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Inductively-Driven Electromagnetic micro-pellet Injector for injection of solid impurities into a Tokamak: Design, Development and Results from ADITYA-U

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Micro-particle injectors used for quenching a burning plasma in case of a disruptive instability have predominantly relied on well-established pneumatic drives. Pneumatic drives are limited by the slow thermal velocity of the propellent gas molecules. Response time is also limited due to mechanical valves present in the gas-feed system. Such methods of acceleration may be therefore unsuitable for shutting down the plasma discharge with large plasma volume requiring a short warning time scale of less than 10 milliseconds. An electromagnetic pellet injector is expected to overcome these limitations easily as higher velocities can be achieved and can meet short warning timescales –both of which are important on large-sized, fusion grade reactors.
This talk will report the design and development of an Inductively Driven Pellet Accelerator and Injector or IPI – a technological innovation and advancement providing an alternate means of injection of solid particles. The device has been uniquely engineered combining the fundamental principles of electromagnetic acceleration, pulsed-power technology and principles of impact & fracture mechanics to achieve acceleration and separation of granular pellets from a cartridge and their injection into a system. The driving forces (Lorentz Forces) are generated in a contactless way by pulsed magnetic fields of one or more electromagnets and currents that are induced on a cartridge located within the magnet. The device may therefore be considered as a pulsed, synchronous version of a linear induction motor (for those familiar with Electrical Technology) or adaptation of "Coilgun"- a tubular induction Electromagnetic Launcher - with several distinct novelties. At the core of the invention is a unique design of a cartridge that undergoes in-situ fracture to release the pellets on-the-fly. The stop-and-rupture mechanism is optimally designed to achieve a certain degree of control over the mean velocity of pellets after their release from the cartridge. The device is adapted to operate at conditions ranging from atmospheric pressure to high/ultra-high vacuum; can accommodate wide range of quantity, size and material of pellets; has a magazine that can inject upto six cartridges without interrupting the vacuum or opening the system; can vary the pellets'velocity over a coarse and fine range and has a modular design such that the maximum velocity can be increased by increasing the number of modules. The IPI therefore brings to table a certain kind of versatility not commonly attributed to contemporary injectors. Higher velocities and short warning time scales can be achieved with IPI. It is now possible to inject micro-granular pellets obviating the need for shattering for easy dispersion/ablation. This paper will discuss a set of experiments from ADITYA-U where pellets of Li2TiO3/ Li2CO3 particles have been injected with a mean velocity of 200 m/s and a thermal quench followed by a rapid termination of plasma current has been achieved within 6 ms. A diverse range of experiments can now be performed and controlled with relative ease to explore the mass, material, velocity of pellets to be used for heat and energetic particle mitigation during disruption.

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