Fusion Engineering and Design xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Fusion Engineering and Design

journal homepage: www.elsevier.com/locate/fusengdes

HELCZA—High heat flux test facility for testing ITER EU first wall components

Jan Prokůpek [a,*], Karel Samec [a], Richard Jílek [a], Pierre Gavila [b], Soběslav Neufuss [c], Slavomír Entler [d]

[a] Centrum výzkumu Řež, s.r.o., Hlavní 130, 250 68 Husinec-Řež, Czech Republic
[b] Fusion for Energy, Josep Pla, 2, Torres Diagonal Litoral B3, 08019 Barcelona, Spain
[c] NUVIA a.s., Modřínová 1094, 674 01 Třebíč, Czech Republic
[d] Institute of Plasma Physics of the CAS, Za Slovankou 3, 182 00 Prague 8, Czech Republic

HIGHLIGHTS

- High heat flux test facility HELCZA for testing full-scale ITER plasma facing components.
- Electron beam based heat flux cyclic loading.
- Testing Beryllium containing first wall panels, divertor inner vertical target and ICRF antenna screens.

ARTICLE INFO

Article history:
Received 3 October 2016
Received in revised form 8 February 2017
Accepted 13 March 2017
Available online xxx

Keywords:
HELCZA
High heat flux
Electron beam testing
Test facility
Plasma facing components
First wall
Divertor

ABSTRACT

The ITER first wall panels are exposed directly to thermonuclear plasma and must extract heat loads of approximately 2 MW/m^2 (normal heat flux) to 4.7 MW/m^2 (enhanced heat flux). The panels are qualified through high heat flux cyclic testing before installation in ITER. Initially, the first wall panel prototypes will undergo full-power tests, they will be followed by the pre-series panels and finally the series ones. The experimental complex HELCZA (High Energy Load CZech Assembly) has been completed and is currently in the commissioning phase. HELCZA shall be optimised to provide a cyclic heating of the ITER EU first wall panels with a heat flux in the multi-MW/m^2 range using an 800 kW electron beam. On a reduced area it is possible to reach GW/m^2 scale. Total available test area in HELCZA is 4 m^2 depending on the experimental setup. Operational conditions of the HELCZA facility enable the temperature of the cooling water to be set between 25 °C and 320 °C, within a pressure range up to 15 MPa. The cooling system provides an optimal flow rate up to 40 m^3/h independent of the pressure.

1. Introduction

The plasma-facing components comprising the first wall (FW) and divertor targets will be the most heat-loaded components of ITER. Among other challenges, they must accommodate a high heat flux from the plasma. The ITER FW panels must extract heat loads of about 2 MW/m^2 (normal heat flux design) and 4.7 MW/m^2 (enhanced heat flux design). The panels will be qualified through high heat flux cyclic testing in a dedicated facility before their installation in ITER [1].

In Europe there exists several electron beam facilities for cyclic heat load testing. FE200 in France [2] for mock-up testing, JUDITH II in Germany [3] for semi-prototypes of FW panels testing, IDTF in Russia [4] for full scale divertor component testing are all electron-beam based test facilities. Furthermore, some other smaller facilities are or have been in operation [5,6]. However, their characteristics do not allow full-scale FW testing, which is the primary goal of HELCZA.

The experimental complex HELCZA is dedicated to the series of acceptance tests of the FW panels, divertor inner vertical targets and ICRF antenna screens, which are part of the EU contribution to the ITER project. The FW panel prototypes will undergo full-power tests followed by the pre-series and finally the series panels tests. HELCZA has recently been completed and is now in its commissioning phase.

* Corresponding author.
E-mail address: Jan.Prokupek@cvrez.cz (J. Prokůpek).

http://dx.doi.org/10.1016/j.fusengdes.2017.03.059

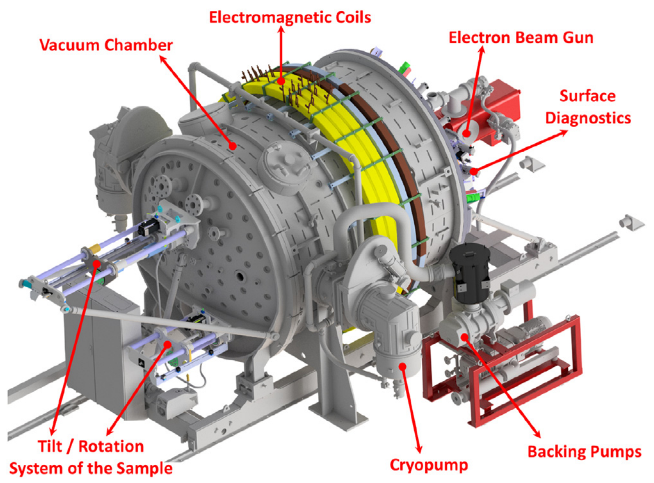

Fig. 1. Overall view of the main parts of the test facility.

2. Test facility description

HELCZA is an electron-beam based test facility for cyclic high heat flux loading of plasma-facing components, thermohydraulic testing with preheated water and infrared thermography. The device is equipped with an electron beam gun with a maximum output power of 800 kW. At the maximum acceleration voltage of 55 kV the electron current exceeds 14 A. HELCZA is primarily intended for full-size testing of the ITER FW modules, divertor inner vertical targets and ICRF antenna screens with a surface area up to 2.2 m^2 and with a power deposition density up to 40 MW/m^2 for unlimited cycles. The potential maximum surface which can be thermally loaded in HELCZA exceeds 4 m^2 depending on the test specimen geometry, the surface heat flux being correspondingly lower. A beam scanning frequency of 20 kHz in horizontal and vertical direction with the primary deflection angle of up to 40° from the gun axis provides very high evenness of the surface heating. A secondary deflection system outside the vessel will be used for ensuring perpendicular beam incidence to the thermally loaded surface or loading irregular surfaces. A view of the main parts of HELCZA can be seen in Fig. 1.

2.1. Mock-up adjustment

HELCZA is equipped with a 3D kinematic system for FW panel tilt and rotation allowing the incidence angle of the beam relative to the surface normal to be adjusted. A mock-up holder with connections for cooling of the modules allows automatic programmable positioning of the mock-ups with a weight of up to one ton during the testing. The angle of incidence of the electron beam is controlled by the electromagnetic deflection system or by the remote-controlled two-axes rotation kinematics. The electromagnetic coils are placed on the outer wall of the vacuum vessel in two sets. The magnetic field of the coils assures the electron beam positioning to the appropriate location within an angular tolerance required for the specimen high heat flux testing.

The handling of the mock-ups is performed by a manipulation system of the mock-up on the rail transporter and the gantry crane. For maintenance of diagnostic equipment, an electron beam gun rail transporter has been designed, allowing easy access to equipment from inside and outside when needed. The vacuum vessel has a volume of 13 m^3. Electron beam irradiation is carried out in vacuum conditions in the range from 10^{-3} Pa to 10^{-1} Pa.

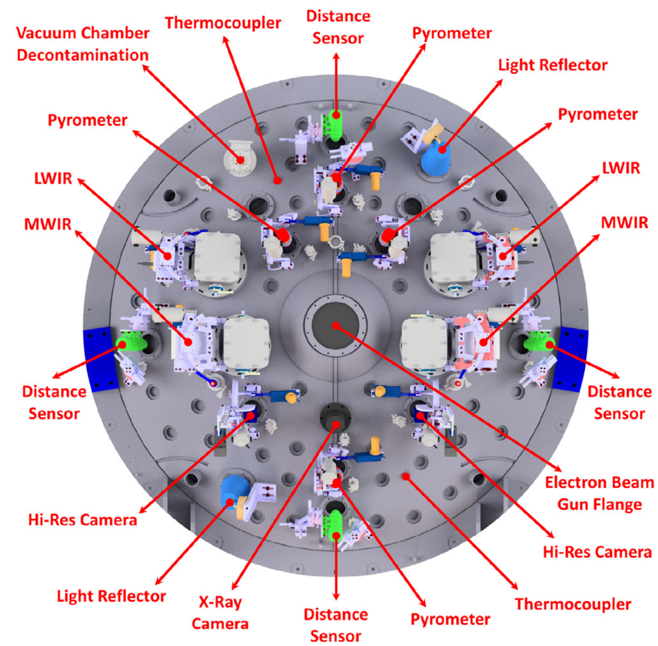

Fig. 2. Distribution of measurement devices on the electron beam gun lid of the vacuum chamber.

2.2. Operational conditions

The size of the thermally loaded area depends on the required value of the heat flux and heat absorption properties of the mock-up surface and also on the quality of the beam pattern at different locations on the mock-up allowing a homogeneous heat deposition over the loaded surface. The thermal loading is applied in cycles which may differ for individual tests. For the tests, the parallel electron beam irradiation (loading of the second surface during a dwell time of the first one) of two defined areas of the mock-up surface will be optimised to shorten the test time.

Operational conditions of the HELCZA facility enable the temperature of the inlet cooling water to be set up to 320 °C, correspondingly the water pressure shall be set up to 15 MPa (PWR water condition e.g. for testing DEMO components). The cooling system provides an optimal flow rate up to 40 m^3/h independent of the pressure at constant pressure drop of 1.8 MPa in the mock-up. This is assured by a mock-up bypass and control valve. The ITER FW modules will be cooled by demineralised water at an inlet temperature of 70 °C and a pressure of 4 MPa and the facility shall be optimised primarily for those tests.

2.3. Diagnostics

All technological devices are monitored and controlled by a central diagnostic and control system. The control system is programmed with the time-dependent and algorithmic sequence of test operations. The test programs can vary, hence the control system allows adjustment of the test sequences according to the experimental demands. The monitored key parameters of the mock-up are the surface temperature and the calorimetric measurement of absorbed heat flux and other test specimen (e.g. evenness of the applied heat flux) and machine protection related parameters (e.g. sudden vacuum level increase, cooling pressure loss, vacuum chamber overheating).

Diagnostics for surface monitoring and mock-up measurements are depicted in Fig. 2. The diagnostics consist of infrared cameras, High-res cameras, X-ray camera, one and two colours pyrometers,

Please cite this article in press as: J. Prokůpek, et al., HELCZA—High heat flux test facility for testing ITER EU first wall components, Fusion Eng. Des. (2017), http://dx.doi.org/10.1016/j.fusengdes.2017.03.059