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Feasibility Study of Particle Image Velocimetry in the Muzzle Flow Fields during the Intermediate Ballistic Phase

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Abstract : This study is part of an ongoing effort to improve the understanding of phenomena occurring during the intermediate ballistic phase, such as muzzle flows. A thorough comprehension of muzzle flow fields is essential for optimizing muzzle device and projectile design. This flow characterization has heretofore been almost entirely limited to local and intrusive measurement techniques such as pressure measurements using pencil probes. Consequently, the body of quantitative experimental data is limited, so is the number of numerical codes validated in this field. The objective of the work presented here is to demonstrate the applicability of the Particle Image Velocimetry (PIV) technique in the challenging environment of the propellant flow of a .300 blackout weapon to provide accurate velocity measurements. The key points of a successful PIV measurement are the selection of the particle tracer, their seeding technique, and their tracking characteristics. We have experimentally investigated the aforementioned points by evaluating the resistance, gas dispersion, laser light reflection as well as the response to a step change across the Mach disk for five different solid tracers using two seeding methods. To this end, an experimental setup has been performed and consisted of a PIV system, the combustion chamber pressure measurement, classical high-speed schlieren visualization, and an aerosol spectrometer. The latter is used to determine the particle size distribution in the muzzle flow. The experimental results demonstrated the ability of PIV to accurately resolve the salient features of the propellant flow, such as the under the expanded jet and vortex rings, as well as the instantaneous velocity field with maximum centreline velocities of more than 1000 m/s. Besides, naturally present unburned particles in the gas and solid ZrO_2 particles with a nominal size of 100 nm, when coated on the propellant powder, are suitable as tracers. However, the TiO_2 particles intended to act as a tracer, surprisingly not only melted but also functioned as a combustion accelerator and decreased the number of particles in the propellant gas.

Keywords : intermediate ballistic, muzzle flow fields, particle image velocimetry, propellant gas, particle size distribution, under expanded jet, solid particle tracers
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