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"THEORY, SIMULATION, VERIFICATION AND VALIDATION"

TSVV TASK 7: PLASMA-WALL INTERACTION IN DEMO

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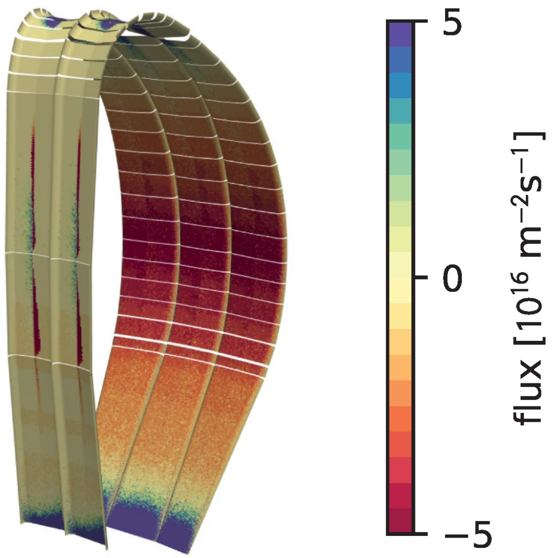
D. Matveev on behalf of TSVV-7 team

JÜLICH Forschungszentrum | KTH VETENSKAP OCH KONST | cea | UNIVERSITÉ SORBONNE PARIS NORD | MAX PLANCK INSTITUTE FOR PLASMA PHYSICS | IPP | UNIVERSITY OF HELSINKI | JSI

TSVV-07 PLASMA-WALL INTERACTION IN DEMO

Erosion-deposition maps with ERO2.0

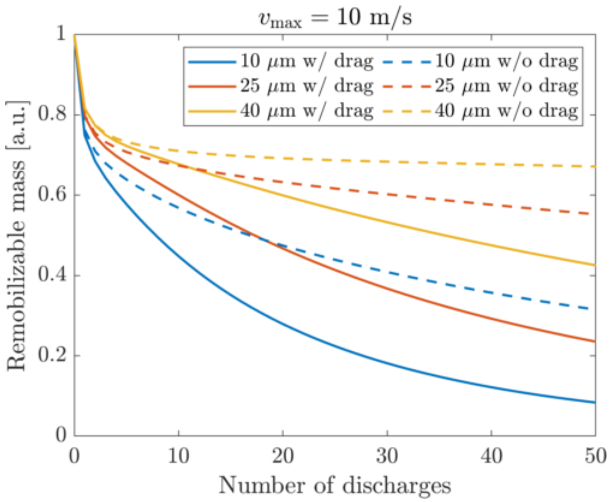
- Using baseline 2017 equilibrium with SOLPS-ITER plasma background (DCT)
- Extrapolation of plasma solution to the wall – major source of uncertainties
- Charge-state resolved background impurities fluxes, energy-resolved CX fluxes, new models for plasma flow, thermal force, high-density sheath (PIC)
- Main wall erosion dominated by CX fluxes and divertor by seeding species
- Working on improved sputtering and reflection data parameterization
- *Paper almost ready to be submitted to Nuclear Fusion*

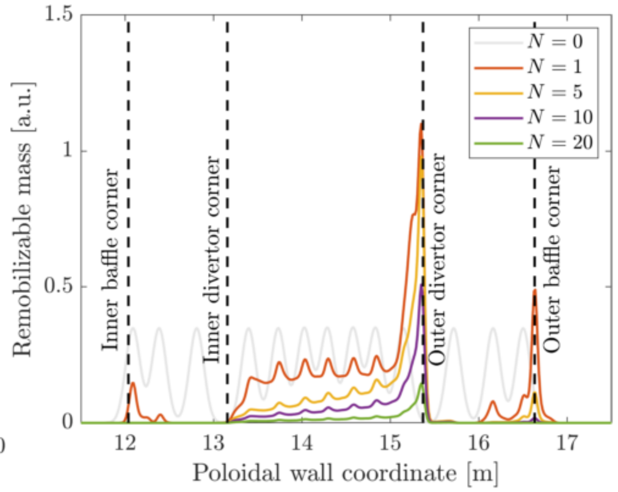


Revised ERO2.0 erosion-deposition rate map

Dust remobilization and transport with MIGRAINe

- Using baseline 2017 equilibrium with SOLPS-ITER plasma
- Tracing dust with pre-defined grain size distributions and speeds
- Injection sites in the divertor and at the top of machine (ERO2.0)
- Vaporization dominant for small grains (<25 µm) along separatrix
- Iteration of single-discharge results to predict long-term inventory
- Initial velocity has major impact on the survival of particles
- Dust accumulates primarily in corner-like geometries





Total in-vessel re-mobilizable dust mass evolution (left) and spatial distribution (right) after multiple repetitive discharges

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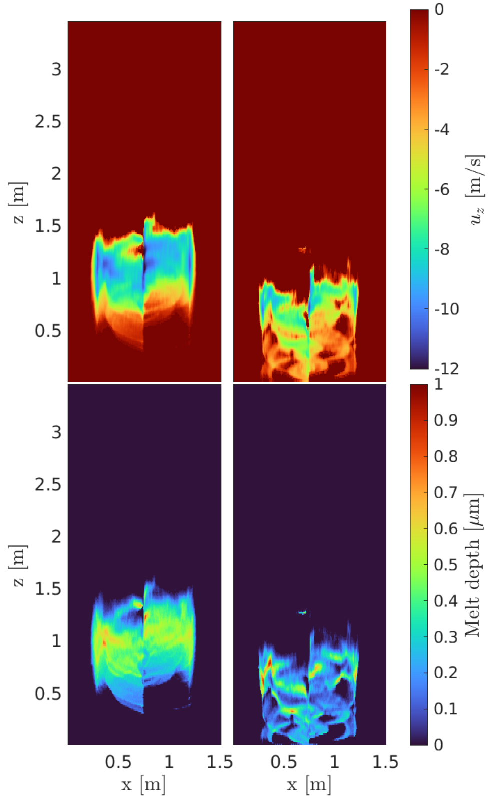
Simulations of transient melting with MEMENTO

- Thermionic emission scaling laws provided by dedicated PIC simulations
- Updated upper limiter damage under current quench with updated heat loads input accounting for time-dependent loading patterns
- No vapor shielding – overestimation of erosion damage
- Instantaneous melt pools up to 0.5 mm depth – prone to splashing.



Melt velocity along JxB (top) and melt depth (bottom) for 50% conversion from all poloidal magnetic energy at two time instants: 40 ms (left) and 60 ms (right) after the start of loading

Tritium retention and permeation with TESSIM and FESTIM

- Soret reduces T inventory and time to steady-state retention
- 3D effects (monoblocks): *R. Delaporte et al, Nucl. Fusion 64 (2024) 026003*
  - Outgassing at sides reduces retention (stronger for thin monoblocks)
  - Surface limited recombination reduces the efficiency of baking
- Neutron-induced traps: *J. Dark et al, Nucl. Fusion 64 (2024) 086026*
  - Increase retention / reduce permeation by orders of magnitude
- Retention/permeation at first wall: *K. Schmid et al, Nucl. Fusion 64 (2024) 076056*
- He clustering model with explicit accounting for dislocations in development

no damage 0 dpa | 1 dpa/FPY 0.0064 dpa | 10 dpa/FPY 0.064 dpa | 100 dpa/FPY 0.64 dpa

T retention field after 200,000 s of plasma exposure for different neutron fluxes using FESTIM code with neutron damage

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Interaction with WPs

- WP-PWIE
  - W sputtering data from lab experiments and modelling (incl. supersaturated W)
  - Experiments in support of development and parameterization of models of tritium (deuterium) transport in materials
- WP-TE
  - Experimental programs at tokamaks (AUG, WEST) for validation of modelling tools (e.g. ERO2.0, MEMENTO)
- DEMO Central Team (DCT)
  - Plasma background(s) for wall lifetime (ERO2.0) and dust inventory (MIGRAINe) simulations – current only single one available
  - Transient heat loads for melting simulations (TQ, CQ) – in progress
  - Transient plasma profiles for start-up and VDEs for dust mobilization and transport – currently not available
- TSVVs & Thrust 2
  - TSVV-05 – EIRENE as part of SOLPS-ITER for consistent plasma backgrounds and CX neutrals distributions
  - TSVV-06 – W impurity sources, screening, coupling to core plasma
  - Potential link to other TSVVs mainly via the need/interest in plasma backgrounds and/or impurity sources (or other PWI data)

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Outlook and perspectives

Capitalize on dedicated experiments under WPTE: focused validation effort ✓ to advance through collaboration with WPTE

- Validation of steady state erosion in full W device with relevant divertor geometry and impurity seeding: ERO2.0 in AUG (approved)
- Validation of dust evaporation and impurity deposition: MIGRAINe + ERO2.0 in AUG (possible within AUG internal program)
- Validation of thermo-mechanical response of W PFCs under runaway electrons (REs): GEANT4 + MEMENTO in AUG (approved)

Address the frontier problem of PFCs damage by REs created during disruptions ✓ to advance through collaboration with TSVV9

- High sensitivity of PFCs response to REs impact characteristics – can be obtained from nonlinear MHD codes such as JOREK
- Explosive W PFCs response under REs: GEANT4 (energy deposition) + MEMENTO (heat transfer) + LSDYNA (flow, fragmentation)

Expand the codes with reactor-relevant physics beyond the initial project scope ✓ to advance through collaboration with WPPWIE

- Effect of multiple isotopes on erosion and fuel retention/permeation for predictive simulations of reactor start-up and T clean-up
- Elaborating the neutron damage model from phenomenology to physics
- ERO2.0 coupling to core transport codes; edge turbulent transport effects on PWI ✓ to advance through collaboration with TSVV4&6

Towards DEMO and beyond ✓ to advance through collaboration with WP-DES (plasma backgrounds with AI)

- Framework test applications (VNS, DTT, BEST, ...) and development of surrogate models for iterative design-cycle applications