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MHI's Manufacturing Techniques applied to ITER Toroidal Field Coil Structure

- to achieve Large-size Structures with High Accuracy and Nuclear-base Quality -

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- Manufacturing Status
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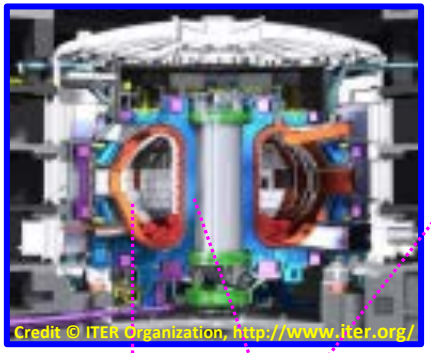
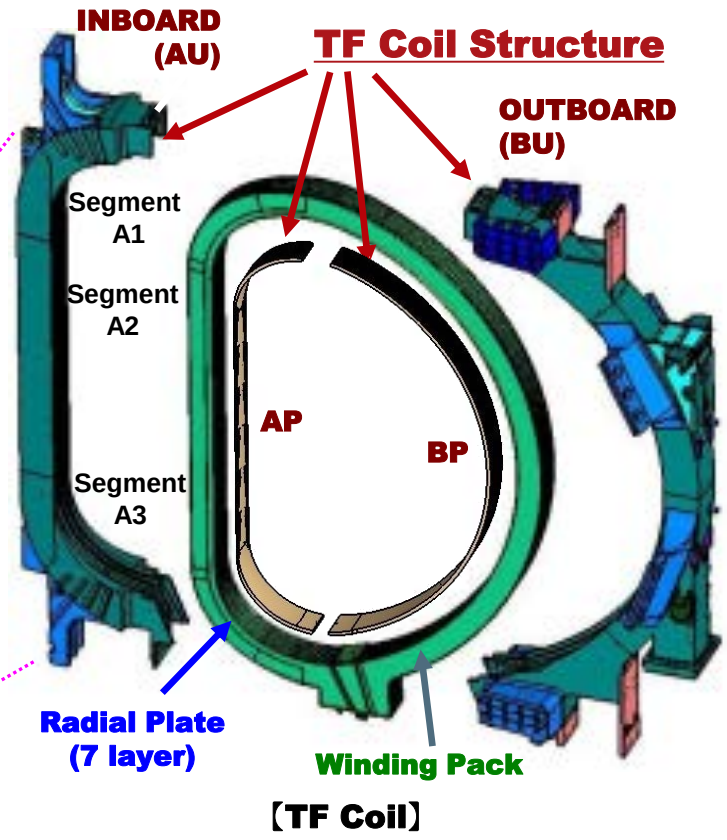
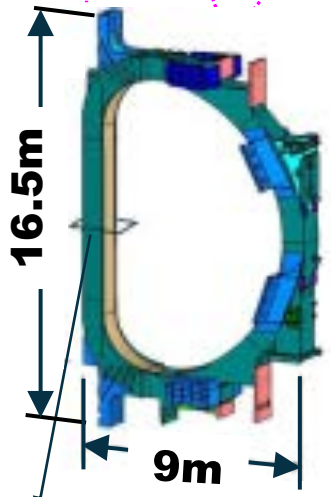
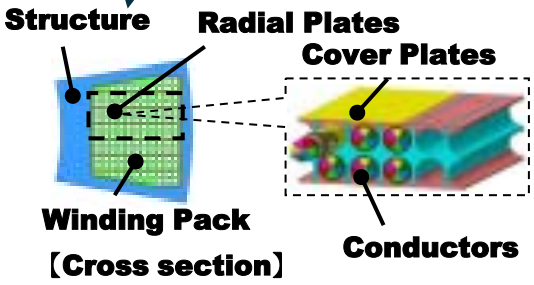
Feature of ITER Toroidal Field Coil





【TF Coil】





【Cross section】

Specifications of TFC

- **Unit**：**18 sets + 1 Spare**
- **Operation Temp.**： **4.2K (-269℃)**
- **Material**：**Stainless steel for Cryogenic (JJ1, Type316LNH/LNM/LNL)**

Coil Structure

- **Profile**：**Complex & severe tolerance ±2mm (IB)**
- **Required severe dimensional control during welding**

Winding Pack

- **Conductor**： **Nb_3Sn**
- **Wind & React**： **650±5℃**
- **Tolerance**：**Max. 8mm/Length (appx.35m/ 1turn)**

Radial Plate

- **Flatness/ Profile**：**Within 1mm**
- **Required severe control of deformation due to welding and machining**

Final assembly

- **Conductor position**： **within ±1mm**
- **Flatness after closure weld**： **within 0.4mm**

Figures : Courtesy by QST, National Institutes for Quantum and Radiological Science and Technology

TFC Manufacturing Status in MHI

三菱重工

■ TF Coil Structure ~19 Inboards (AU/AP)

5 units : Completed

11 units : Final Assembly/Machining

3 Units : Segment Assembly

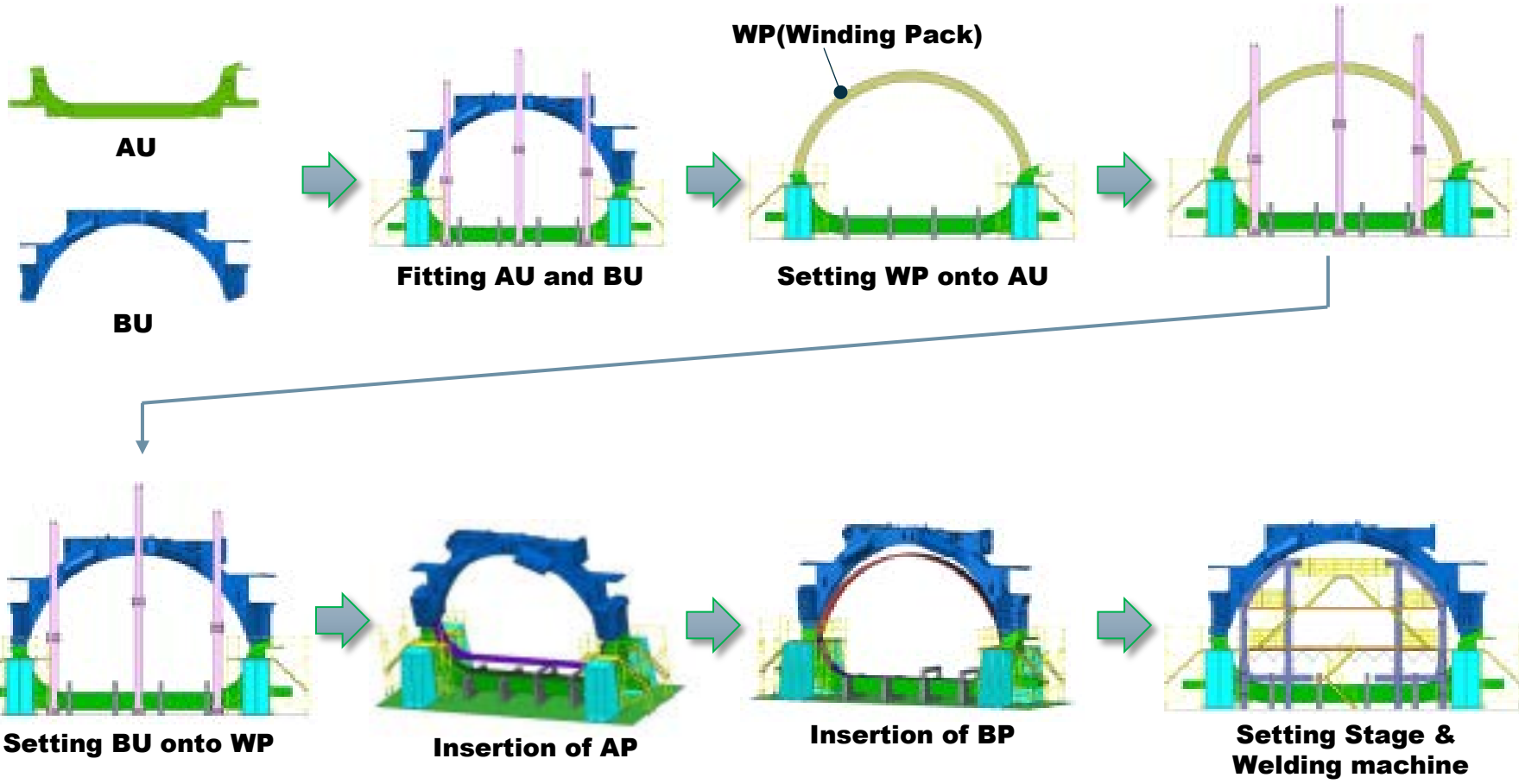
■ TF Coil Winding Packs + Integration of AU&BU ~5 Units

2units : WP final completed、Integration under preparation

1 unit : WP final under preparation

2 unit : DP manufacturing

Integration of TFC structure and Winding Pack

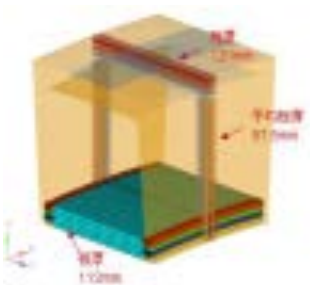


（Video ~ 2min）

TF Coil Structure – Segment Welding & Integration

三菱重工

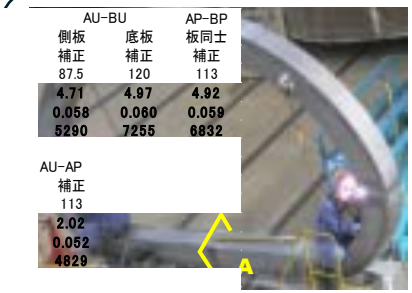
● Optimizing welding condition by FEM Analysis + scale testing

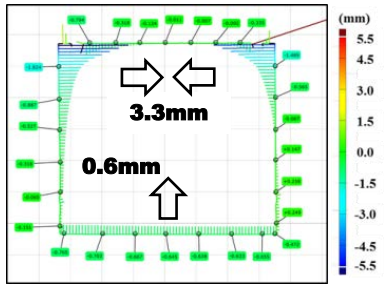


Strain measurement by plate samples

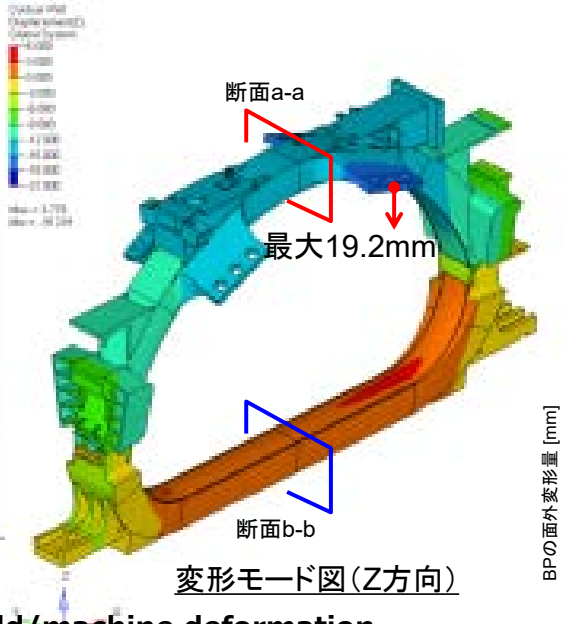
	AU–BU 側板補正	AU–BU 底板補正	AP–BP 板同士補正
	87.5	120	113
横収縮S mm	4.71	4.97	4.92
角変形2θ rad	0.058	0.060	0.059
縦収縮力 kN	5290	7255	6832

	AU–AP 補正
	113
横収縮S mm	2.02
角変形2θ rad	0.052
縦収縮力 kN	4829

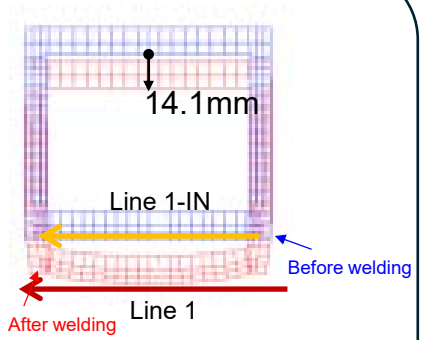


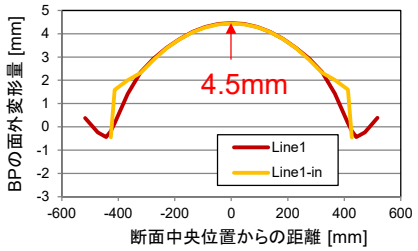


1/3 scale testing for welding deformation



変形モード図(Z方向)





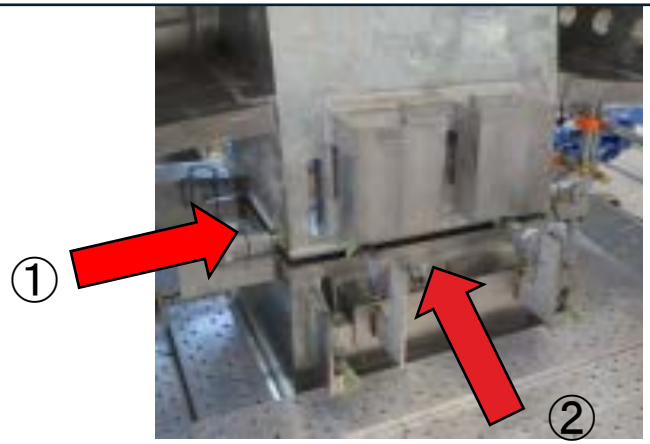
Full scale testing for weld/machine deformation

三菱重工原子力技術資料:クラスB

TF Coil Structure Integration Fitting Test

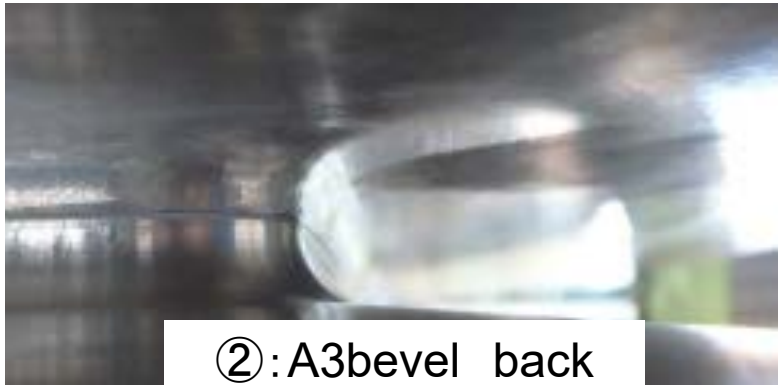
三菱重工

- Vertical Fitting Test – First of a Kind
- Bevel clearance 0.5±0.5mm、gap±0.5mm（side）/±1.4mm（back）⇒Integration under prep from 12/M



A3

0.5±0.5mm以内

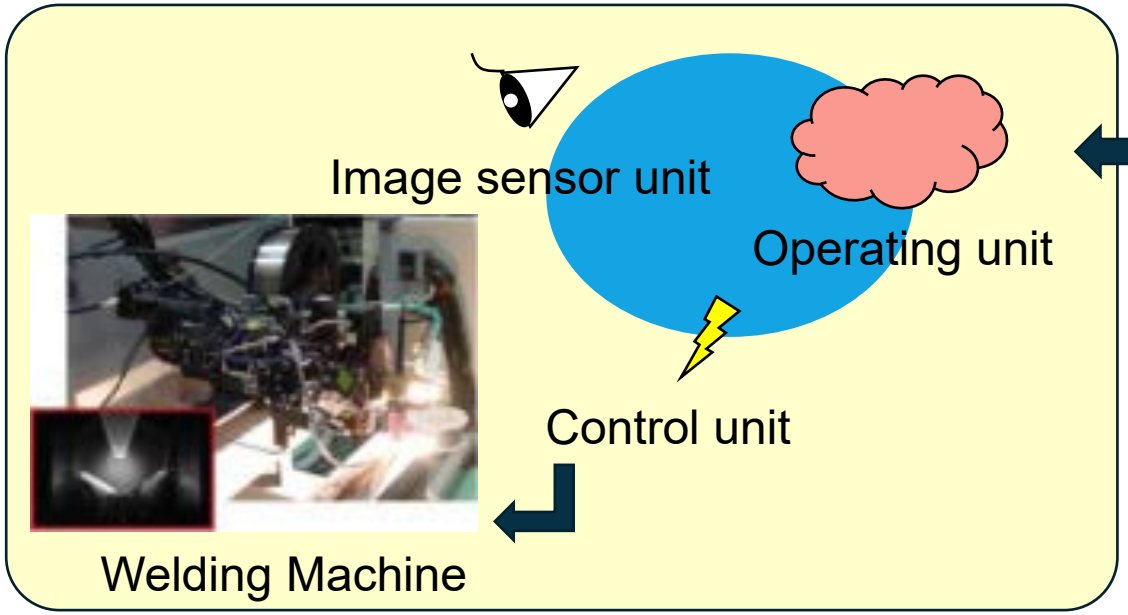


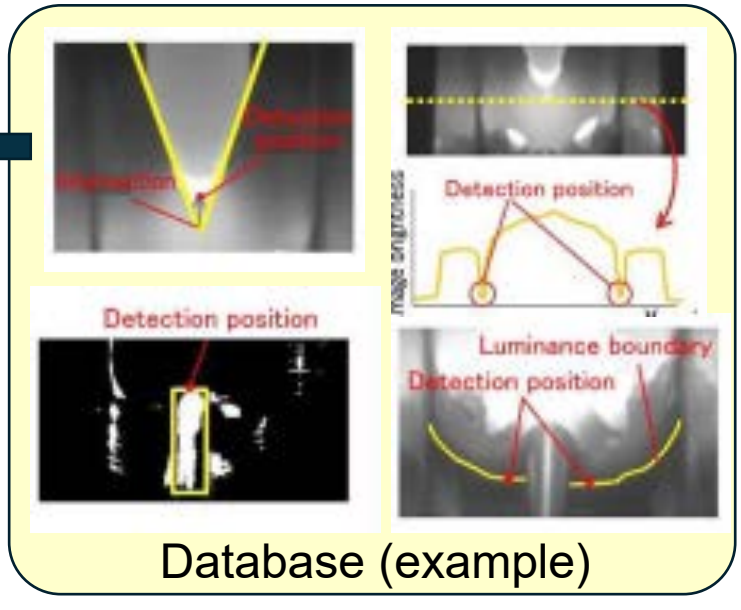
Effects of application of ITER manufacturing technology

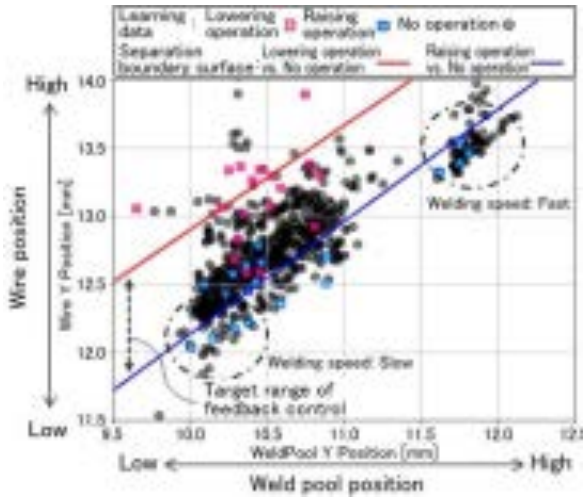
Improve of foundation technology	For Special stainless material (hard-to cut and welding- high N contain) ・Improve welding condition and welding material including manufacturing process ・Improve and optimize machining condition based on trial results	Data base for newly material Applying for Harsh environment device(Cryogenic, Aero space, Deep submergence device)
Establish of newly welding procedure	For TF Coil manufacturing, ・Improve technology by complex technology and applying dissimilar weld, full penetration weld	Apply for welded structure (Pressure vessel, Diverter, Vacuum vessel)
Improve of manufacturing technology for complicated shape	From results of mock up and analysis, ・Low deformation welding process ・High efficiency 5 axis machining for large machine	Improve of Designing and manufacturing process for complicated shape Apply for component (large-precise-complicated shape) and Vacuum vessel
Cooperation with International project	Obtain valuable experience of global project for young engineer.	Obtain much knowledge and engage in global project based on ITER experience

Automated Welding Machine with Machine Learning

三菱重工







Machine Learning on Skilled welding Operator

施行例

The machine learning welding technology will be applied for Future Nuclear and Advanced Field machine manufacturing also by utilizing database accumulated in ITER TFCoil welds.

Effects of application of ITER manufacturing technology

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