05
Specific gravity kg/mm^3	7.86E−06	7.86E−06	7.86E−06	7.86E−06	7.86E−06	7.86E−06	7.86E−06
Specific heat kJ/kg℃	0.452	0.493	0.523	0.553	0.578	0.62	0.678
Emission coefficient $kJ/mm^2s℃$	Air: 1.16e−8; Water: 6.66e−5						



Thermal expansivity



Mechanical properties of weld metal and base metal

Reference: “The forth volume of JANTI-VIP-05”, Atomic Energy Society of Japan, Vol. 4.

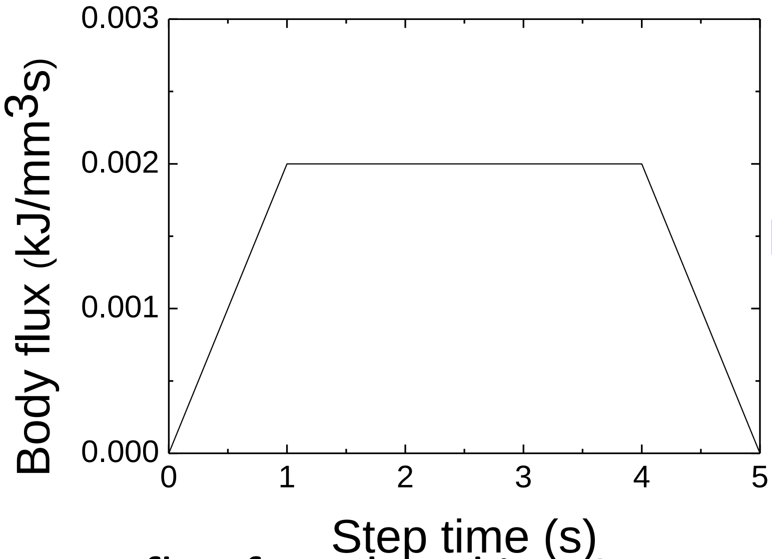
Heat histories of weld beads for SGA and FCTDA

■SGA and FCTDA

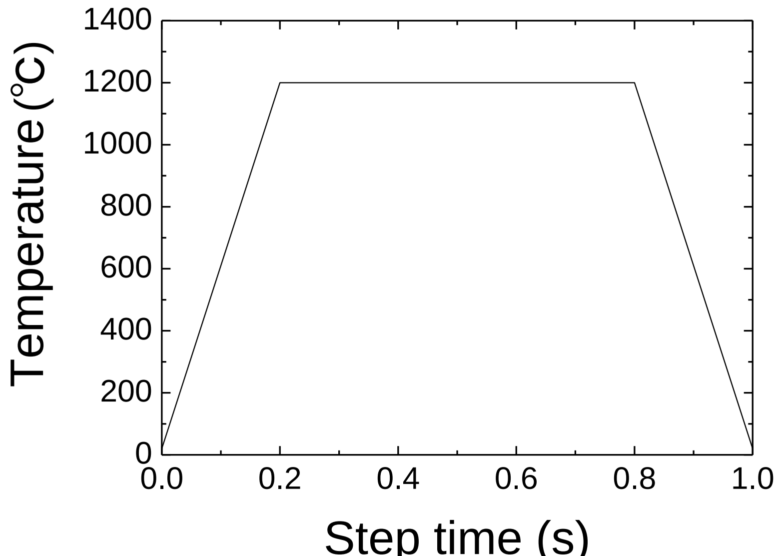
- □Defining the temperature amplitude curve for SGA;
- □Using subroutine to produce heat in FCTDA

  Max. temp.: ≥1180℃;

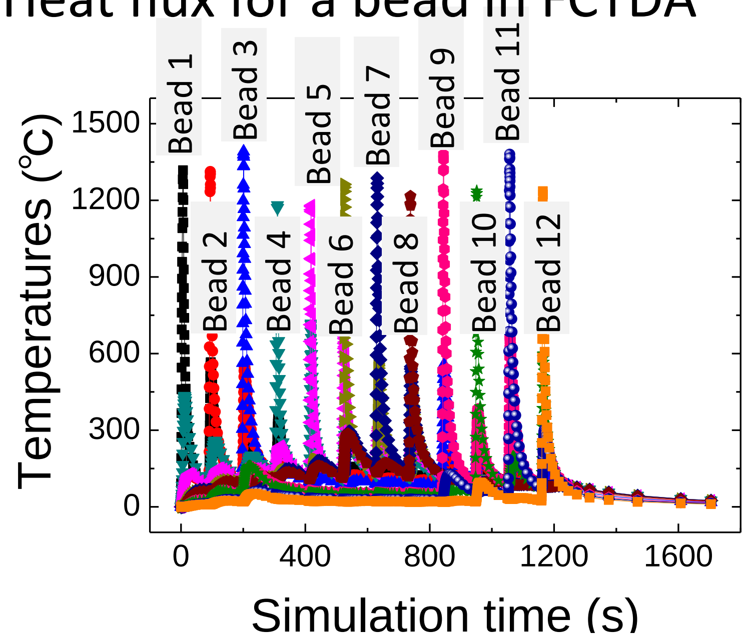
  Layer temp.: ≤180℃



Heat flux for a bead in FCTDA



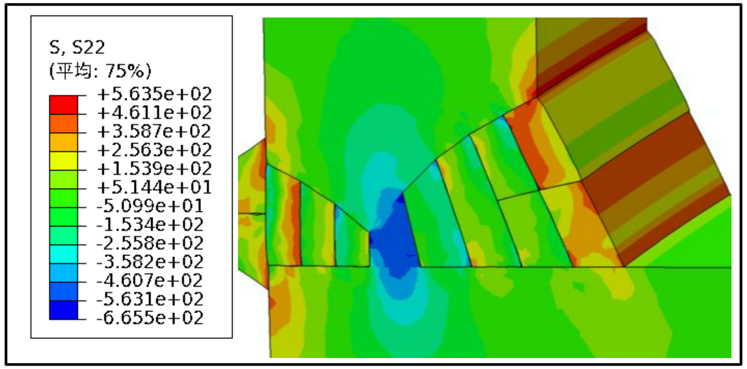
Temperature for a bead in SGA



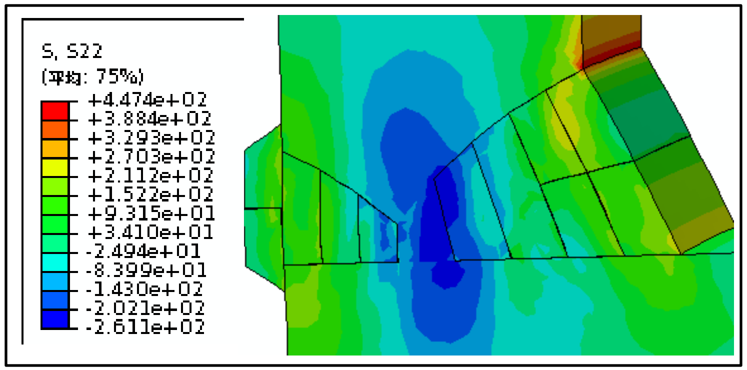
Temperatures in beads in FCTDA

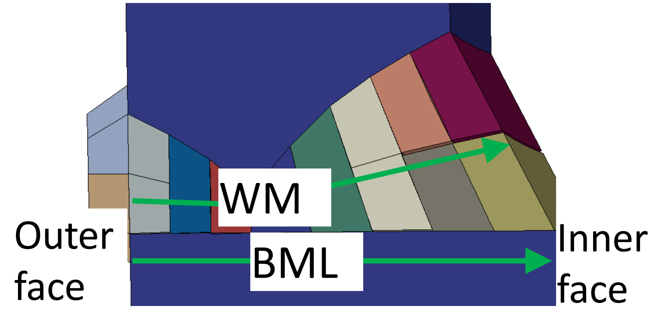
Comparison of SGA and FCTDA

Axial stress by SGA



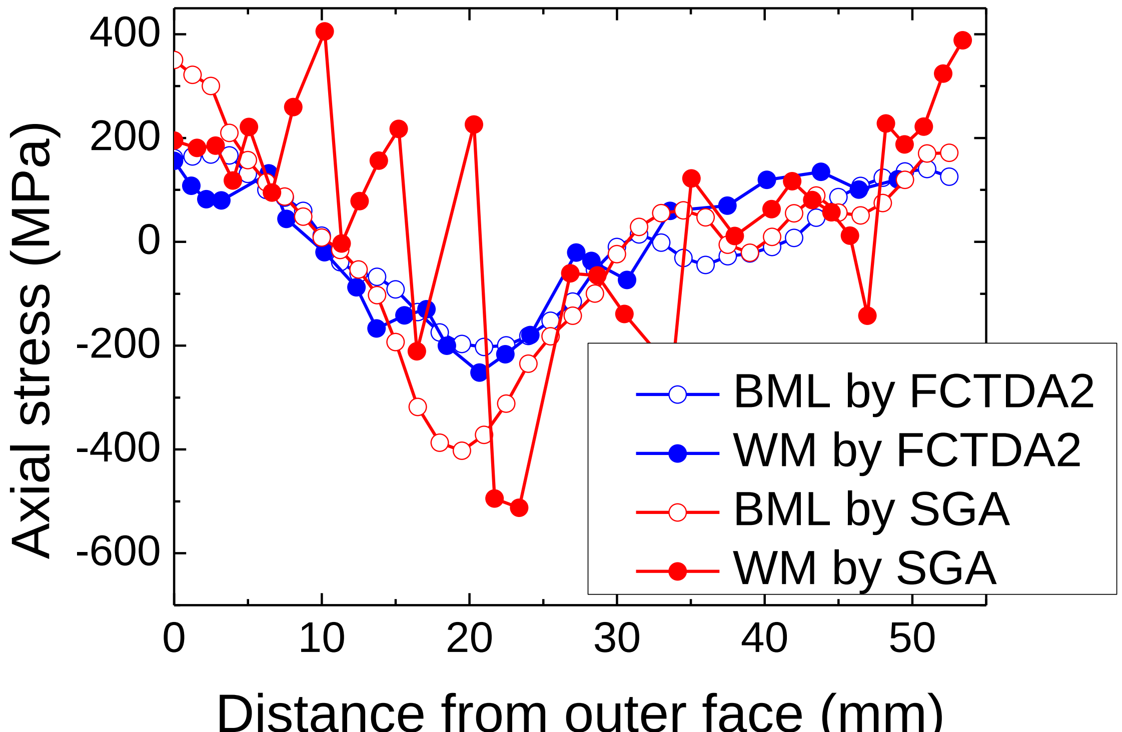
Axial stress by FCTDA2





BML, 3.6mm to weld metal in distance

Paths of weld metal (WM) and base metal (BML)

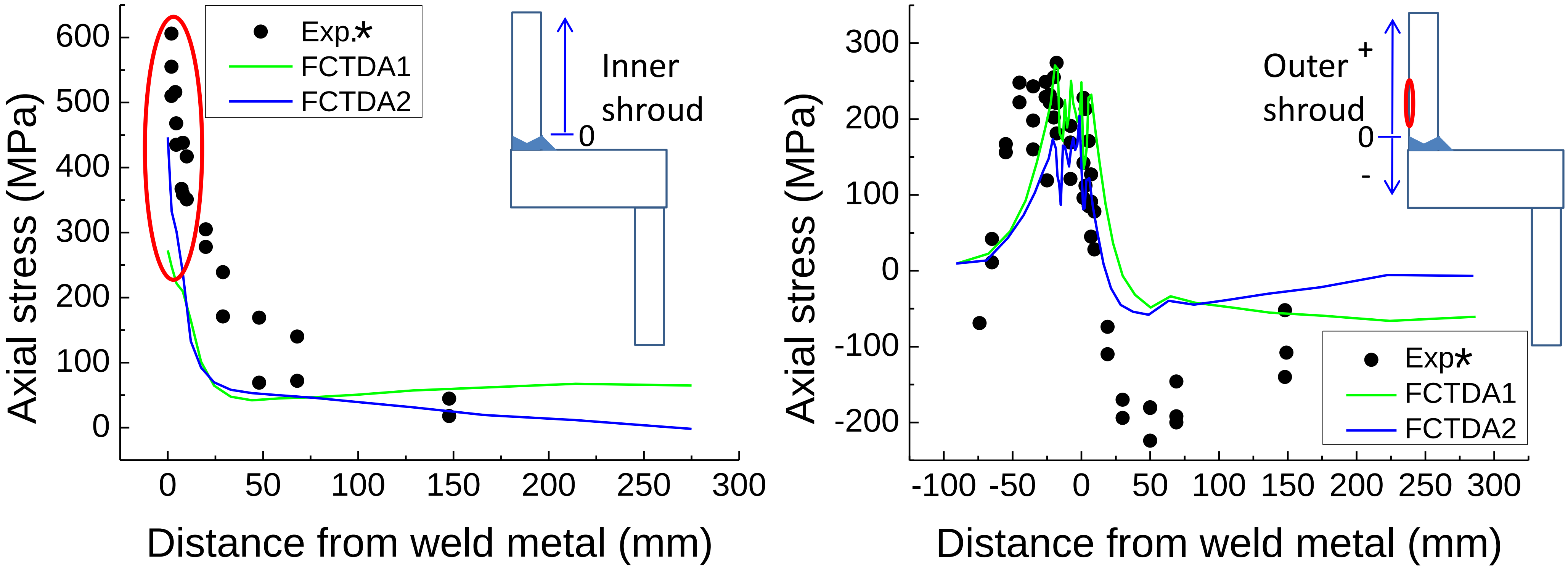


Axial stress through the wall of model

Maximum tension stress is at the out surface and maximum compression stress is at inner of the wall. Simulation with FCTDA is better due to consideration of heat transfer.

Simulation results by FCTDAs comparing with experimental results

Axial stress in the inner and outer faces (axial stress paralleling to the axle of the core shroud, FCTDA1: Cooling in air; FCTDA2: Cooling with water)



Simulation results are better by FCTDA2 than by FCTDA1. Water cooling decreases tension stress at outer face while increases tension stress at inner face of the model. Simulation results at the base metal by FCTDA2 are not accurate according to experimental results.

*Reference: "The forth volume of JANTI-VIP-05", *Atomic Energy Society of Japan*, Vol. 4.

Summaries and Future work

Summaries:

- Three different analysises were adopted to simulate the multiple-bead welding progress. The FCTDA2 can give the much better simulation results with considering heat transfer and cooling with water.
- Maximum tension stress are located at the out surface and maximum compression stress are at the inner region of the wall of the model.

Future work:

Simulation of initiation and propagation of SCC:

- Relaxation of residual stress
- Radiation induced segregation
- Radiation induced hardening

Thank you for your attentions!