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Simulation of the divertor targets shielding during major disruption in DEMO

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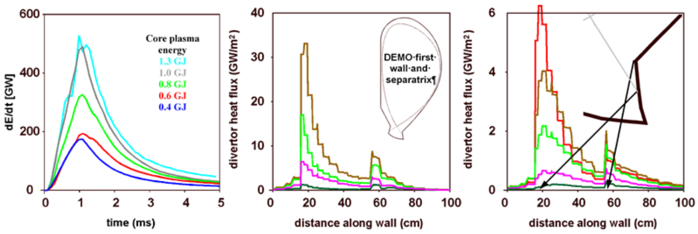
ABSTRACT

- Simulation of W divertor target damage during thermal quench of the disruption in future DEMO tokamak has been performed using the TOKES code.
- Maximum melt depth on the divertor targets is ~80 µm, independent of the energy content E_0 in the core.
- The melted pool maximum area grows from ~20 m² for 0.4 GJ disruption to ~120 m² for 1.3 GJ disruption.
- Maximum erosion depth is 4 µm for 1.3 GJ disruption and decreases to less than 1 µm with decreasing E_0.
- Total quantity of vaporized tungsten ranges from $2\cdot10^{21}$ to $3\cdot10^{24}$ atoms for disruptions of 0.4 – 1.3 GJ.
- An additional parametric study has revealed weak dependence of the results, from the characteristic widths λ_q of the disruptive flux in the Scrape-Off Layer (SOL).

FITTING THE DISRUPTION PARAMETERS IN THE TOKES CODE

- The disruptive fluxes are simulated in the TOKES code by increase in cross magnetic field transport.
- This model uses the Rechester and Rosenbluth's assumption that disruptive turbulence results in destruction of magnetic surfaces, when the field lines wander ergodically with small amplitude.
- As a result the cross-transport coefficients became proportional to the parallel ones with smaller amplitude.
- These amplitudes have been adjusted to ensure the TQ duration of 1-2 ms
- This fit has been performed in dedicated TOKES runs with plasma shielding switched off.



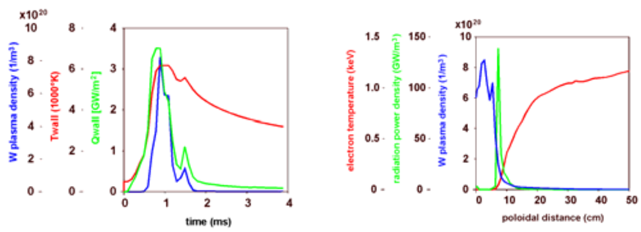
1.3 GJ in the core
0.4 GJ in the core

- Estimations for the heat flux width in the SOL are rather uncertain because of large extrapolation distance.
- We have chosen the e-folding width λ_q ~1.5 cm at TQ in the central plane of the SOL.
- An additional parametric study varying the λ_q parameter has been performed.
- The heat flux in the SOL is an interplay of (electron and ion) cross-field thermoconductivity and cross-diffusion through the separatrix combined with the parallel electron and ion thermoconductivity and convection along the magnetic field.
- All these processes resulted in heat flux at the divertor targets.
- The resulting heat flux at the target is roughly exponential
- The e-folding width λ_w for the heat flux at the target is recalculated to the equivalent λ_q at the midplane.

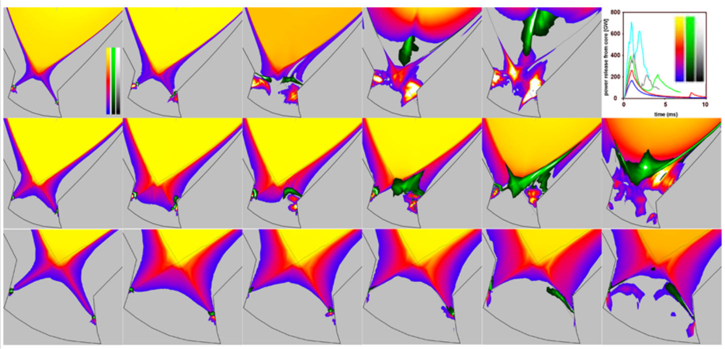
MAJOR DISRUPTION SIMULATION RESULTS WITH SHIELDING

1D structure of the shield

- The shield consists of 3 regions:
  1. dense W plasma close to the target (which is at the coordinate origin) with small T_e;
  2. T_e rise outside the W plasma cushion;
  3. sharp radiation power density (P_r) peak in the intermediate region of 100-200 eV.

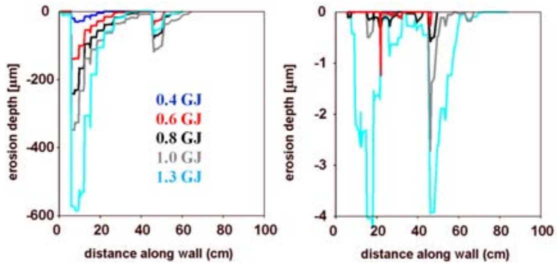


2D structure of the shield

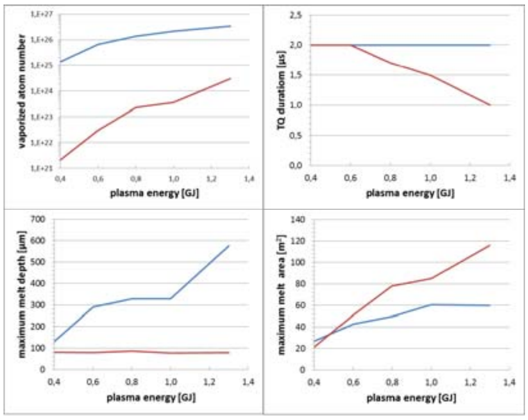


COMPARISON FOR THE TARGET DAMAGE WITH AND WITHOUT SHIELDING

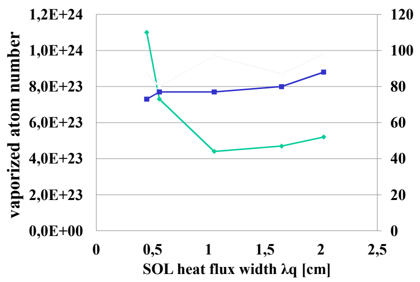
- Vaporization erosion depth profile along the outer divertor target for the disruption of the core energy



Parametric study of target damage with the disruptive core plasma energy



Parametric study of the target damage with the e-folding width λ_q



CONCLUSIONS

- The simulation of divertor target damage during TQ of the disruptions in the present DEMO tokamak design has been performed using the TOKES code and taking into account the plasma shielding.
- The damage has been estimated for the disruptions of 0.4, 0.6, 0.8, 1.0 and 1.3 GJ of plasma energy in the DEMO core.
- The maximum melt depth on the divertor targets is ~80 µm independent of the energy content in the core.
- The melted pool maximum area grows from ~20 m², for 0.4 GJ disruption to ~120 m², for 1.3 GJ one.
- Vaporization erosion maximum depth ranges from 4 µm for 1.3 GJ disruption to less than 1 µm for 0.4 GJ.
- The total amount of vaporized tungsten ranges from $2\cdot10^{21}$ to $3\cdot10^{24}$ atoms for disruptions of 0.4 – 1.3 GJ.
- An additional parametric study of the damage dependence of λ_q in the SOL has revealed its weak dependence in the interval 0.5 cm < λ_q < 2 cm.

Acknowledgements:

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