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Overview on Decade Development of Plasma-Facing Components at ASIPP

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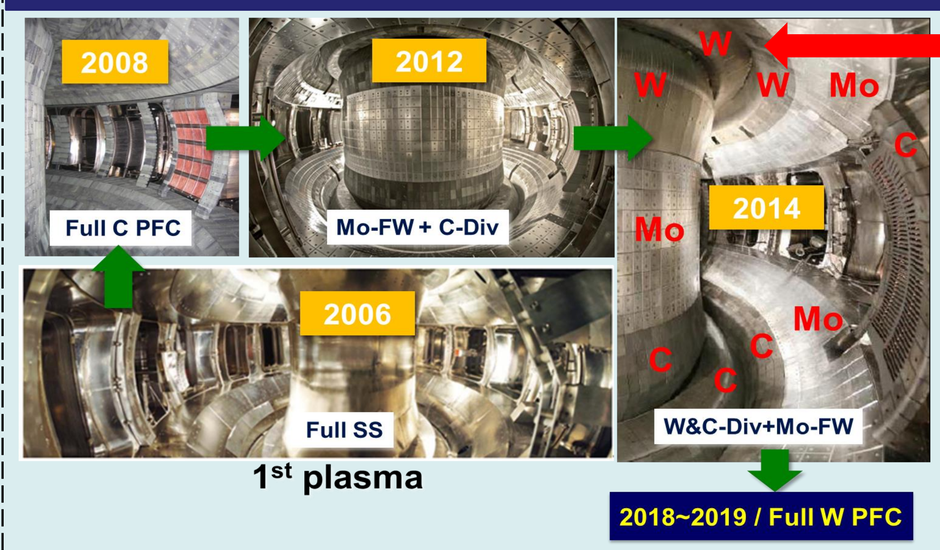
ASIPP

Introduction

- The first EAST plasma was ignited in 2006 with non-actively-cooled steel plates as plasma-facing materials and components (PFMC). The first wall was then upgraded into full graphite and further into TZM in 2012.
- Around the end of 2012, the W/Cu divertor project was launched, aiming at achieving actively-cooled full W/Cu-PFCs for the upper divertor, with heat removal capability up to 10 MW/m^2. In the spring of 2014, the W/Cu upper divertor was finished.
- Commissioning of the EAST upper W/Cu divertor in 2014 was unsatisfactory and then several practical measures were implemented to improve the design, welding quality and reliability, which helped us achieve successful commissioning in 2015 campaigns.
- In collaboration with IO and CEA teams, we have demonstrated our technology capability to remove heat loads of 5000 cycles at 10 MW/m^2 and 1000 cycles at 20 MW/m^2 for the small scale monoblock mockups, and surprisingly over 300 cycles at 20 MW/m^2 for the flat-tile ones.

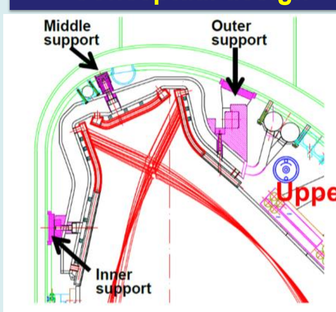
PFM/C evolution in EAST



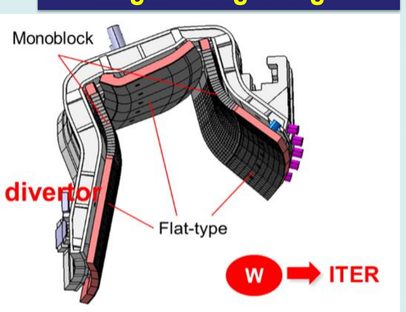
PFCs+CB assembly: 80
IVT/OVT/DOME: 80 each
Monoblock PFUs: 720
Monoblock W: 15,000
Flat-type PFUs: 240
Flat W tiles: 24,000
E-beam seam: > 4000
W raw powders: > 10 tons
CuCrZr plates: > 8 tons
CuCrZr tubes: 720 pcs/360m

Development of W/Cu divertor for EAST

Conceptual design

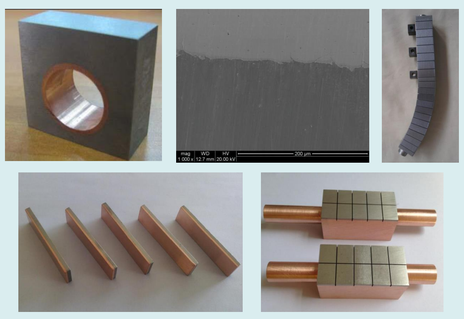


Engineering design

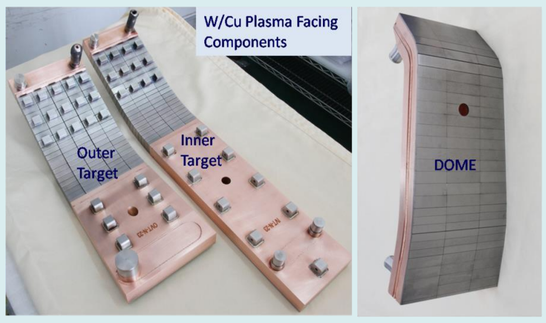


There are 80 modules supported by inner rail, outer rail and middle support in vacuum vessel. Each divertor module includes a Cassette Body (CB) and three PFCs, namely inner target, outer targets, and dome.

Monoblock and flat-tile PFCs

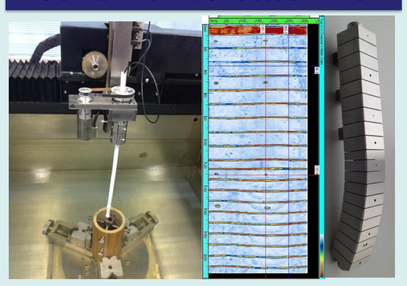


W/Cu PFCs for EAST upper divertor

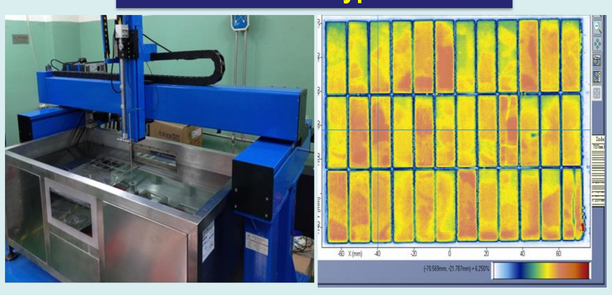


- The monoblock PFCs: (1) HIP for cladding OFC to the inner surface of the W monoblocks, (2) HIPing for the bonding between the clad monoblocks and CuCrZr cooling tube.
- The flat-tile PFCs for baffles and domes are manufactured by casting OFC onto the rear side of W tiles firstly, followed by HIPing of the W/OFC tiles onto CuCrZr heat sink plate.

US-NDT for Monoblock PFU



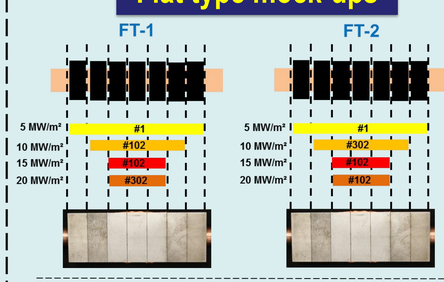
NDT for flat type PFU



- The acceptance criterion for the W/Cu and Cu/CuCrZr joints of the W/Cu monoblock PFUs is that no defects shall be greater than 2×3 mm, and that for the flat-tile PFCs requires defects less than Φ2 mm.

High heat flux test of W/Cu PFCs

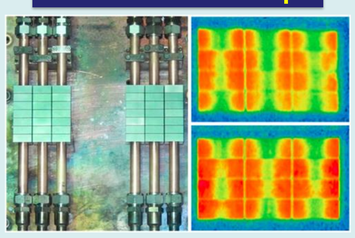
Flat type mock-ups



In cooperation with CEA

- FT-1: 102 cycles @ 10 MW/m^2, 102 cycles @ 15 MW/m^2, 302 cycles @ 20 MW/m^2
- FT-2: 302 cycles @ 10 MW/m^2, 102 cycles @ 15 MW/m^2, 102 cycles @ 20 MW/m^2

Monoblock mock-ups



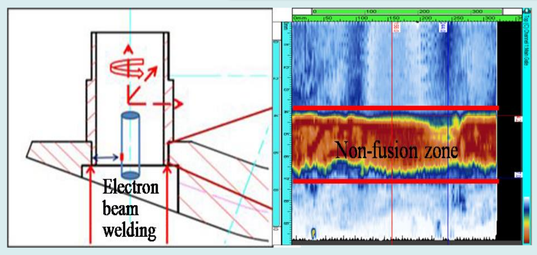
In cooperation with ITER

- 6 small scale monoblock mock-ups: tested on IDTF (ITER Divertor Test Facility)
- All the mock-ups: 5000 cycles @10 MW/m^2 and 1000 cycles @ 20 MW/m^2 in accordance with the qualification program.

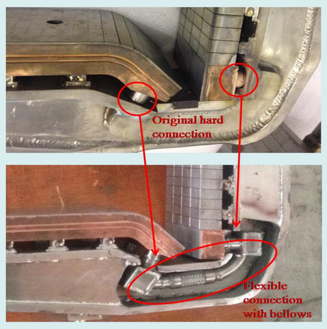
Performance of EAST W/Cu divertor during campaigns

- Commissioning of the EAST upper W/Cu divertor in 2014 failed due mainly to leaks of e-beam welding between cooling tube and manifold box during the EAST baking around 200 ˚C.
- After the campaign, we examined the leaking PFCs carefully and reviewed the whole process from design, manufacturing to installation, and then put forward several practical measures to improve connection design, component welding quality and installation welding reliability.
- In the 2015 winter and 2016 spring campaigns, the W/Cu upper divertor withstood more severe irradiation by EAST plasma and no similar leaks occurred again.

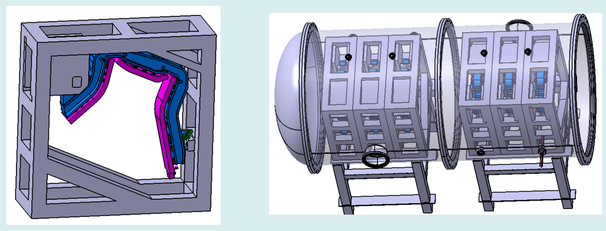
Three measures to improve the W/Cu divertor



01 Developing NDT for the welding seam of pipe-plate joint



02 Optimizing the cooling tube connection



03 Performing leak detection on the pre-assembled divertor module

Summary

- The W/Cu upper divertor for EAST was finished in the spring of 2014. HIP technology is widely used in the bonding of W/Cu and Cu/CuCrZr. NDT quality control system has been established in order to control the bonding quality and ensure the lifetime of the PFCs and the safety of EAST device;
- In collaboration with IO and CEA teams, we have demonstrated our technology capability to remove heat loads of 5000 cycles at 10 MW/m^2 and 1000 cycles at 20 MW/m^2 for the small scale monoblock mockups, and surprisingly over 300 cycles at 20 MW/m^2 for the flat-tile ones.
- Commissioning of the EAST upper W/Cu divertor in 2014 was unsatisfactory and then several practical measures were implemented to improve the design, welding quality and reliability, which helped us greatly in the following campaigns.
- The experience and lessons we learned from batch production and commissioning are valuable for ITER engineering validation and tungsten-related plasma physics.

Disclaimer: The views and opinions expressed herein do not necessarily reflect those of the ITER Organization.

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