Effect of Off-Normal Events on DEMO First Wall

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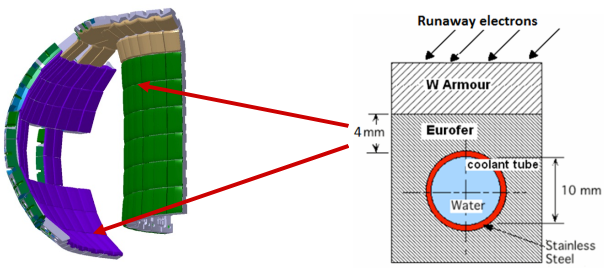
Objectives:

- Assessments of the RE and VDE parameters for DEMO conditions
- Energy deposition and erosion of the FW of DEMO due to the runaway electrons (RE) and VDE events
- Viability of W/EUROFER blanket module for the FW of DEMO under off-normal events

Blanket First Wall Block Structure



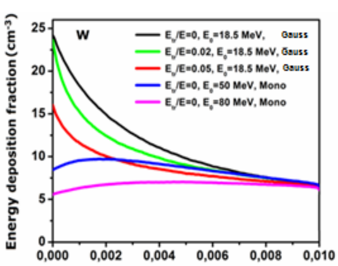
RE and VDE parameters for DEMO

- Extrapolation from ITER data based on simple scaling arguments
- For DEMO (PPCS model C) design parameters (R=7.5m, a=2m, B=6T etc.)

Event	Energy density, MJm^{-2}/deposition time, sec	Deposited area, m^2	Max. Eurofer temperature, K	Molten Layer Thickness (mm)	Evaporated Thickness(mm)
Hot VDE	~50-100/1	24	~1610	~0.85	0.011*
Cold VDE	~30-50/0.3-1	24	~1260	~0.740	0.009*
RE	~100/0.05-0.3	0.8	~1500	~1.8	~0.035

Energy deposition into Tungsten armour

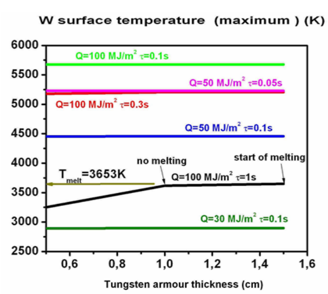
- Calculations of the VDE/RE energy deposition and consequent erosion were performed by means ENDEP and MEMOS codes
- For a VDE energy deposition is a surface phenomenon,



Volumetric heat generation (normalized to the RE input energy) in W armour as a function of the penetration depth for mono-energetic and a Gaussian energy distribution of the RE beam

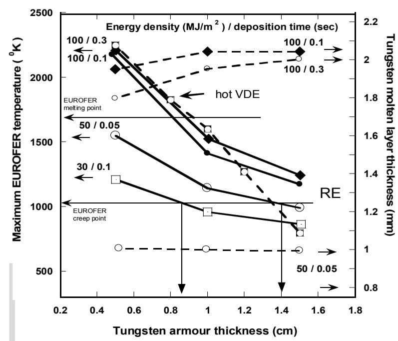
•Deposition is larger for smaller RE energies & shallow incidence angles.

•The mono-energetic RE beams deposit a smaller amount of energy because of the drop of the non-elastic cross-section for high energies.



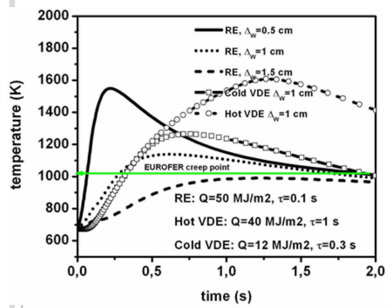
Maximum W surface temperature as a function of exposure time for mono-energetic RE beams of $100MJ/m^2$ and shallow incidence angle.

Maximum EUROFER temperature vs W thickness.



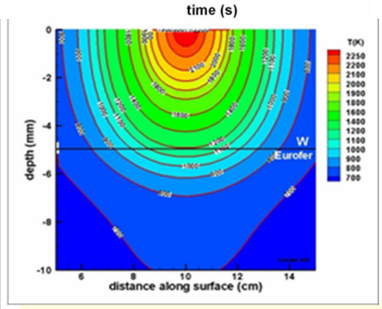
For typical RE energy deposition $50MJ/m^2$ and 0.1s exposure time), the W armor thickness must exceed 1.4cm in order to reduce the interface's temperature below the creep point.

- the higher incident energy and the smaller the exposure time, the larger the molten layer thickness



Maximum EUROFER temperature and maximum W melt layer as a function of W armour thickness.

• The EUROFER creep point limits the minimum W thickness (indicated by vertical arrows for 30 and $50MJ/m^2$, τ=0.1s); ; the case of mono-energetic RE beams and ~1° of the incidence angle and hot VDE.



Temperature contour plot on a plane normal to the W armour surface for $Q=50MJ/m^2$ during 0.1s, taken about 0.3s after the RE impact.

The RE beam incidence point is at (0,10) cm and the W-armour thickness is 0.5cm

Conclusions

• For the RE case, a volumetric heat generation occurs in W armour in particular for mono-energetic RE beams. Consequently, RE energy deposition results in thicker melt layer, higher maximum EUROFER temperature and heat flux to the coolant and the evaporated thicknesses than for a cold VDE

• For the hot VDE case, the heat generation in W armour occurs very close to the surface and there is no major difference between the RE and the hot VDE cases in terms of EUROFER temperature melt layer thickness and heat flux to the coolant. The evaporated thickness is smaller owing to the vapor screening effect.

• The total melted and evaporated thickness is ~2 mm for W, which, depending on the VDE and RE frequencies, would seriously affect the armour lifetime.

• The RE and VDE transients will pose in W/EUROFER FW structure a major lifetime issue depending on their frequencies. Future effort is required to better understand the characteristics of transients and areas of energy deposition.

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