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Pellet fueling technology development in India

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Plasma fueling and disruption mitigation studies are two key aspects of the future fusion reactors. To meet these challenges, development of pellet injectors and associated technologies has been initiated in India to cater the domestic fusion program. As a first step towards it, a single pellet injector system (SPINS-IND) is successfully developed. The injector, depending on the barrel and sleeve size, freezes cylindrical hydrogen pellet (size ranging from 1.6 mm - 4 mm) and propels it using helium gas to a velocity in the range of 700 - 1000 m/s (depends on release pressure of propellant gas and pellet size). The system uses a closed loop GM cycle cryocooler, a cryogen free unit, to freeze pellet. The cryocooler provides ease of handling and operational reliability to the pellet freezing process. SPINS-IND is installed on SST-1 tokomak for pellet injection related experiments. System dimension is ˜2 m (length) x ˜0.5 m (width) x ˜2m (height).

Successful development of SPINS-IND gave confidence to initiate development of shattered pellet injector(SPI-IND) to aim at disruption mitigation studies (DMS). The injector cryostat is designed to freeze cylindrical pellets of size up to 10 mm, having equal length and diameter. The integration, commissioning of the system is completed. Preliminary testing of the cryo system and the vacuum system is successfully completed. Formation of pellet is tested.

Diagnostic systems such as light gate and fast imaging camera are used to measure the pellet speed and size, respectively. Additionally, a microwave cavity diagnostic system having resonant frequency of 3.2 GHz is under development for the pellet mass measurement.

In addition to the in-situ pipe gun type injector, development of a twin-screw hydrogen extruder system is ongoing for continuous fueling. It is designed for extrusion throughput in the range of 400 mmˆ3/s to achieve pellet size of 3 mm (L) x 3 mm (D) with a frequency of 10Hz. In the present design, a counter rotating intermeshing twin-screw geometry with square thread is selected. Each screw has 28 mm root diameter, 4 mm screw cavity depth and 10 mm pitch with a screw helix angle of 6.5 degree. The main extrusion circuit will have four stage cooling mechanism namely, 80K hydrogen pre-cooler, 40K pre-cooler, liquefier and solidifier. Two numbers of two-stage Gifford-McMahon cycle crycooler will be used for 40K precooling, liquefaction and extrusion application.
To know the hydrogen extrusion process, a non-Newtonian, non-isothermal ANSYS-CFD model was developed. The model is validated with the experimental data of already published literature for single and twin screw extrusion. At present, the assembly and integration process is ongoing.

Thus, India is progressing in the field of development of pellet injector technology with the successful demonstration of SPINS-IND, upcoming shattered pellet injector (SPI-IND) and twin-screw extruder system.

Speaker's title

Ms

Speaker's email address

ranjana@ipr.res.in

Speaker's Affiliation

Institute for Plasma Research Bhat Gandhinagar, Gujarat, India 382428

Member State or IGO

India

Primary authors: Dr GANGRADEY, Ranjana (Institute for Plasma Research); Mr MISHRA, Jyoti Shankar (Institute for plasma research bhat gandhinagar, gujarat, india 382428); Mr MUKHERJEE, Samiran (Institute for plasma research Bhat Gandhinagar, Gujarat, India 382428); Mr PARESH, Panchal (Institute for plasma research Bhat Gandhinagar, Gujarat, India 382428); Mr NAYAK, Pratik (Institute for plasma research Bhat Gandhinagar, Gujarat, India 382428); Mr GUPTA, Vishal (Institute for plasma research Bhat Gandhinagar, Gujarat, India 382428); Mr HEMANG, Agrawat (Institute for plasma research Bhat Gandhinagar, Gujarat, India 382428); Mr SAINI, Rohit (Institute for plasma research Bhat Gandhinagar, Gujarat, India 382428)

Presenter: Dr GANGRADEY, Ranjana (Institute for Plasma Research)

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