§32. Development of Gas Gun for Target Injection in Laser-Fusion Reactor

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In fast-ignition-type inertial fusion energy, a target is injected in the center of a reaction chamber and irradiated by laser beams for compression and heating (ignition). Therefore, a target injector is required to inject a target with a specified attitude, speed, and direction. In this study, we report the results of projectile-shooting experiments using a simple gas gun, focusing on flight attitude.

The gas gun is composed of three parts: a gas reservoir, solenoid three-way valve, and acceleration tube. The acceleration tube has a smooth bore. The length of the acceleration tube is 2193 mm and the inner diameter is 10.21 mm. Simple cylindrical projectiles, which represent sabots protecting fuel capsules during acceleration in a future target injector, were used. The projectiles were made of DURACON® acetal copolymer (a kind of polyoxymethylene resin; Polyplastics Co., Ltd., Tokyo). Their diameter was 10.15 mm. The lengths of the projectiles were 10.5, 21.0, 42.0, and 84.0 mm. A projectile is shot into a diagnostic vacuum chamber. In the present experiments, the initial pressure of the gas reservoir was 300 kPa and that of the diagnostic chamber was 300 Pa.

The flight speed was measured by a laser-path-cut method. A flying projectile cut a laser beam path twice during its flight, and the timings of the cuts were observed using a photodiode and an oscilloscope. Figure 1 shows the measured flight speed. The error bars show the overall range of the scattered data. The flight direction was measured by using a target catcher at the end of the diagnostic chamber. We carefully inspected the position at which the projectile was stopped. The flight direction results are shown in Fig. 2. The plotted flight direction is the deviation from the average for same-length projectiles. The typical required performance (one mrad) was attained by the 84-mm-long projectiles. The flight attitude was directly observed using a series of LED flashes and a digital still camera. The shutter of the still camera was opened for sufficient time. The timing, pulse duration, and number of LED flashes were controlled using a high-speed pulse generator triggered by the laser signal used for speed measurement. Figure 3 summarizes the results for flight attitude: the vertical axis shows the rotation speed of the projectiles, which was obtained from the observed inclination of a projectile and the flight time (flight distance divided by flight speed). As shown in Fig. 3, flight attitude was significantly improved for longer projectiles. A typical allowable rotation speed is 1.2 rad/s. Although the projectiles were simple cylinders in the present experiments, the 84-mm-long projectiles satisfied the typical requirement of flight attitude.

We carried out fundamental experiments on a gas gun with smooth bore for studying key elements of a target injection system for fast-ignition-type inertial fusion energy. The influence of projectile length upon injection performance was investigated in particular. Longer projectiles showed better performance. More precisely, 84-mm-long projectiles satisfied the flight direction and attitude requirements. This projectile length corresponds to approximately eight times the projectile diameter.

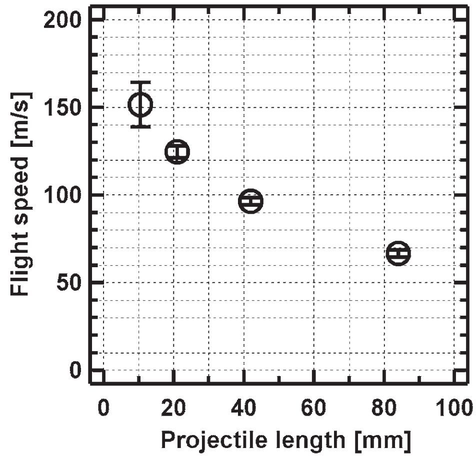

Fig.1 Flight speed.

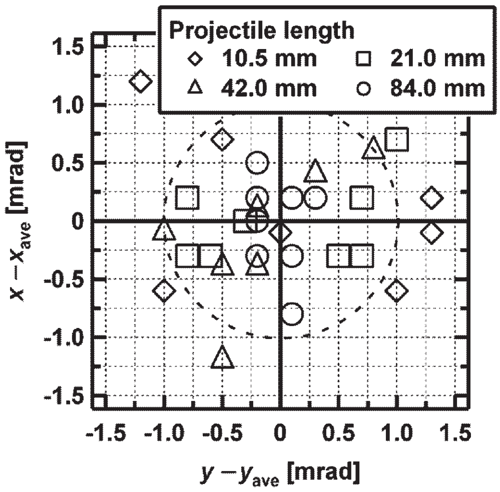

Fig.2 Flight direction.

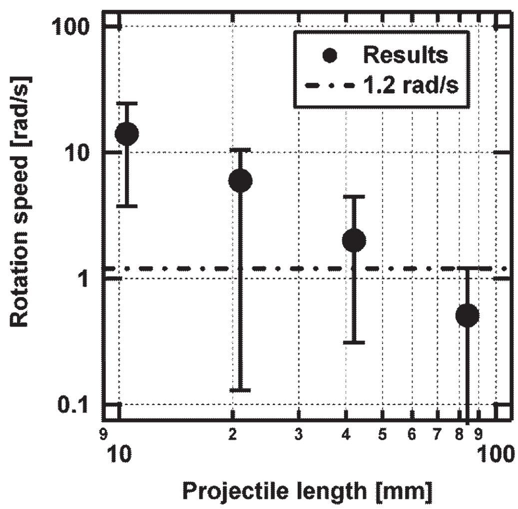

Fig.3 Rotation speed (Flight attitude).