EUROfusion

31st SOFT 2020

Structural assessment of the EU-DEMO WCLL Central Outboard Blanket Segment under normal and off-normal operating conditions

I. Catanzaro[a*], P. Arena[b], G. Bongiovì[c], P. Chiovaro[a], A. Del Nevo[b], P.A. Di Maio[a], R. Forte[a], I.A. Maione[c,], E. Vallone[a]

[a]Department of Engineering, University of Palermo, Palermo, Italy
[b]ENEA CR Brasimone, Camugnano, Italy
[c]Karlsruhe Institute of Technology (KIT), Institute for Neutron Physics and Reactor Technology (INR), Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany

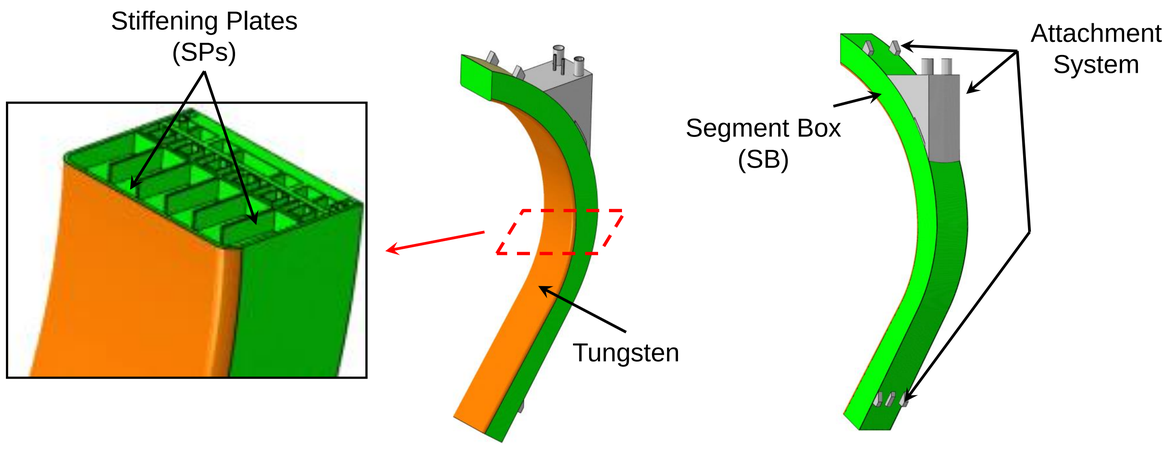
ilenia.catanzaro@unipa.it

Abstract

Within the framework of the EUROfusion design activities concerning the EU-DEMO Breeding Blanket (BB) system, a research campaign has been carried out at the University of Palermo with the aim of investigating the structural behaviour of the DEMO Water-Cooled Lithium Lead (WCLL) Central Outboard Blanket (COB) segment. The assessment has been performed considering three different loading scenarios: the Normal Operation (NO), the Over-Pressurization (OP) and the Vertical Displacement Event up (VDE-up). In particular, NO scenario represents the loading case referring to the nominal operating conditions, whereas the OP scenario refers to the loading conditions due to an in-box LOCA accident, listed as one of the BB design basis accidental events. Lastly, the VDE-up scenario is an off-normal event reproducing the plasma disruption caused by an uncontrolled vertical motion of the plasma volume. This event brings the plasma in contact with the upper walls, generating a sudden energy discharge accompanied by relevant electromagnetic (EM) forces on the structure. The study has been conducted following a theoretical-numerical approach based on the Finite Element Method (FEM) and adopting the quoted ABAQUS v. 6.14 commercial FEM code. In particular, a detailed 3D FEM model of the whole COB segment, including the back-supporting structure and its attachment system to the vacuum vessel, has been set up. Several simulations have been carried out to assess the thermo-mechanical performances of the segment under the afore-mentioned loading scenarios, taking into account also the impact of the W-armour on the overall structural response. The structural integrity assessment has been also evaluated in view of the RCC-MRx structural design rules.

1. Central Outboard Blanket segment model

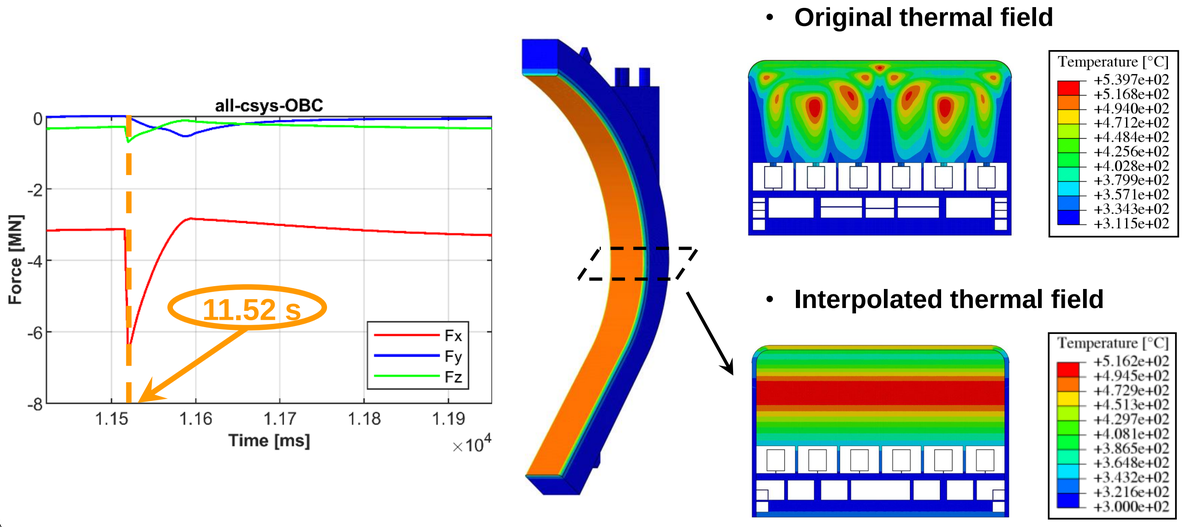
3D FEM model of the WCLL Central Outboard Blanket segment has been set-up. Moreover, with the aim of studying the impact of the tungsten on the thermomechanical behavior of the structure, two different models have been performed.



2. Thermo-mechanical loads and boundary conditions

Finite Element model composed of ~2.3 M nodes connected in ~ 4.6 M tetrahedral and hexahedral linear elements. The loading conditions concerning NO, OP and VDE-up scenarios have been considered in order to investigate the COB segment thermo-mechanical behavior.

	NO scenario	OP scenario	VDE-up scenario
Non-uniform thermal deformation field	Imposed thermal field drawn from reference WCLL COB Equatorial Region analysis	Imposed thermal field drawn from reference WCLL COB Equatorial Region analysis	Imposed thermal field drawn from reference WCLL COB Equatorial Region analysis
Pressure	• 17.825 MPa on the coolant-wetted surfaces • 0.575 MPa on the breeder-wetted surfaces	• 17.825 MPa on the coolant-wetted surfaces • 17.825 MPa on the breeder-wetted surfaces	• 17.825 MPa on the coolant-wetted surfaces • 0.575 MPa on the breeder-wetted surfaces
Gravity load	Gravity acceleration	Gravity acceleration	Gravity acceleration
Electro-Magnetic (EM) loads			• Maxwell´s forces • Lorentz´s forces
Mechanical restraints	COB attachment system	COB attachment system	COB attachment system

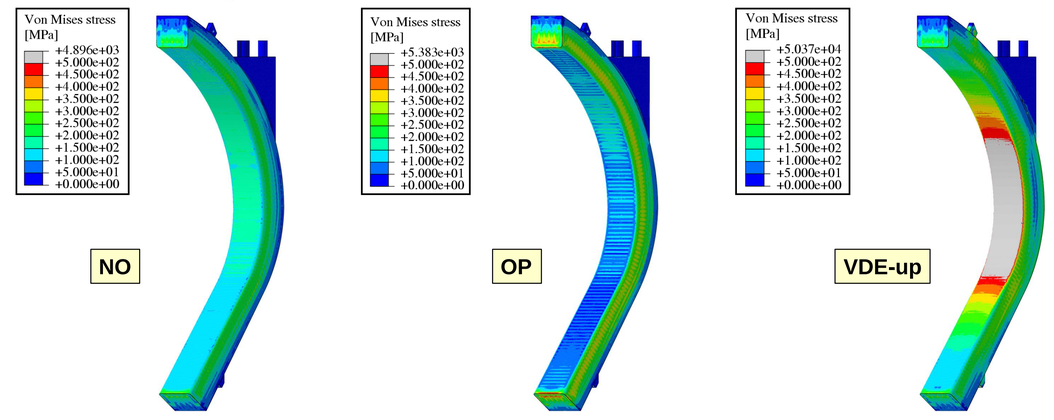


- **Original thermal field**

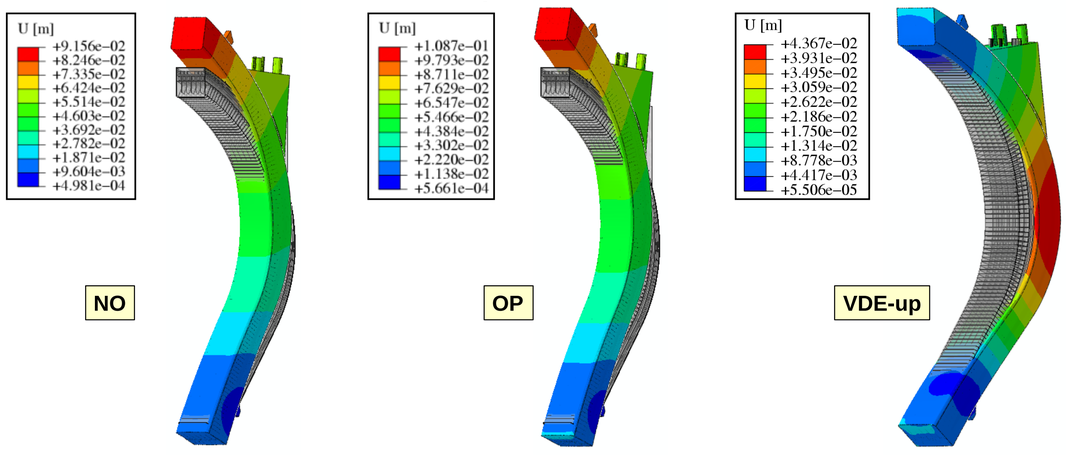
- **Interpolated thermal field**

3. Results

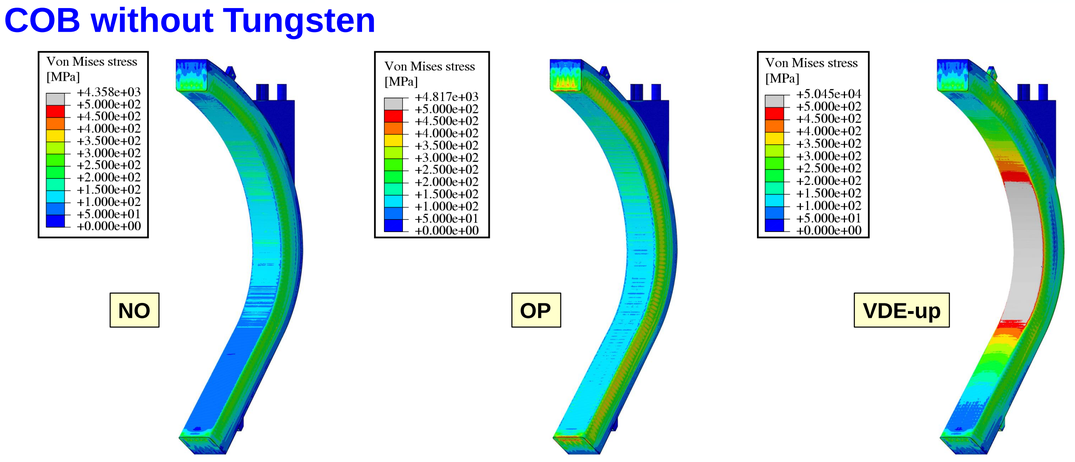
- **COB with Tungsten**



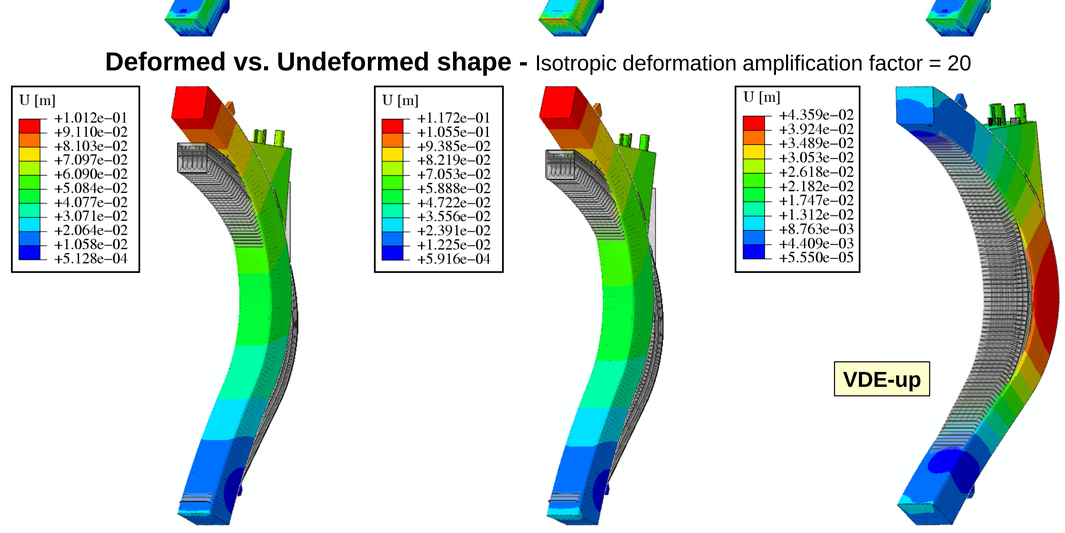
Deformed vs. Undeformed shape - Isotropic deformation amplification factor = 20



- **COB without Tungsten**



Deformed vs. Undeformed shape - Isotropic deformation amplification factor = 20



UNIVERSITÀ DEGLI STUDI DI PALERMO
ENEA ENTE PER LE NUOVE TECNOLOGIE, L'ENERGIA E L'AMBIENTE
KIT Karlsruher Institut für Technologie

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 and 2019-2020 under grant agreement No 633053. The views and opinions expressed herein do not necessarily reflect those of the European Commission.