Projectile launch characteristics in laser-driven in-tube accelerator

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The Laser-driven In-Tube Accelerator (LITA) is a unique device of laser propulsion, which is characterized primarily by accelerating a projectile in a tube; the impulse is enhanced by the confinement effect; the species and the fill pressure of the propellant gas can be tunable. In the present paper, we study the impulse generation characteristics in LITA operation. (1) The impulse is in inverse proportion to the propellant speed of sound. (2) The impulse increases with increasing the fill pressure only when the fill pressure is lower than about 100 kPa. It becomes saturated for higher fill pressures. These impulse characteristics can be well interpreted by considering the dependences of the generated overpressure and of the force exertion duration period on the respective control parameters.

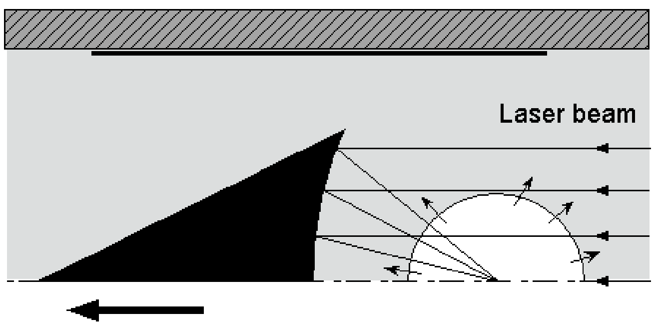

Fig.1 Impulse generation principle in LITA

The schematic illustration of LITA operation principle is shown in Fig. 1. A projectile is placed in an acceleration tube. It comprises a centerbody, struts and a shroud. The incident laser beam and an impulsive load are received on to the centerbody. The latter two are necessary for practically stabilizing the attitude of the centerbody. The tube is filled with propellant gas, which hereafter will be referred to as 'propellant.' Note here that the propellant is chemically inert like argon or xenon. The laser beam is supplied from either the front or the rear side of the projectile. Figure 1 shows the case of the rear incidence. In either case, the laser beam is focused behind the centerbody of the projectile. The breakdown in the propellant occurs at the focus, and then a laser-driven blast wave is generated. The interaction between the blast wave and the centerbody yields a propulsive impulse on to the projectile. With the laser beam being repetitively irradiated, repetitive impulses are produced. The time-average of the impulses yields a thrust.

In this paper, the performance characteristics of the LITA are analyzed based on the vertical launch performance and the acceleration tube wall overpressure measurements. The mechanisms of the impulse generation can be understood by analyzing the overpressure and duration period of force exertion. Figure 2 shows overpressure histories measured on the acceleration tube inner wall. The time is scales by multiplying the speed of sound of the propellant. On this scaled time, the overpressure histories become almost similar. It implies that the overpressure is independent of the speed of sound, while the duration period is in inverse proportion of it. As the result, the impulse is in inverse proportion to the speed of sound (see Fig. 2).

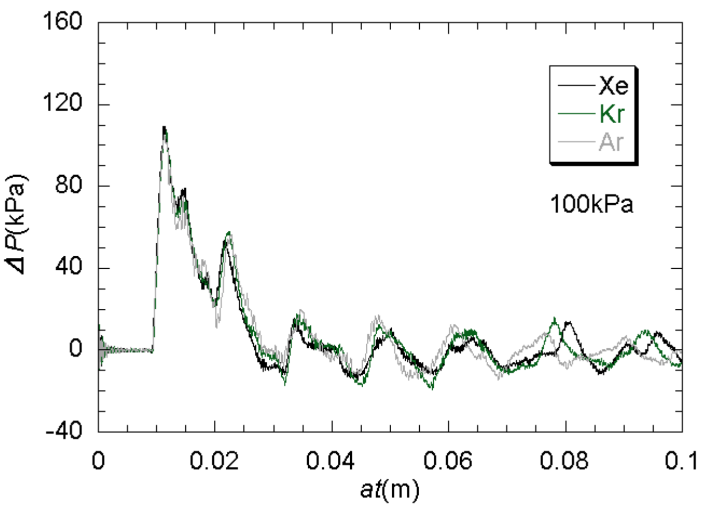

Fig. 2 Overpressure histories on acceleration tube wall on the scaled time coordinate

The overpressure increases with increasing the propellant fill pressure while the duration period is an decreasing function of it. As the result, the impulse is increased only for a low fill pressure. The impulse becomes saturated for a high fill pressure.

It should be noted that here these two parameters are controllable only in the in-tube configuration. The results of the present study will be utilized in tuning the LITA operation condition. The presented performance is limited only to an extreme condition that the projectile velocity vanishes. The impulse characteristics in vertical launch operation with a finite acceleration tube length is a current subject, which will be presented at the colloquium venue.

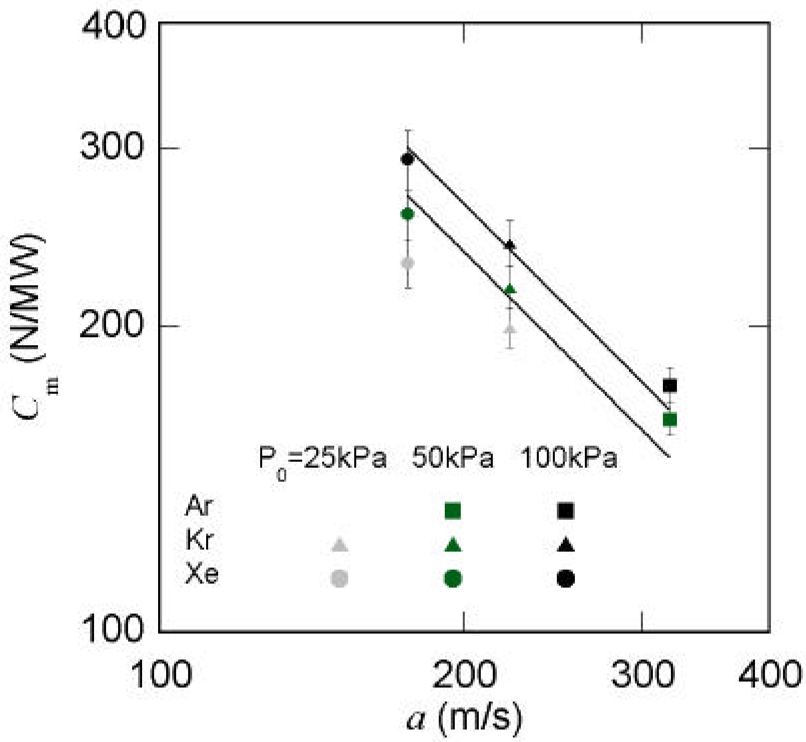

Fig. 3 Momentum coupling coefficient, C_m, vs. speed of sound, *a*