Thermo-mechanical limits of a magnetically driven fast-ion loss detector in the ASDEX Upgrade tokamak

J. Hidalgo-Salaverri[1,2], J. Gonzalez-Martin[1,2], J. Ayllon-Guerola[1,2], M. Garcia-Munoz[1,3], B. Sieglin[4], J. Galdon-Quiroga[3], D. Silvagni[4], E. Viezzer[1,3], J. Rueda-Rueda[1,3], T. Lunt[4], A. Herrmann[4] and the ASDEX Upgrade Team

[1] *Centro Nacional de Aceleradores (CNA), Universidad de Sevilla, CSIC, J. De Andalucía, Seville, Spain*
[2] *Department of Mechanical Engineering and Manufacturing, University of Seville, Seville, Spain*
[3] *Department of Atomic, Molecular and Nuclear Physics, University of Seville, Seville, Spain*
[4] *Max-Planck-Institut für Plasmaphysik, Garching, Germany*

A real-time control system is being developed for a magnetically driven Fast-Ion Loss Detector (FILD) at the ASDEX Upgrade tokamak [1,2]. The insertion of the diagnostic head will be adjusted in real-time to react to changes in the graphite head temperature, plasma position and appearance of MHD instabilities. The graphite probe head of the detector is exposed to an intense heat flux (located ~3 – 5 cm from separatrix) [3]. The control algorithm performance is constrained by: the graphite head sublimation temperature, the ultimate stress limit, the reaction time of the controller and the retraction time. In this work, the temperature and thermal induced stress distribution on the probe head are assessed to determine what temperature-related magnitude is the limiting factor.

The heat flux at the probe head has been estimated from time-averaged thermography measurements of the divertor tiles [4] using the λ_q (decay length of the parallel heat flux) model [5]. A field line tracing algorithm determines which regions of the probe head receives a weighted heat flux due to shadowing (self-induced or from other structures) and the incidence angle of the field lines. A finite element model is used to simulate the temporal evolution of the graphite head temperature and to perform a mechanical analysis. The temperature spatial distribution at the probe head is validated against infrared measurements of the probe head for different FILD systems, showing a good agreement. The model concludes that the maximum stress (~50 MPa) does not overcome the graphite mechanical limit (170 MPa) and that the probe head is not affected by fatigue. Therefore, the graphite sublimation temperature (2000ºC) is set as the limiting factor of the new control system.

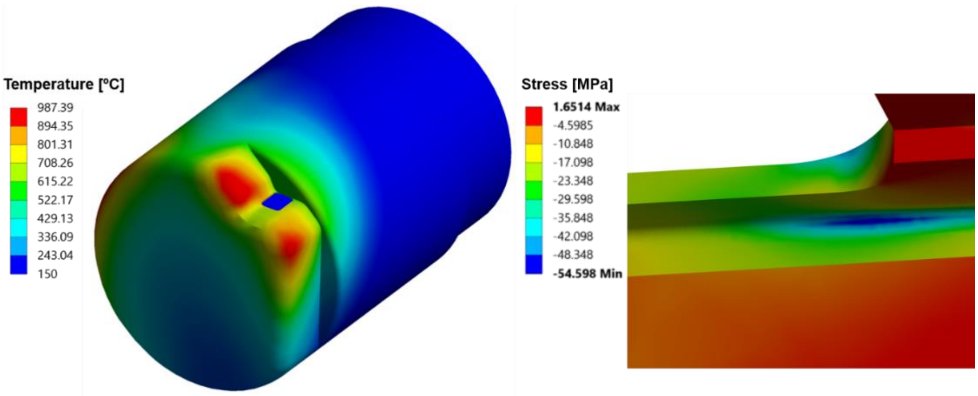

Figure 1 a) Probe head temperature distribution and b) inner probe head slot mechanical stress at the end of a simulated 4 second plasma discharge

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