ITER Vacuum Vessel Loads

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Introduction

- As we consider alternative materials for our vacuum vessel, it is natural to compare to the ITER vessel
- To make appropriate use of their analyses, we must understand the loads they took into account and the stresses resulting from those loads
- Hence, I will review the loads considered in the design of the ITER VV

References

- Load Specification for the ITER Vacuum Vessel - ITER_D_2F52JY v.2.2
- ITER Vacuum Vessel Dynamic Stress Analysis of a Disruption, B. W. Riemer, D. L. Conner, D. J. Strickler, D. E. Williamson, from osti.gov
- Structural Analysis of the ITER Vacuum Vessel from Disruption Loading with Halo Asymmetry, Bernard W. Riemer, Royce 0. Sayer, from osti.gov
- Design and development of the ITER vacuum vessel, K. Koizumi, et al, Fus Eng Des, 41(1998)299–304

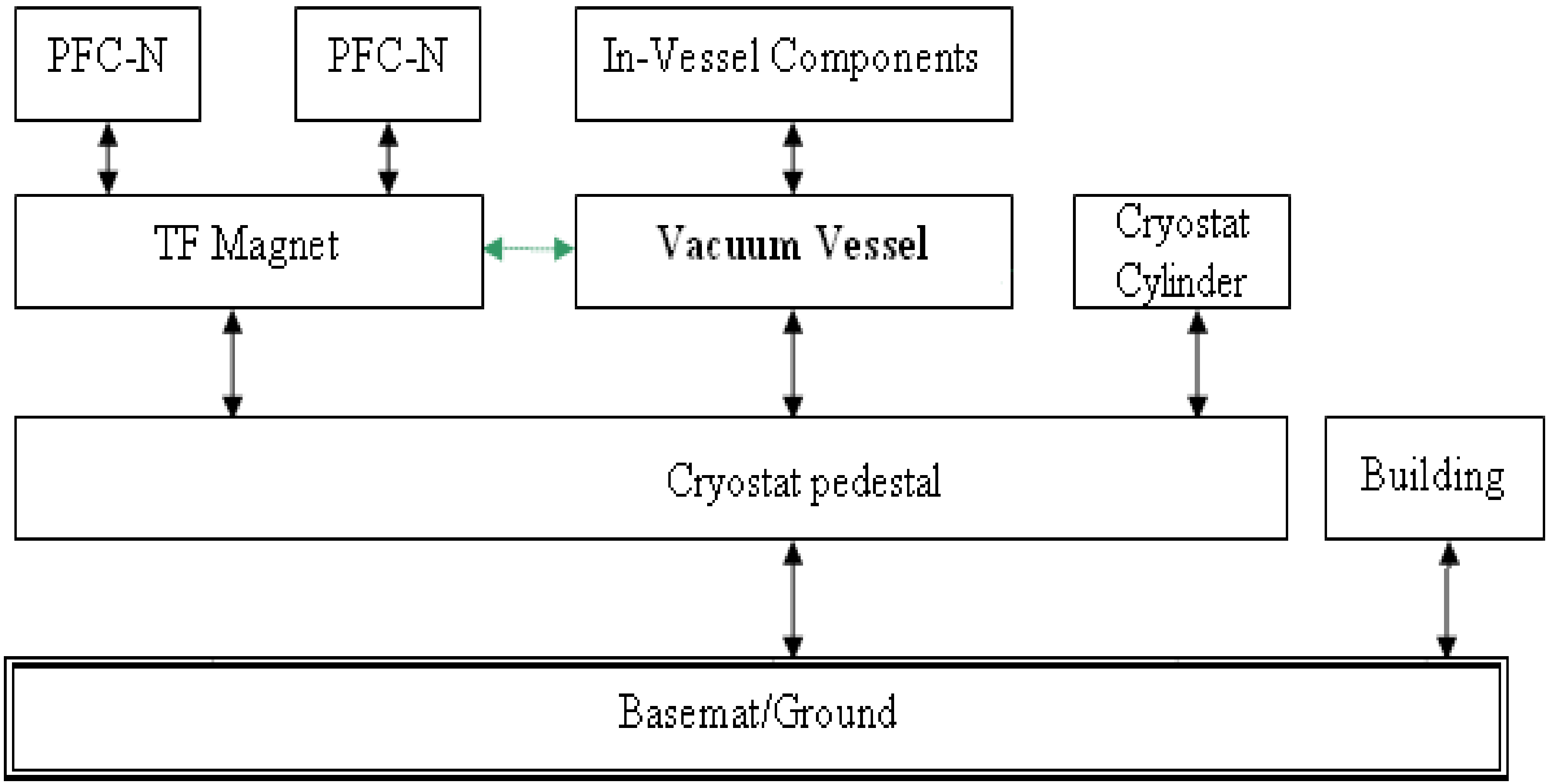
Types of Loads

- Inertial loads: gravity and seismic events
- Electromagnetic loads (plasma disruptions, VDEs, and magnet current fast discharge)
- Pressure loads
- Thermal loads (nuclear heating)
- Pretension loads: Due to the pretension of the divertor cassettes and the following bolts:
  - the cryostat bolts of the supports,
  - of the port plugs,
  - of the in-wall shielding,
  - of the blanket modules,
  - of the sockets of the blanket electrical straps,
  - of the in-vessel coil supports,
  - others.

Load Path

- VV and magnetic coils rest on pedestal ring.
- Magnet support is columns resting on pedestal ring
- PF coils are connected directly to TF magnet assembly
- The VV thermal shield is attached to TF coil system
- VV is supported at lower ports
- Blanket modules and divertor directly supported by the vessel.
- Cryostat is supported by the basemat

Load Path


PFC-N
PFC-N
In-Vessel Components
TF Magnet
Vacuum Vessel
Cryostat Cylinder
Cryostat pedestal
Building
Basemat/Ground

Load Cases (Single)

- Baking
- Pressure test in the pit
- Requalification pressure test
- Pressure test on single sector
- SL 1 and 2 (seismic)
- Major disruptions I and II
- VDE_{TM}, VDE_{WC}, $VDE_{WC\text{-}D}$
- Magnet fast discharge
- In-vessel FW pipe leakage
- In-vessel blanket pipe break during baking
- Multiple FW pipe break
- Large VV ex-vessel coolant pipe break
- LOFA during normal operation
- Loss of coolant in port cell
- Ingress in Cryostat

Non-Specific Load Cases

- Weight of in-vessel transporter
- Transient effects during heating and cool down before and after baking.
- EM loads during ramp-up of magnetic coil currents
- Thermal shield leak
- Loads during transport and assembly of the sectors
- EM loads due to pulsed operation of central solenoid
- EM loads due to ramp-up of magnet coils.

Interfaces

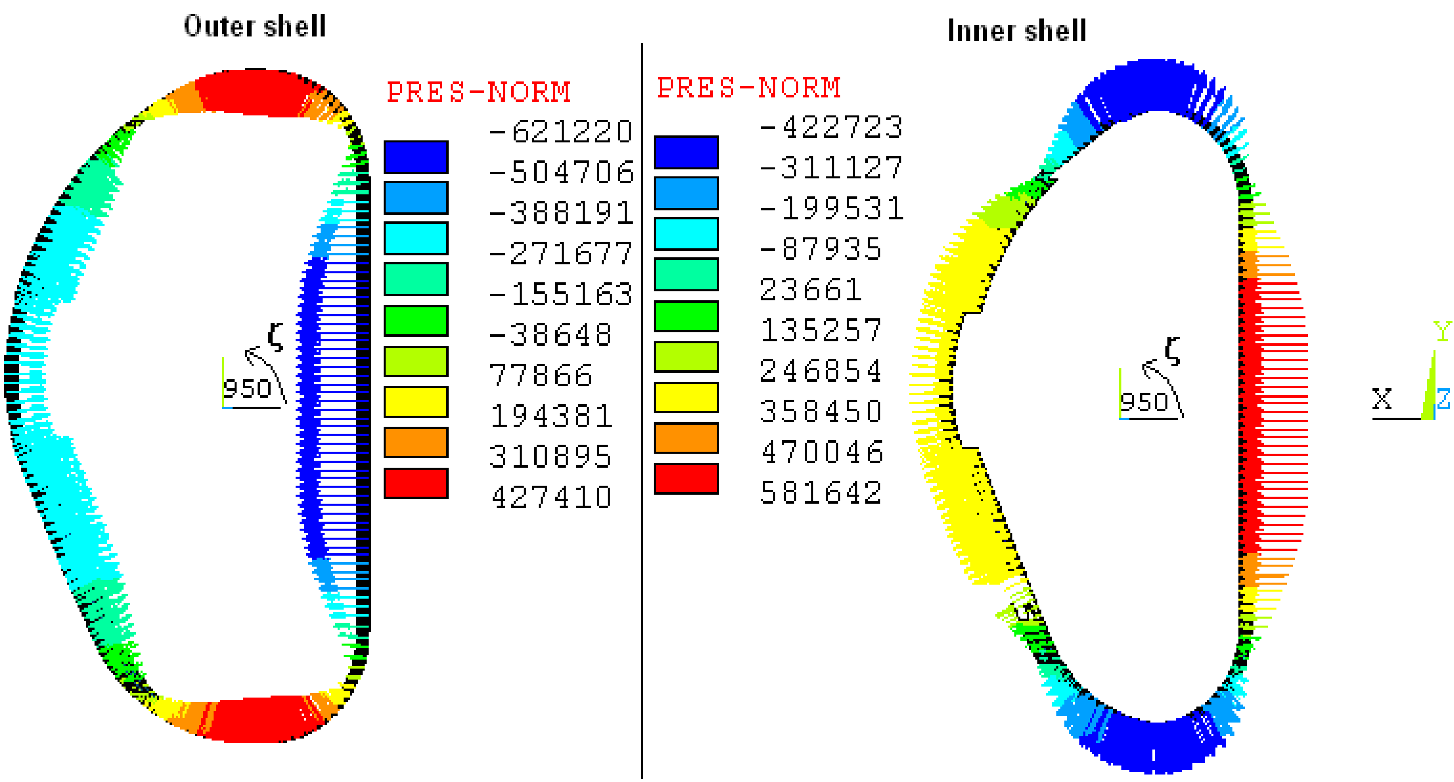
- VV support - Cryostat
- Bellows between ports and cryostat
- Magnetic coupling effect
- Divertor inboard support
- Divertor outboard support
- Divertor lower stop
- Blanket radial suppor
- Outboard blanket stub keys
- Inboard blanket intermodular key
- Inboard blanket toroidal centring keys
- Prismatic shear key, module #10
- Blanket electrical strap
- Blanket branch pipe coaxial connector
- Blanket manifold - tokamak cooling water
- In-vessel coils supports
- Remote Handling System
- Port Plugs
- Diagnostic systems
- Thermal Shield

Combined Loads

- Single load cases must be combined appropriately
- Combined loads are classified as normal, exceptional, hypothetical, and test

Disruption Types

- Current Quench – 36 ms, 1-2 per life; 36-50 ms, 400; >50 ms, 2600



Pressure due to eddy current, major disruption II, [Pa]

Disruption Types

- Vertical Displacement Events
  - Induced currents and halo currents
- VDEs combine with slow or fast current quench
- These lead to vertical loads, sideways loads, and tilting moments

Representative VDE Loads

- Vertical Force: 108 MN
- Sideways Force: 48 MN
- Tilting Moment: 216 MN-m
- Pressure on Inboard Wall: 3.67 MPa

Magnet Fast Discharge

- Coil currents drop rapidly to 0 (through discharge resistors)
- Decay of poloidal field induces toroidal currents
- Expect 500 fast discharges of CS and PF coils, and 50 discharges of all coils simultaneously
- Pressure on order of 1.55 MPa

Off-Normal Events

- Large VV ex-vessel coolant pipe break
- Loss of forced flow in the VV cooling loop
- Cryostat ingress of coolant or air/helium
- Loss of coolant in port cell
- In vessel ingress of coolant events (leak into plasma chamber)
  - In-vessel first wall pipe leakage -15 times, p=0.15 MPa
  - In-vessel blanket pipe break – p=0.15 MPa
  - Multiple first wall pipe break – p=0.20 MPa

Results

- Stresses due to disruption are on the order of 300 MPa in VV

Conclusions

- VV Loads seem to be manageable, but not trivial