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Shatter Plume Analysis from the JET, KSTAR, and DIII-D Shattered Pellet Injectors

Shattered pellet injector systems have been installed on DIII-D, JET, and KSTAR and used to experimentally determine the effectiveness of the shattered pellet injection (SPI) process in mitigating the deleterious effects of a tokamak plasma disruption. The SPI process starts by desublimating deuterium, neon, or argon gas into the barrel of a pipe gun cooled to cryogenic temperatures to form a cylindrical pellet. When formed, the pellet is dislodged from the barrel using high pressure gas delivered by a fast opening valve or a mechanical punch. The pellet travels through an injection line that contains gaps for propellant gas removal. The pellet then strikes a bent tube, known as a "shatter tube"causing the pellet to shatter before entering the plasma. The process of pellet fragmentation is a chaotic process that can be described in terms of fragment size distribution through a statistical model that incorporates effects of the pellet material and impact characteristics [1]. The optimal fragment size distribution needed for thermal mitigation or runaway electron dissipation is under investigation. In addition to the fragment size distribution, the shatter plume has other characteristics of interest such as a particle velocity distribution and temporal mass evolution. The particle velocity distribution is important because it is needed to accurately model the spread and location of the ablation in the plasma over time. The temporal mass evolution is necessary to determine the time resolved delivery of mass to the plasma.

Due to installation constraints, the shatter tube currently installed on JET has a unique geometry with a modest S bend followed by a sharp 20-degree bend at the end of the tube. The DIII-D and KSTAR shatter tube design is a simple tube bent through an angle of 20-degrees followed by a straight section. The resulting shatter spray from the JET and KSTAR shatter tubes, and a 20-degree miter bend shatter tube were experimentally characterized for various pellet materials and speeds. Laboratory testing of these shatter tubes allows the use of fast cameras to capture the fragment spray traveling through a large vacuum chamber. These high-speed videos of the shatter plumes allow the fragment size distribution, temporal mass evolution, and velocity distribution of the fragments within the plume to be determined. This paper presents a comparison of the unique geometry of the JET shatter tube to the bent tube and miter bend geometries normally used for shattering and some insight to the variables that may be adjusted to produce the optimal shatter spray. The impact of entrained propellant gas on the resulting shatter spray was examined during testing.

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

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