On Focusing of Strong Shock Waves

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Introduction

Focusing of shock waves has many applications, ranging from medical treatments to cutting and cleaning of hard surfaces with water jets. Also, the non-linear dynamics that occur during the focusing process are of great interest. Experiments on shock wave focusing have been performed since the beginning of the 1950's.

To be able to study the whole focusing and reflecting process, a new shock tube was built at **KTH Mechanics**. *The test section of the shock tube has an exchangeable reflector boundary and hence it is possible to use different shapes of reflectors to shape the shock wave.*

Experimental Setup

The experimental setup consists of a light source, a laser, a horizontal shock tube and a schlieren optics system. The shock tube has a test section where shock waves are focused and reflected. That process is visualized by the schlieren system with a camera.

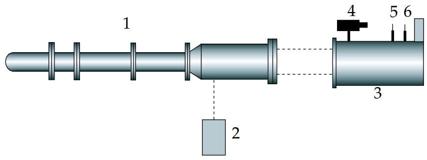


Fig 1. 1. Shock tube, 2. Pulse Laser, 3. Schlieren optics, 4. PCO CCD Camera, 5. Lens, 6. Schlieren Edge.

The 2.4 m long circular shock tube consists of two main parts, the high pressure part and the low pressure part which are separated by a 0.5 mm thick aluminum membrane. A schematic illustration of the shock tube and its main elements is shown in Fig. 1 above.

To create a shock wave the low pressure part is evacuated from gas to a certain pressure. Then the high pressure part is filled with a gas and at a certain pressure difference between the two parts the membrane bursts, creating a shock wave which will become planar in the inlet section of the low pressure part.

To control the membrane opening, a knife cross is placed in the inlet of the low pressure part. The knife-cross helps the membrane to open evenly. Also, an even membrane opening prevents unnecessary disturbances and helps to prevent pieces come loose from the membrane.

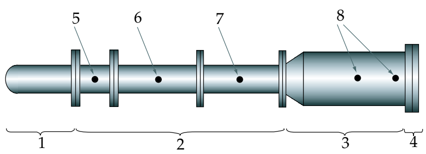


Fig 2. 1. High Pressure Part, 2. Inlet Section, 3. Transformation Section, 4. Test Section, 5. Low Pressure Sensor, 6. Vacuum Valve, 7. Vacuum Pump, 8. Shock Speed Sensors.

At the end of the annular part of the shock tube the test section is mounted. After a sharp 90° bend the annular shock wave enters the test section and the focusing and reflection process begins. The gap between the two facing glass windows in the test section is 5 mm and hence the cross section area is reduced to half of that in the annular part.

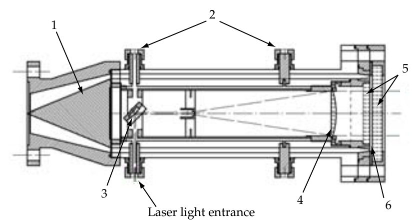
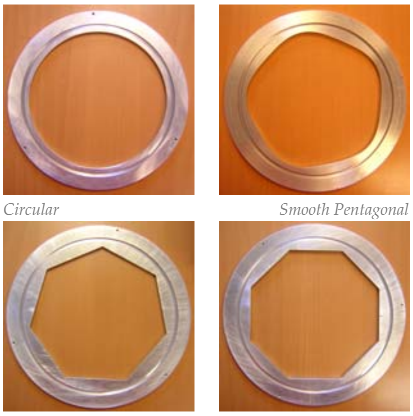


Fig 3. The annular part of the shock tube: 1. Inner body with a cone, 2. Supports, 3. Mirror, 4. Lens, 5. Glass windows for visualization, 6. Obstacle positioning area.

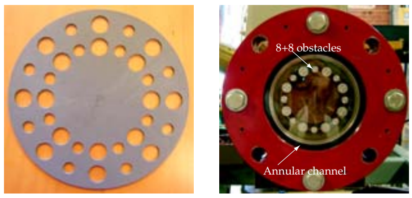
Shaping the Shock Waves

Two methods to shape the shock waves has been used in the present experiment. The first method is to change the reflector boundary inside the test section. Four different shapes have been used:



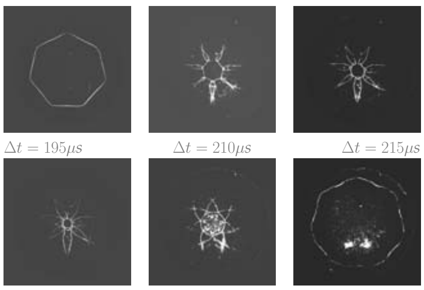
Circular — *Smooth Pentagonal* — *Heptagonal* — *Octagonal*

The second method is to place obstacles inside the test section in various patterns and positions.



Positioning template — *Rear part of shock tube*

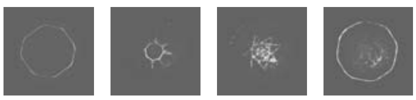
Results: Heptagonal Reflector Boundary



$\Delta t = 195\mu s$ — $\Delta t = 210\mu s$ — $\Delta t = 215\mu s$

$\Delta t = 218\mu s$ — $\Delta t = 230\mu s$ — $\Delta t = 270\mu s$

Results: Octagonal Reflector Boundary

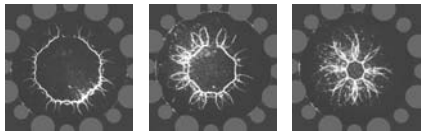


$\Delta t = 185\mu s$ — $\Delta t = 202\mu s$ — $\Delta t = 230\mu s$ — $\Delta t = 265\mu s$

Results: 8 Obstacles

$\Delta t = 200\mu s$ — $\Delta t = 205\mu s$ — $\Delta t = 210\mu s$ — $\Delta t = 216\mu s$

Results: 8+8 Obstacles

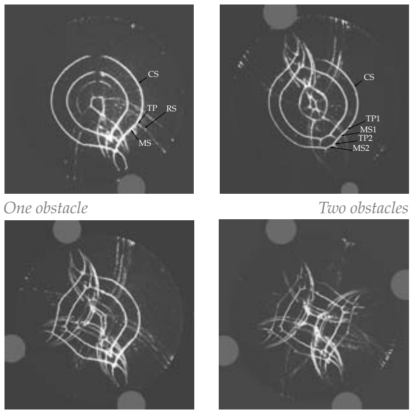


$\Delta t = 200\mu s$ — $\Delta t = 205\mu s$ — $\Delta t = 215\mu s$

Results: 3+2+3 Obstacles

$\Delta t = 200\mu s$ — $\Delta t = 210\mu s$ — $\Delta t = 217\mu s$

Results: 1, 2, 3 & 4 Obstacles



One obstacle — *Two obstacles* — *Three obstacles* — *Four obstacles*

Conclusions

We summarize the most important conclusions:

- The initial form of the shock wave can be tailored by the appropriate choice of reflector boundary or by introducing cylindrical obstacles in a specific pattern in the flow.
- The non-linear dynamics, between the shape of the shock front and the velocity of it, is observed. If a symmetric n-gonal shaped shock wave is created, it will transform to a double n-gonal and then back again to an n-gonal shape, oriented opposite to the first one. This behavior continues to repeats during the whole convergence process.
- The reflected shock wave has at first a cylindrical shape for all cases. Then the shock wave is influenced by the flow ahead of it and changes its form.

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