Modeling runaway electron induced damage to ITER plasma-facing components

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Relativistic runaway electrons (RE) carrying currents of up to 10 MA and kinetic energy up to 20 MJ could be formed during the current quench phase of plasma disruptions in ITER [2]. The power width of this runaway beam is expected to be extremely small (~mm) and would thus impact plasma-facing components (PFC) in very localized areas. Additionally, depending on the timescale of the RE loss, a substantial fraction (up to hundreds of MJ) of magnetic energy stored in the runaway beam can be converted to kinetic energy.

The objective of this work is to assess melt damage to the ITER PFCs induced by a RE beam strike. To do so, the existing DINA-SMITER-MEMOS-U workflow, recently developed at ITER for the study of disruption transient PFC thermal plasma loading [3-4], has been extended to include the GEANT4 toolkit. The latter uses Monte Carlo methods to simulate the passage of high energy REs through matter, allowing the calculation of volumetric heat deposition distributions in the impacted components. These deposition profiles are then used as input to the MEMOS-U code to estimate the melt damage. A first step has been to validate the workflow on published observations of RE-induced melt damage on bulk beryllium inner wall limiter tiles of the JET ITER-Like Wall [5-6]. By matching the simulated melt pattern to the one found experimentally, the RE radial power width and the impact energy can be determined. In this way, the power width of energy deposition has been estimated to be 1~2 mm. The deposition energy is about 100 kJ on one Be tile during 6 ms. This leads to a significant volumetric melting (~ 4 cm^3) with a substantial fraction of 40% of the material above boiling temperature. The melt depth reaches up to 3 mm in the localized area below the tile apex, and ~ 0.9 g of Be are evaporated.

The workflow is now being applied to ITER itself to determine the possible damage on the actively cooled ITER PFCs during the impact of accidentally formed RE beams. This will contribute to the disruption management effort to ensure that the nominal lifetime of the PFCs can be met and will inform on the impact on operations of RE beam formation during the different stages of the ITER Research Plan.

References

[1] J. Mailloux et al. “Overview of JET results for optimising ITER operation” to be published in Nuclear Fusion Special issue: Overview and Summary Papers from the 28th Fusion Energy Conference (Nice, France, 10-15 May 2021).

[2] M. Lehnen et al. “Disruptions in ITER and strategies for their control and mitigation”, Journal of Nuclear Materials **463** (2015) 39.

[3] J. Coburn et al. “Energy deposition and melt deformation on the ITER First Wall due to disruptions and vertical displacement events”, 28th IAEA Fusion Energy Conference, 10-15 May 2021.

[4] J. Coburn et al. “Reassessing energy deposition for the ITER 5 MA vertical displacement event with an improved DINA model,” Nuclear Materials and Energy, 28, (2021) 101016.

[5] G. F. Matthews et al., “Melt damage to the JET ITER-like Wall and divertor”, Phys. Scr. **T167** (2016) 014070

[6] C. Reux et al., “Runaway electron beam generation and mitigation during disruptions at JET-ILW”, Nucl. Fusion **55** (2015) 093013