Contribution ID: **56** Type: **Poster**

Development of shell injection system for the future IFE power plant

Wednesday, October 24, 2018 2:00 PM (20 minutes)

A laser-driven inertial fusion energy (IFE) reactor should achieve the fusion of injected fuel pellets, which are continuously delivered into the reaction chamber and engaged by laser beams at 10's Hz. Using a repetitive, 100-fs ultra-intense laser HAMA[1], we have demonstrated the engagement of 1-Hz-injected flying pellets involving fusion neutron reaction for the first time[2]. To induce the fusion burn, injected fuel pellets should be imploded to reach a high-density states that beyond 1000 times of solid density and an ignition temperature beyond 5 keV. A spherical shell is most reliable target design to achieve such a high-density state which has been confirmed in several inertial confinement fusion (ICF) facilities.

We have developed a testbed of shell injection system that delivers a spherical shell of deuterated polystyrene with 500 μm in diameter and 7 μm in thickness. The testbed was placed in a vacuum chamber with pressure below 0.02 MPa. 25 shells are lined up in a horizontal tube and pushed by the horizontal needle to the injection point. The vertical needle dropping speed, which is driven by the free-fall gravity, was carefully tuned not to destroy the shell being stuck each other due to static electricity. We found that shells were distorted by a force of the horizontal needle. When the number of shells exceeded 25, they started to be distorted by the needle force and then lost sphericity to the level less than 88%. The friction of the tube surface is the key of the system. The number of injected shells was also depending on the tip structure of the vertical tube. In the current system, the "cone dip"structure with line contact to the surface of the shell has in the best result for release and injection of the shells resulting injection-success-ratio of 75%.

We demonstrate that (i) repetitive shell injection was possible with the needle speed of 28 cm/sec to release the shell one by one without distortion of the shell structures, and (ii) distribution of injected shell after 18 cm free-fall was within 11 mm diameter circle, which is still 10 times larger than that of the bead injection system, and the laser-hit-ratio would be the level of 5%. This specification is enough for the first laser engagement experiment.

[1] Y. Mori et al., Nucl. Fusion 53 (2013) 073011.
[2] O. Komeda et al., Sci. Reports 3 (2013) 0730113.

Country or International Organization

Japan

Paper Number

IFE/P4-6

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Session Classification: P4 Posters

Track Classification: IFE - Inertial Fusion Experiments and Theory