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Pellet fragmentation process in the context of the SPI technology for the ITER DMS: analysis of the fragment characteristics supported by numerical simulations and image diagnostics of shatter tests

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The disruption mitigation system (DMS) for ITER is based on the shattered pellet injection (SPI) technology. The principle of operation is to form cylindrical cm-sized cryogenic pellets and accelerate them to high speeds towards a shattering chamber, where the pellets disintegrate into a plume of fragments of different sizes and velocities, which then enter the plasma for the mitigation process. The effectiveness of this mechanism is governed by the material assimilation, which strongly depends on the fragment size and velocity distributions resulting from the shattering process. In order to optimize this, it is important to know how the impact characteristics, namely the pellet material, velocity, impact angle, etc., influence the fragmentation properties. The ITER DMS task force has launched a program to characterize and study the fragmentation both experimentally and via numerical simulation. In parallel, many modelling activities are ongoing to study the effect of the injected fragmented pellet material on the disruption dynamics. In order to provide predictions for ITER with a high degree of confidence, it is essential to utilize a fragment size and velocity distribution that is as realistic as possible as an input to these models.

As part of this ongoing program, Fraunhofer EMI is developing numerical models and computer codes to simulate and analyze the complex fragmentation process. A broad range of impact scenarios are simulated for different pellet materials and impact velocities, as well as for different pellet shattering chamber designs, based on calibrated and validated models. The resultant fragment characteristics are systematically analyzed in terms of fragment size and velocity distributions. The goal is to optimize the pellet shattering chamber design as well as to derive guidelines for optimized impact conditions in order to get the desired fragment characteristics.

Our presentation will begin with a short overview of the modeling approach as well as of its calibration and validation process. Subsequently, we present the results of simulations for various impact scenarios, which illustrate the fragmentation process, and analyze and discuss the distributions of fragment size and velocity. The statistical fragmentation model, as described by Parks [1], will be applied to the pellet shattering process and compared with direct results from numerical simulation as well as analyzed shattering videos from either experiments and simulations. Our simulation results show deviations from Parks'model, which might influence the ablation process of the fragments in the plasma.

[1] P. Parks, "Modeling dynamic fracture of cryogenic pellets", Tech. Rep. GA-A28325, June 2016.

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