Influence of physical and geometrical parameters on vortex rings generated by a shock tube

(proposed as spoken presentation)

M. Havermann[1], M. Kainuma[2], K. Takayama[2]
(havermann@isl.tm.fr)

[1] French-German Research Institute of Saint-Louis (ISL), BP 70034, FR-68301 Saint-Louis CEDEX, France
[2] Shock Wave Research Center, Tohoku University, Sendai, Japan

Key words: vortex ring, shock tube, schlieren visualization, growth rate, stability

Vortex rings are currently studied in the frame of future non-lethal weapons [1, 2] . In this field their possible operational applications range from impulse impact to target-directed transport of substances without mechanically hurting the target. Because of a desired propagation velocity of at least several tenths of meters per second, the vortex rings under consideration are mainly formed in the compressible flow regime. Up to now, little is known about the physical influence parameters on range, growth, and stability of compressible vortex rings.

It is convenient to use an open-end shock tube for a systematic study of generation and physical properties of such rings, because the unsteady and impulse flow of a shock tube is well-known.

In the frame of a joint research project between the Shock Wave Research Center in Sendai/Japan and the ISL, a series of systematic experiments was conducted to learn more about these influence parameters. A medium-size shock tube was used for the experiments and the vortex ring was visualized by means of a large-field schlieren optics in combination with a high-speed CCD-camera. Three different shock wave numbers and 4 different muzzle area ratios were studied. Additionally, the muzzle geometry was varied by using a sharp or a blunt expansion corner. From the recorded pictures, the vortex ring velocity, growth rate and stability could be measured.

The results have shown that the propagation velocity is proportional to the muzzle area ratio and to the shock wave Mach number. The growth rate of the vortex ring diameter scales linearly with the propagation distance up to a non-dimensional distance x/d of about 15. The vortex ring growth rate is increased at a higher shock wave Mach number, which leads to a reduced range, however. The range of the vortex ring was determined from the flow visualization by the decay of the ring structure. The experiments performed at the Shock Wave Research Center in Japan will be continued at ISL with the aim of obtaining a stable vortex ring with a reduced growth rate.

[1] J. A. Edwards, ”Initial simulations of a Single Shot vortex Gun”, *Proceedings of the 2nd European Symposium on Non-Lethal Weapons*, Ettlingen, Germany, May 13-14, 2003, pp. 31.1.-31.6.

[2] P. Gnemmi, J. Haertig, C. Rey, C. Boeglen, “Preliminary Work on the Generation of a Vortex Ring“, *Proceedings of the 2nd European Symposium on Non-Lethal Weapons*, Ettlingen, Germany, May 13-14, 2003, pp. 51.1-51.3.