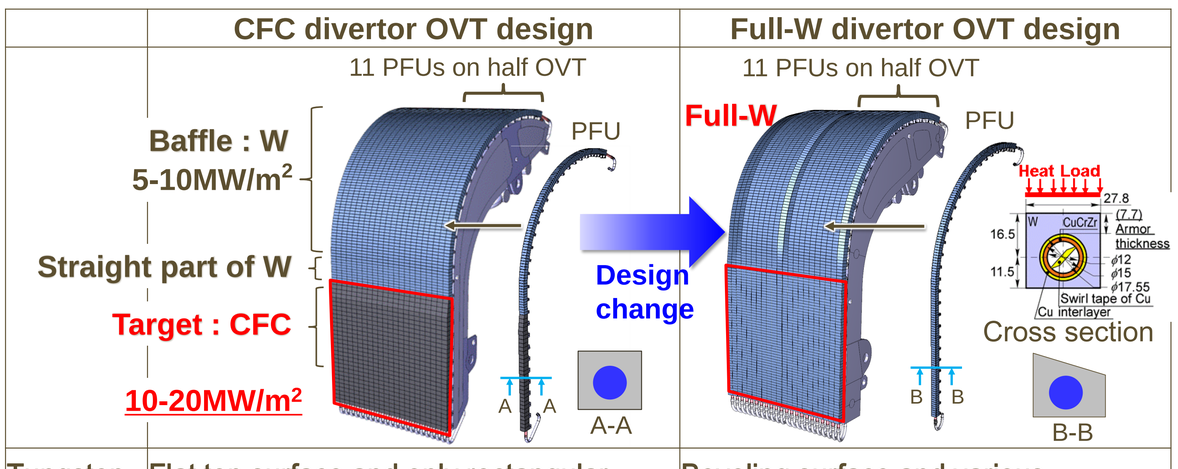
FIP: 2-1Ra

Progress of Qualification Testing for Full-Scale Plasma-Facing Unit Prototype of Full Tungsten ITER Divertor in Japan

Yohji Seki[1], K. Ezato[1], S. Suzuki[1], K. Yokoyama[1], H. Yamada[1], T. Hirayama[1], T. Hirai[2], F. Escourbiac[2], A. Volodin and V. Kuznetsov[3]

1. Japan Atomic Energy Agency , 2. ITER Organization , 3. D.V. Efremov Institute

1 What's the technical challenge for W divertor?

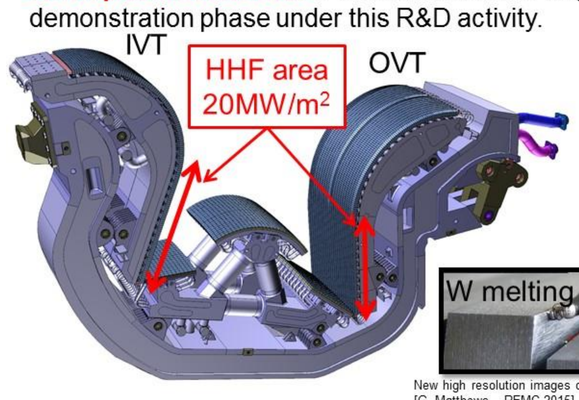


	CFC divertor OVT design	Full-W divertor OVT design
Tungsten geometry	Flat top surface and only rectangular geometry	Beveling surface and various trapezoidal geometry
Machining	Grinding surface to control the Surface accuracy	Machining W surface is difficult after assembly.

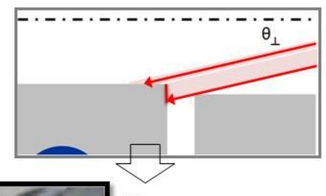
JADA faced three challenges,
(i) inspection for the dissimilar armour joint,
(ii) dimensional control of PFU to meet required dimensional and geometrical tolerances,
(iii) demonstration of the durability of full-scale prototypes against repetitive 20 MW/m^2

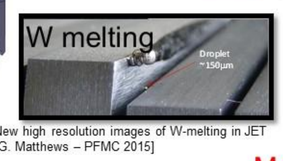
2 Profile tolerance of surface on PFUs

Strict profile tolerance of the surface at the target part **is one of the challenges** in the full-scale demonstration phase under this R&D activity.



Problem : Step of W monoblock causes increasing heat flux at leading edges.

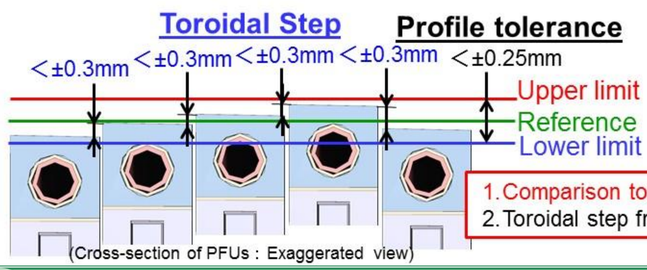




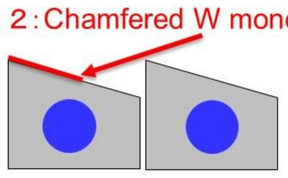
New high resolution images of W-melting in JET [G. Matthews – PFMC 2015]

Two measures are taken for all W monoblocks to prevent the leading edges of the W monoblocks from over-heating.

Measure 1 : Strict tolerance



Measure 2 : Chamfered W monoblock

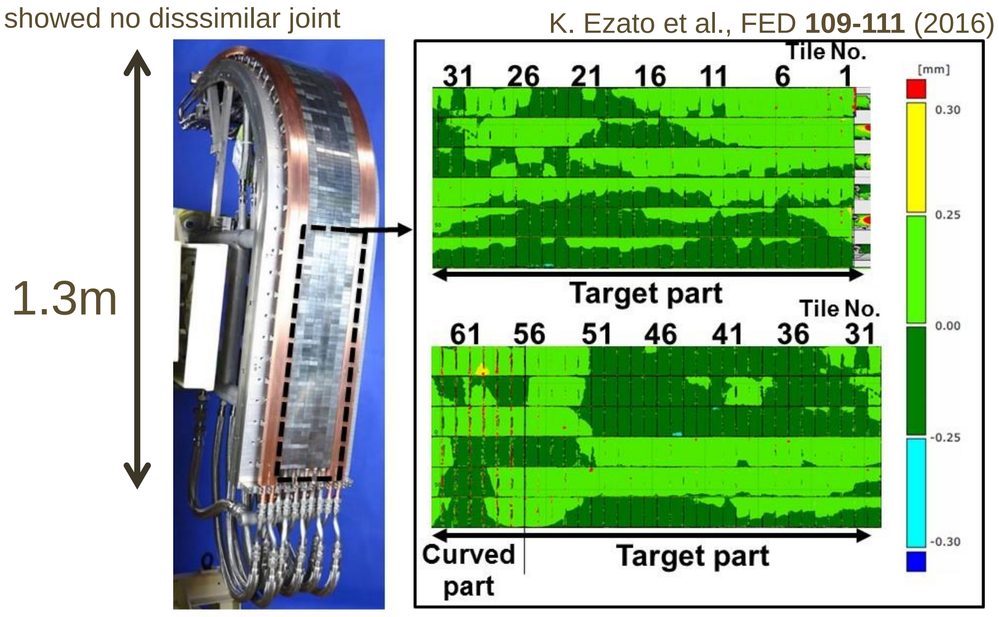


1. Comparison to CAD model : surface tolerance, ±0.25mm
2. Toroidal step from each neighbouring W monoblock, ±0.3 mm

3 3D measurement on surface profile of the 6 PFU prototypes

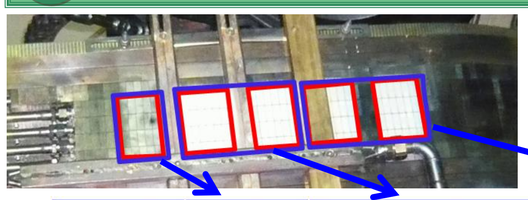
The results of UT for 4 PFU prototypes with W monoblocks and the casted Cu interlayers showed no disssimilar joint

K. Ezato et al., FED **109-111** (2016) 1256-1260.

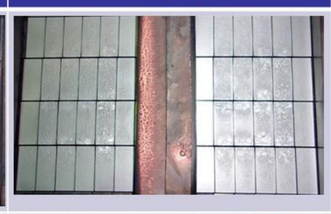
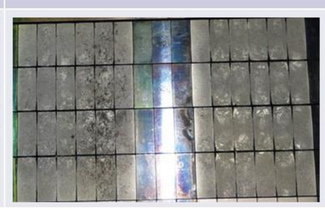


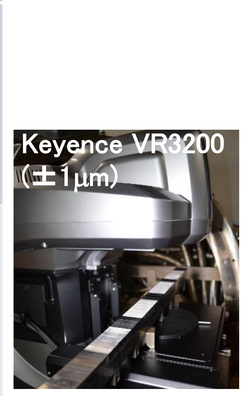
W monoblock surface in the target part was located within ± 0.25 mm from the CAD model data. JADA succeeded in demonstrating feasibility of the requirement of the stringent surface profile with tight tolerance of its parts of test assembly.

4 Durability for HHF and deformation W monoblock



The HHF testing for four full-scale PFU prototypes was carried out at the Efremov Institute.
10 MW/m^2 10s×5000cycles
20 MW/m^2 10s×1000cycles : more than requirement of 300cycles

Zone	2	3&4	5&6
10MW/m^2 x 5000cycles 20MW/m^2 x 300cycles			
10MW/m^2 x 5000cycles 20MW/m^2 x 1000cycles			

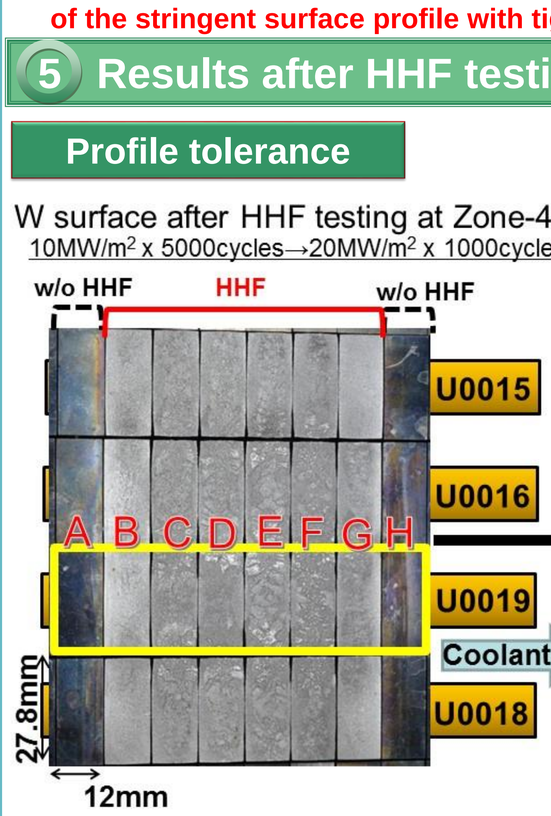


None of W monoblock showed macroscopic cracks along the coolant tube axis.
- 10MW/m^2 x 5000cycles→20MW/m^2 x 300cycles : No recrystallized and No plastically deformed
- 10MW/m^2 x 5000cycles→20MW/m^2 x 1000cycles : Deformation within ±0.25mm.

5 Results after HHF testing for full-W full-scale PFU prototypes

Profile tolerance

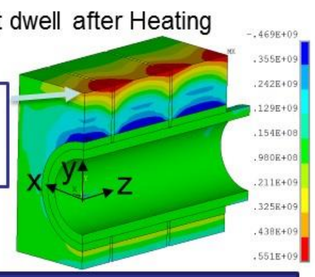
W surface after HHF testing at Zone-4
10MW/m^2 x 5000cycles→20MW/m^2 x 1000cycles



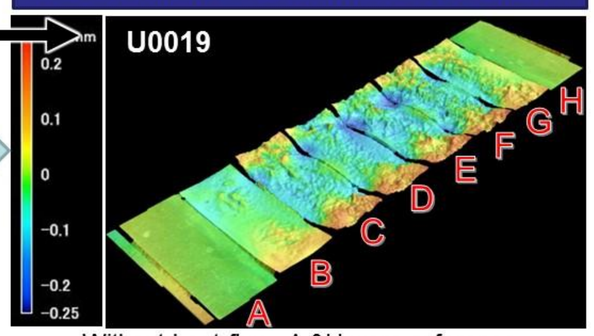
Analysis

X-stress at dwell after Heating

Max tensile stress in X-direction (σ_{xx})
470 MPa at center of W



Measurement of deformation on W surface

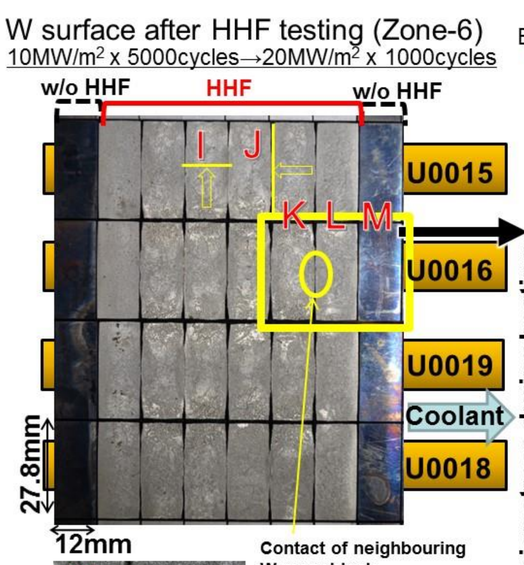


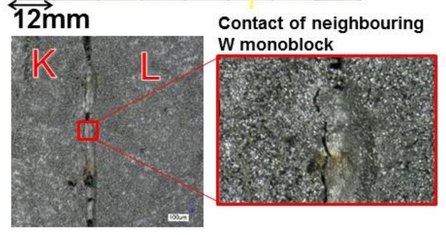
W surface temperature during HHF testing
- Loading (10s) : 2000°C、
- Dwell (10s) : 70°C (Coolant temp.)

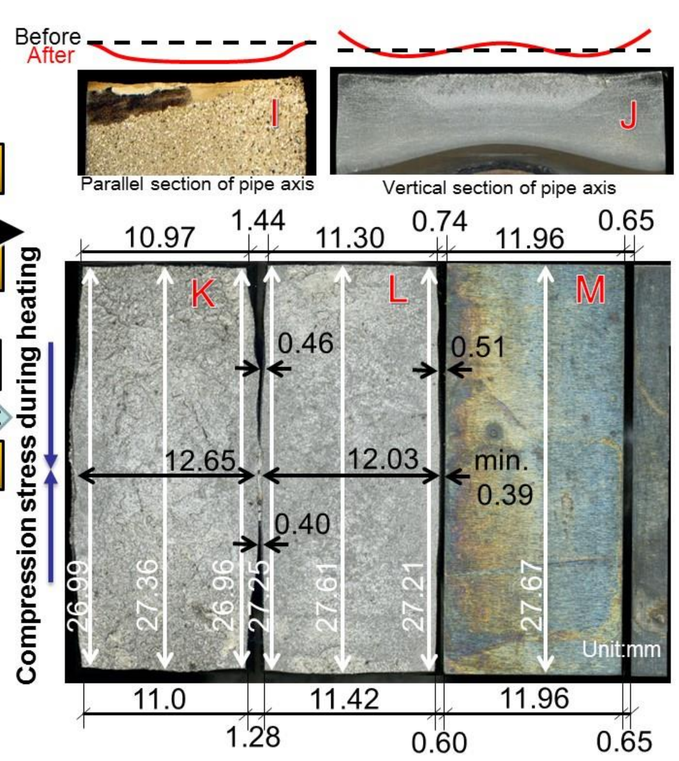
- Without heat flux - A &H were reference.
- With heat flux - B to G corners was raised. (Max deformation of +0.25 mm)
- Center of W above coolant pipe axis yielded (Max deformation of -0.25 mm)

Visual & dimensional inspection

W surface after HHF testing (Zone-6)
10MW/m^2 x 5000cycles→20MW/m^2 x 1000cycles







6 Summary

Through full-scale prototyping, JADA demonstrated the manufacturing ability of the full-tungsten plasma facing unit.

1. **All joint surfaces in four PFUs with a casting Cu interlayer successfully passed ultrasonic testing.**
2. **Surface profile in the target part stayed within the required profile tolerance of ± 0.25 mm.**
3. **Full-scale prototype withstood the repetitive heat load of 10 MW/m^2 × 5000 cycles and 20 MW/m^2 × 1000 cycles which is more than three times higher than the requirement (300 cycles).**