High Energy Concentration by Shock Focusing

M. Liverts, N. Tillmark, N. Apazidis

MECHANICS, KTH- ROYAL INSTITUTE OF TECHNOLOGY

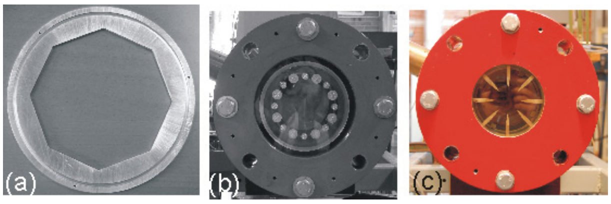
Introduction

The main objective of the present research is to investigate, understand and actively control the complex, highly-nonlinear physical mechanisms of strong shock propagation in gas and liquid-gas systems. Why shocks? Shocks are closely connected to high energy density. A shock or a blast wave is often created by an abrupt release of energy confined in space. This is manifested by extreme temperatures and pressures in e.g. gas that are hard or even impossible to achieve by other methods. These extreme conditions may result in substantial material damage when occurring uncontrolled or may be used with advantage if monitored in a well-defined environment. If this is so, isn't this a perfect way to obtain an ever increasing energy concentration by e.g. focusing a spherical shock at the center of a sphere? Unfortunately this is prevented by the instability of the converging shock. The question of stabilization of converging shocks is one of the examples of important physical properties of strong shocks that has been addressed and successfully resolved by our research.

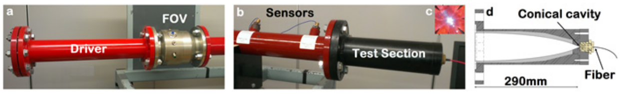
Methods

We study stability of converging shocks in specially constructed shock tube with a fast opening valve (FOV) separating the driver and driven sections and replaceable test sections that are able to create cylindrical, polygonal or spherical converging shocks

Cylindrical shock tube with a fast opening valve (FOV) and axisymmetric test chamber for spherical shock focusing



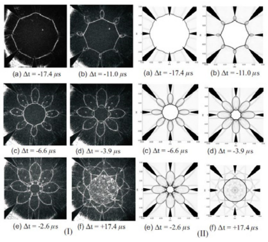
Cylindrical shock formation and stabilization by various methods: (a) reflector boundary (b) cylindrical objects (c) thin wing profiles



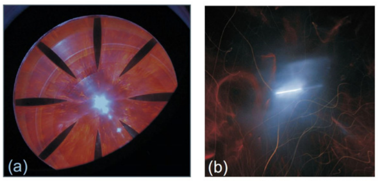
Spherical shock formation and focusing by a smooth conical test section

Results

Cylindrical shocks are unstable. A small perturbation of the shock front is amplified during the convergence process and destroys the symmetry of the converging shock resulting in significant mitigation of the focusing effect since different portions of the shock will arrive at different locations and in separate times in the focusing region. The converging cylindrical shock is stabilized by transforming it to a symmetric polygonal form which becomes dynamically stable and preserves the symmetry of the shock front through the convergence procedure

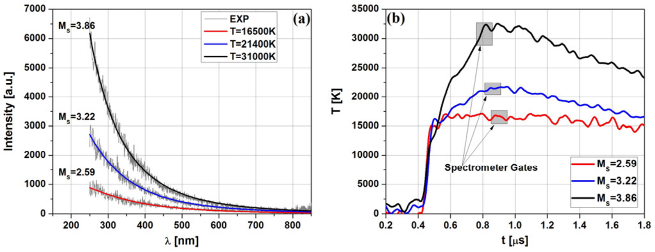


A series of experimental and numerical images showing the convergence of an octagonal shock created by thing wing profiles in the test chamber.



Heated and radiating Ar-gas core at the instant of implosion. (a) The test chamber is illuminated by the glowing gas. (b) Magnification of the core showing its 2 D structure.

Spherical shocks result in a significantly more powerful amplification during focusing. We measure the radiation of the heated Ar plasma by spectral methods and obtain the maximum temperature in the order of 40,000 K



(a) Spectra and (b) temperatures of the radiating Ar-plasma as function of time for various initial Mach numbers.

References

1. Apazidis, N., Lesser, M.B. 1996 On generation and convergence of polygonal-shaped shock waves. *J. Fluid Mech.*, **309**
2. Eliasson, V., Apazidis, N., Tillmark N., 2006 Controlling the form of strongconverging shocks by means of disturbances. *Shock Waves.*, **17**
3. Eliasson, V., Tillmark, N., Szeri, A. J., Apazidis, N., 2007 Light emission during shockwave focusing in air and argon. Phys. Fluids, 1**9** 106106.
4. Eliasson, V. Kjellander,M., Apazidis, N. 2007 Regular versus Mach reflection for converging polygonal shocks. Shock Waves **17**
5. Kjellander M., Tillmark N., Apazidis N., 2010 Thermal radiation from a converging shock implosion, Phys. Fluids **22,** 046102.
6. Kjellander M., Tillmark N., Apazidis N., 2012 Energy concentration by spherical converging shocks generated in a shock tube, Phys. Fluids , **24**, 126103.
7. Kjellander, M.,Tillmark, N., Apazidis, N., 2010 Shock dynamics of strong imploding cylindrical and spherical shock waves with real gas effects. Phys. Fluids, **22**, 116102.
8. Kjellander, M. Tillmark, N. Apazidis, N. 2011 Experimental determination of self-similarity constant for converging cylindrical shocks. Phys.Fluids, **24** , 126103
9. Apazidis, N. Kjellander, M. Tillmark, N. 2013 High energy concentration by symmetric shock focusing. Shock Waves, **23.**