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Development of Fuel Target Injection Systems for Fast Ignition

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In future inertial fusion power plants, fuel targets must be delivered to the laser focus point many times per second. These targets are often small, and their shapes are especially complex in the case of fast ignition. Therefore, it is difficult to control their speed and direction accurately.

In this study, two types of fuel target injection systems for fast ignition fusion were developed and tested: a gas-driven system [1] and an electromagnetic coil-based system [2]. Figures 1 and 2 show the schematic diagrams of the injection system and the target assembly, respectively. The aluminum target mimics the shape of fast ignition target which has a fuel shell with a corn. As shown in Fig. 2, a holder made of DURACON ® is screwed into an sabot, and a target is mounted into the holder. The assembled target is placed at the entrance of the acceleration tube, and injected by nitrogen gas or magnetic coils. The assembled target runs in the acceleration tube and reaches the sabot separator. Ring shaped permanent magnets are placed as the separator. When the assembled target passes through the separator, eddy currents are induced on the surface of the sabot. A Lorentz force induced by the magnetic field of permanent magnets and eddy currents acts on the sabot and decelerate it. As a result, the target flies out from the target holder due to inertia.

Figure 3 shows that the target velocity increases with the injection gas pressure, reaching up to 100 m/s, which satisfies the velocity requirement for fusion reactors. However, the flight angle of the target varies significantly between shots.

Figure 4 shows the target velocity as a function of the number of coils. It is seen that the target velocity increases with the number of coils but saturates beyond a certain point. One possible reason is the backward pull caused by a delay in magnetic field cutoff. We investigated this effect using numerical simulations. The results suggest that by turning off the current at an appropriate timing, the target can be further accelerated more effectively. Although the achieved velocity is still below reactor requirements, the results demonstrate the feasibility of electromagnetic injection, and future improvements in current amplitude and timing control are expected to enhance performance.

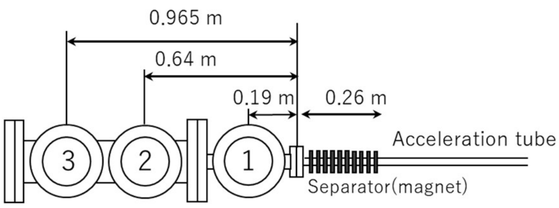

Figure 1. Schematic diagram of injection system.

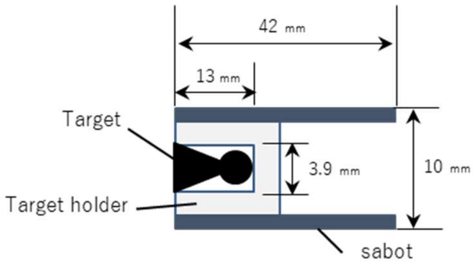

Figure 2. Schematic diagram of target assembly.

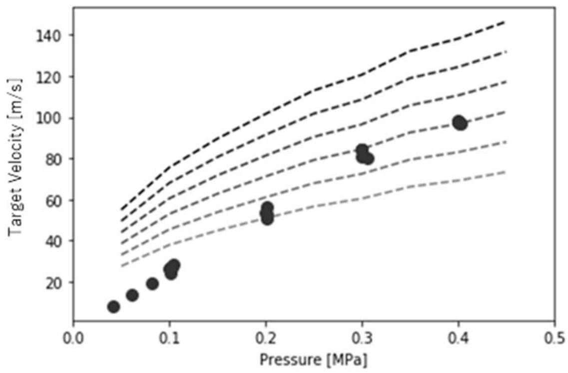

Figure 3. Target velocity as a function of gas pressure.

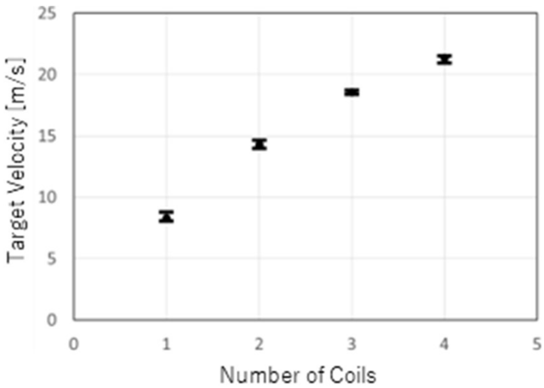

Figure 4. Target velocity as a function of the number of coils.

These studies provide valuable insights into the engineering challenges of reliable, high-speed, and repeated fuel target injection systems for inertial fusion reactors. Details are presented at the conference.

References

[1]M. Koga, et al. Plasma and Fusion Research 17 2404052 (2022).
[2]M. Koga, et al. Plasma and Fusion Research 18 2404060 (2023).