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Hydrogen Pellet Formation, Release, Survivability, and Shattering Research Supporting the ITER SPI System

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Large hydrogen pellets will be the primary injected material for the ITER disruption mitigation (DM) system, based on the shattered pellet injection (SPI) technique. Shattered pellet injection utilizes cryogenic cooling to desublimate gas into the barrel of a pipe gun, forming a solid cylindrical pellet. SPI systems deployed worldwide usually operate with deuterium as the primary pellet material so the issues pertaining to utilizing much larger hydrogen pellets for SPI have not been encountered until recently. The physical properties: material strength, heat of sublimation, and thermal conductivity of hydrogen are less favorable than deuterium for large pellets (>16 mm in diameter) resulting in limitations on the formation duration and release of large intact hydrogen pellets. The current method of releasing pellets from a barrel consists of using a fast-operating valve to deliver a high-pressure pulse of gas to the rear of the pellet. The resulting warm gas pulse delivers a large force, which can have deleterious effects on a large hydrogen pellet.
A series of experiments were conducted to study the formation and release requirements for various sizes of hydrogen pellets. Experiments showed that 20 mm diameter pellets are approaching the largest hydrogen pellets that can be released intact using a pulse of high-pressure propellant gas. Pellets with diameters of 28.5 and 23.5 mm were formed and catastrophically fractured during the release process, independent of propellant pressure and amount of propellant gas delivered (within relevant conditions). Release of intact pellets is essential for the reliability of ITER's DM system. To better understand the survivability and fragmentation mechanics of hydrogen, low angle impact tests were conducted using 10 and 20 mm H2 pellets impacting a flat angled plate to determine the highest possible impact velocity these pellets can survive, known as the fracture threshold velocity. This measured parameter is utilized in the statistical fragmentation model to determine the ratio of impact energy versus the minimum impact energy survivable [1]. Since the use of hydrogen as the base pellet material for SPI on ITER is a relatively new development, it was not included in the original studies dedicated to measuring and understanding the survivability limits and fragmentation.

[1] T. E. Gebhart et al., IEEE Trans. Plas. Sci. (2020)

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