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Fabrication and acceptance of ITER vertical target divertor full scale plasma facing units fabricated by HRP

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HIGHLIGHTS

- R&D activities for the manufacturing of ITER divertor high heat flux plasma-facing components (HHFC).
- ENEA and Ansaldo have jointly manufactured several actively cooled monoblock mock-ups and prototypical components.
- ENEA and ANSALDO jointly participate to the European program for the qualification for ITER divertor IVT procurement.
- Successful manufacturing by HRP (Hot Radial Pressing) of full-scale Full-W IVT prototypes.
- New equipment for NDT control by ultrasonic technique.
- Dimensional check of full-scale Full-W armoured IVT qualification prototypes.

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ABSTRACT

ENEA and Ansaldo Nucleare S.p.A. are currently working on the fabrication of full scale prototypes of inner vertical target component for ITER (International Thermonuclear Experimental Reactor). The requirements is to manufacture a component by means of a qualified technology which uses armour and cooling pipe materials defined by ITER organization specification.

A dedicated new Hot Radial Pressing facility was designed and finally installed in ENEA for the fabrication of the full scale Plasma Facing Units of the inner vertical target component prototype.

HRP technology was widely tested with small mock-ups and medium qualification prototypes but its applicability to fabricate full scale units has to be anyway demonstrated and, therefore, their joint quality and also dimensions and shape has to be properly checked.

The compliance of the joint quality with the acceptance criteria is then performed by ultrasonic water gap technique, using the qualified ENEA testing equipment. Dimensional check is performed as well by analyzing acquired data points compared to the reference drawings and 3D model.

1. Introduction

The inner vertical target is a plasma-facing component of the ITER divertor and its strike point region has to be designed and manufactured to withstand high steady state thermal fluxes. Their lifetime is limited mainly by thermal fatigue caused by cyclic thermal loads inducing high mechanical stresses.

ENEA is involved in the development of these manufacturing technologies since 2000 [1]. During this period non-destructive testing techniques were also developed and certified.

Since 2005 a stable collaboration on this subject was established with Ansaldo Nucleare S.p.A. with evident improvements in the fabrication processes.

The capability of CFC (carbon fibre composite) and W (pure tungsten) armoured components to withstand cyclic thermal flux over 20 MW/m^2 was assessed [1,2,11] according to ITER/F4E/EFDA requirements and specifications.

In the frame of these R&D and fabrication activities ENEA/ANN are nowadays involved in the ITER-IVT full-W armoured reference concept development.

2. Manufacturing processes and parameters

The reference contract for this activity, F4E-OPE-138 (MS-IV) Lot. 1, launched during 2011 by F4E, has its objective in 'The Pre-Production Qualification for the procurement of the ITER Divertor

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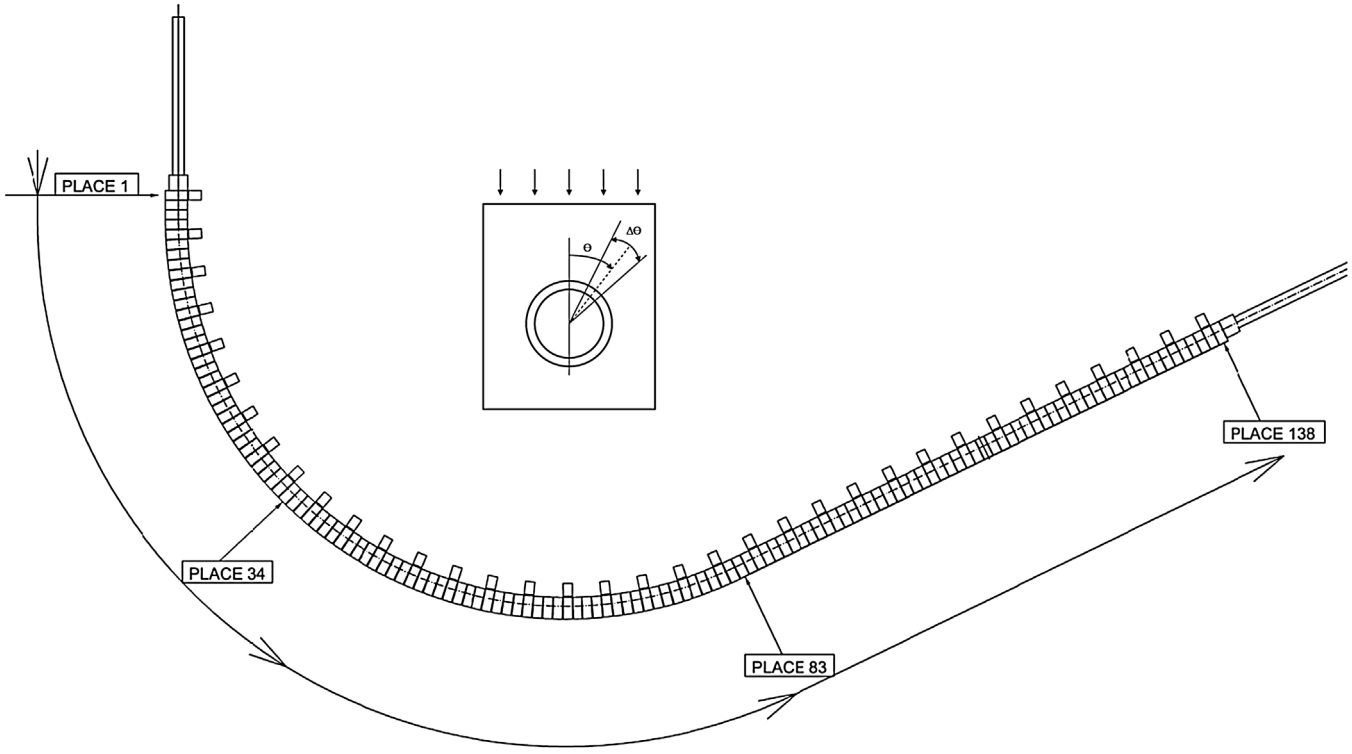

Fig. 1. PFU monoblock numbering system.

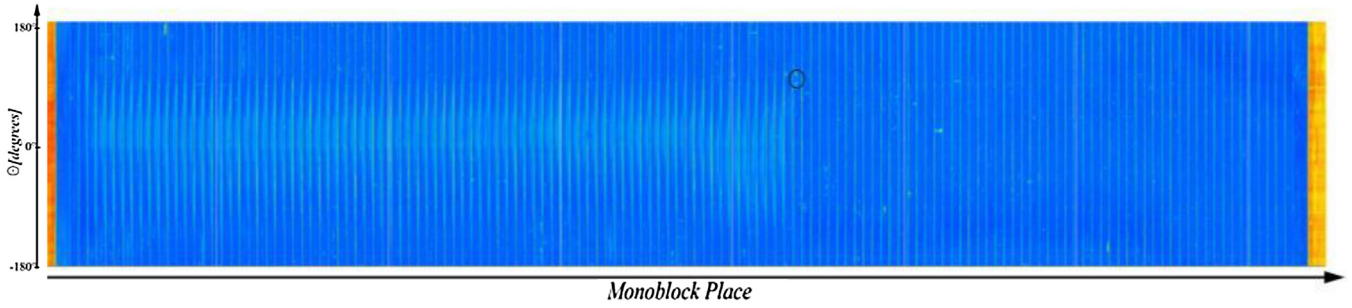

Fig. 2. C-scan of acquired signal for PFU-U0006.

Table 1
Ultrasonic test results for manufactured PFUs.

PFU	Checked (Y/N)	# sized defects	Max defect dimension detected		Acceptance limit	Circumferential position	HRP joint acceptable (Y/N)	NOTE
			L (mm)	Δθ (°)	Δθ (°)	θ (°)		
U0001	Y	7	4.3	28	68.7	77	Y	
U0002	Y	2	5.7	11.4	70	87	Y	
U0003	Y	9	6.4	38.6	50	−76.8	Y	
U0004	Y	5	12	183.1	30	−17.3	N	One block of 138 (pos 83) exceeds acc. criteria
U0005	Y	7	4.6	38	40	111	Y	
U0006	Y	5	6	28	50	91	Y	
U0007	Y	4	2.5	14	120	123	Y	
U0008	Y	2	1,7	12	32	172	Y	
U0009	N						NA	Not checked – Rejected for W cracks on lateral surface
U0010	Y	26	3.7	28	50	−63	Y	
U0011	Y	16	6.3	38	70	72	Y	

Inner Vertical Target'. In this procurement contract, ENEA is in charge of the manufacturing of the plasma facing units (PFUs).

The PFUs are the plasma-facing parts of the IVT. They are protected by the armour which is exposed to plasma particles. The reference armour material for ITER is W because of its low sputter yield, low tritium retention, high melting temperature and good thermal conductivity.

The so-called monoblock design geometry is used for PFUs. It consists of a number of blocks in W with a drilled hole in which the heat sink, a precipitation hardened copper alloy (CuCrZr code

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