Plasma shielding during transients on ITER

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Abstract

Simulations using the TOKES fluid code transient heat loads on ITER, in particular those expected during unmitigated major disruptions have shown that significant target melt damage can be expected on the tungsten (W) divertor targets. Although, every effort will be made to minimize the number of such events on ITER through the use of prediction, avoidance and mitigation strategies, they cannot be completely avoided, particularly in the early years of ITER operation when these strategies are being developed. These TOKES results also show, however, that, when plasma shielding due to ionization of the vapourized W material is included in the simulations, the degree of damage (in terms of melt depth and the melted surface area) can be reduced by several factors in comparison with the unshielded case,. The plasma energy released in the transient is converted into radiation inside the shielding layer close to the target and the radiation redistributes the energy onto the surrounding wall more evenly than the disruptive plasma itself does. Code results indicate, importantly, that the vapour shielding effect switches on at comparatively low transient energy density, so that some plasma shielding benefit may already be derived early on in the ITER experimental program when unmitigated disruption and edge localized mode transients will be more frequent.

The talk will describe key aspects of the TOKES code [1] relevant to the modelling of shielding and show first the results of code benchmarking against 2MK-200 plasma gun experiments on W [2], followed by examples of application to ITER divertor target transient loading [3]. Further plasma gun experiments, currently being planned in Russia under a contract with ITER and which will also be benchmarked against TOKES, will be mentioned and would hopefully contribute to the future vapour shielding CRP. The ITER simulations clearly show the importance of taking into account the 2D nature of the target interaction and show that the majority of re-radiation of the transient energy pulse is ascribed to medium W charge states (e.g. W^{15+} - W^{25+}) and may be described with acceptable accuracy in an optically thin approximation. Accurate optical data is important for correct simulation of the amount of vapourized material, but less important for simulation of solid wall damage. The talk will highlight those areas in which atomic data is missing, with key elements being accurate data for W ion lines (particularly medium charge states), ionization and recombination rates as well as the excitation rate coefficients for all ions.

References

[1] I. Landman, "Tokamak Code TOKES Models and Implementation", Forschungszentrum Karlsruhe Technical Report, FZKA 7496, September 2009. https://www.deutsche-digitale-bibliothek.de/binary/3AUMYCAPPEW2L5JTKNG2APUWWICXBNSB/full/1.pdf

[2] S. Pestchanyi, R. A. Pitts, V. Safronov, "Validation of TOKES vapor shield simulations against experiments in the 2MK-200 facility", Fus. Eng. Des. **124** (2017) 401

[3] S. Pestchanyi, R. A. Pitts, M. Lehnen, "Simulation of divertor target shielding during transients in ITER", Fus. Eng. Des. **109-111** (2016) 141