DESIGN AND ANALYSIS OF SHOCK TUBE

S. Saravanan[1] and V. Nandhini Devi[2]
Assistant Professor1, PG scholar2
Department of Aeronautical Engineering
PB college of engineering,
Anna University
Chennai, India.

ABSTRACT:

Topology optimization of shock tube involves the design modification of a conventional shock tube based on pressure and area ratios in order to achieve supersonic Mach number. A conventional shock tube consist of two sections namely the driver and the driven section. The interface between the two sections is said to be "DIAPHRAGM". The driven and the driver sections are filled with atmospheric air and helium respectively under predominant condition. The three phases to achieve supersonic Mach number:

1. Dividing the driven section into number of sections.

2. Varying the cross section of the shock tube.

3. Changing the medium of the flow inside shock tube.

Pressure transducers could be used to measure the aerodynamic parameters in terms of pressure by which other flow properties such as velocity and Mach number could be calculated. The calculations are made mathematically and its optimization is done through simulation CFD.

Keywords: Shock Tube, Driver Section, Driven Section, Diaphragm, Pressure, Velocity, Mach number.

1. INTRODUCTION:

In order to produce the supersonic Mach number, the cylinder of diameter 14mm is divided into two sections and helium is filled equally at each part of the sections at variable pressure. Initially, the shock tube utilizes the difference in pressure between the gases separated by the diaphragm to create a normal shock wave and the diaphragm ruptures at rupture pressure which results in adversely pressurized flow by moving normal shock waves. Thus a supersonic flow is achieved at the end of the driven section. By introducing a dump tank and nozzle further in the design, a shock tunnel is created where models could be tested at supersonic range. Here we have simulated the shock tube with single and double diaphragms and their resultant variation in Mach number is analyzed. The inventor model of the shock tube consisting of driver and the driven section is shown in figure 1.

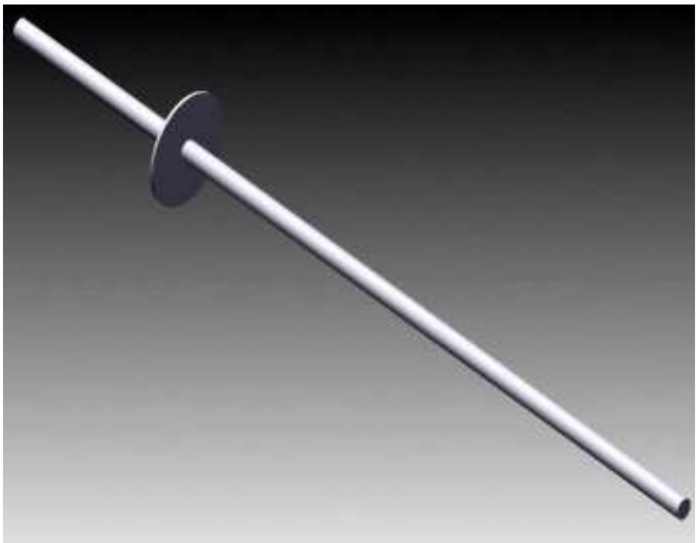

Figure 1. The inventor model of the shock tube

1. 1 DIMENSIONS:

Table No. 1 : Dimensions of model.

Total length	1400 mm
Driver length	350 mm
Driven length	1050 mm
Cylinder diameter	14 mm
Diaphragm thickness	2 mm

2. COMPARISON OF PROPERTIES OF HELIUM AND NITROGEN:

The driver section is the important section in a shock tube because the length of the driver, the pressure inside it and the gases filled inside it play a vital role in determining the efficient working of the shock tube. Also the location of the diaphragm, its rupturing pressure and the method of rupturing are the critical processes in a shock tube since they decide how a shock tube would work.

The properties of helium and nitrogen are studied and the suitable medium is chosen as working medium inside the shock tube to achieve supersonic Mach number.

3. SIMULATION OF SHOCKTUBE WITH SINGLE DIAPHRAGM:

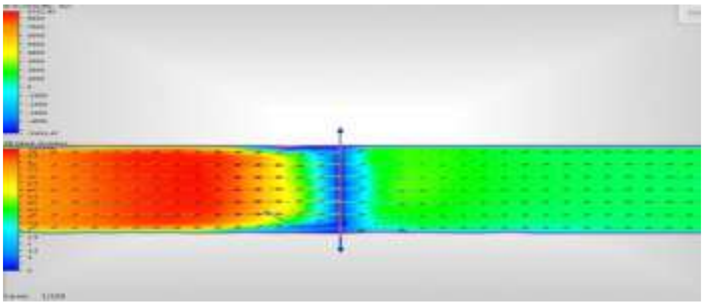

Figure.2: Simulation model

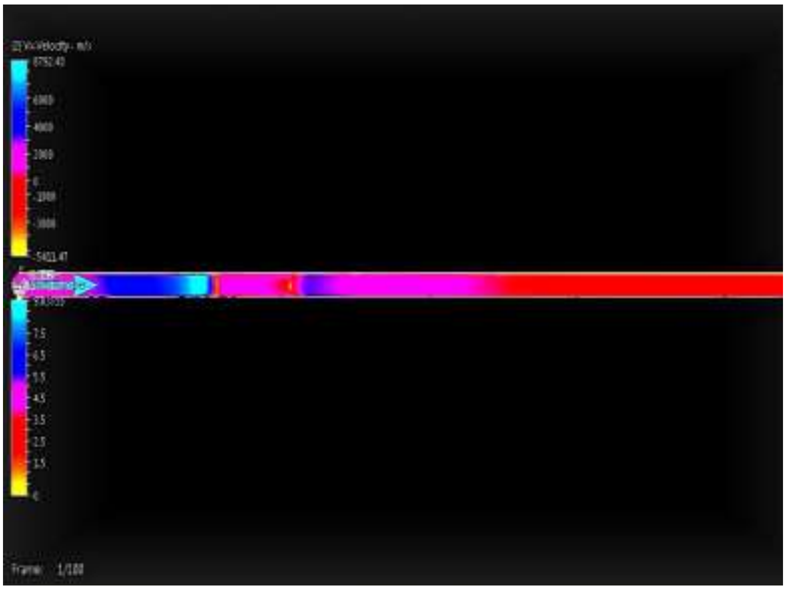

Figure No. 3: Simulation model.

First a shock tube is simulated with single diaphragm with above mentioned dimensions using simulation CFD2014 software. The study made is as follows:

Here a supersonic Mach number of 2.7 is achieved. The rupture of diaphragm is viewed clearly. A redistribution of flow happens when the reflected shock wave and expansion fan meets together. So in case any inclusion of diaphragm further, this region has to be considered for its location. The pressure at rupture reaches a peak value of 2.4 MPa whereas at the end of the shock tube, it reaches 1.4 Mpa. The pressure at the region where expansion fan and reflected shock wave meets holds a constant value of 1.6 MPa.

Mach number of 1.2 is achieved during rupture and the rupture occurs within three to five seconds of the pressure delivery inside driver section. The actual planar view of shock tube with single diaphragm is as follows:

Actual planar view of shock tube with single diaphragm:

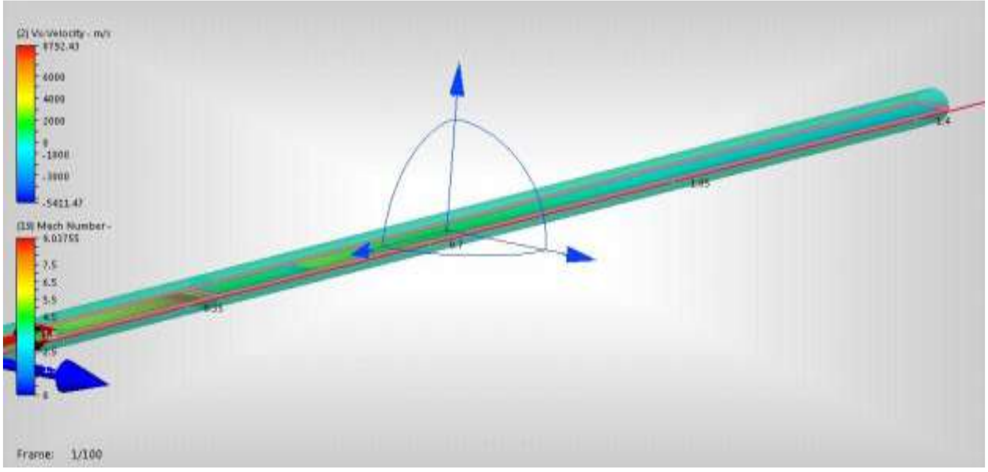

Figure No.4. Actual planar view of shock tube

3.1 Velocity variation :

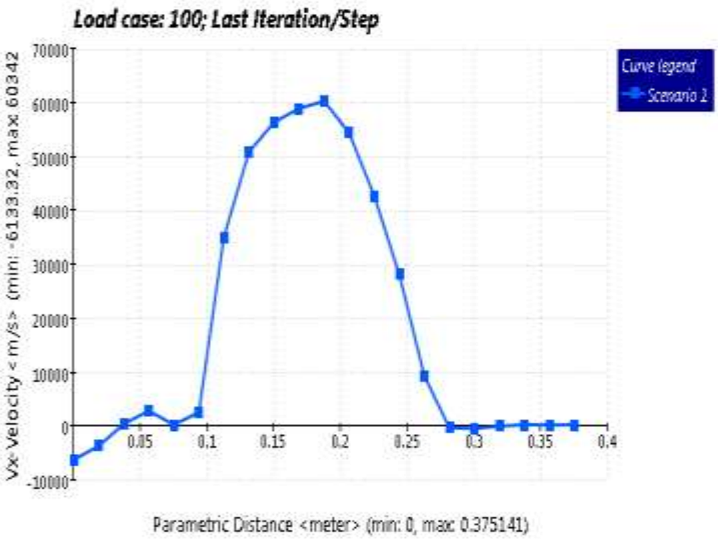

Figure No. 5 Velocity analysis.

3.2. Velocity and pressure variations along the rupture is plotted as follows:

Pressure variation :

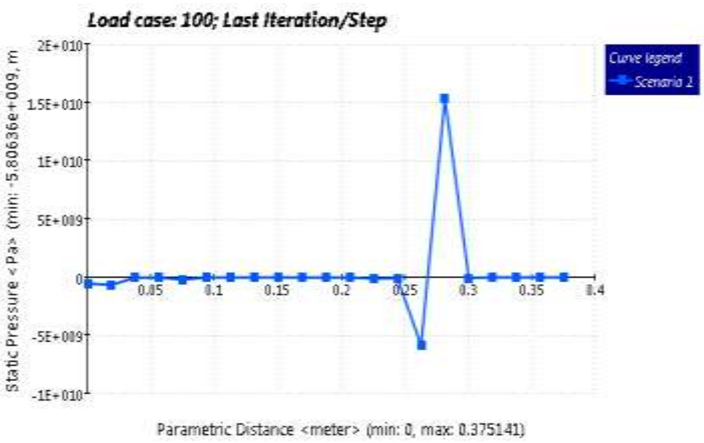

Figure. No.6. Pressure variation.

4. RESULT AND DISCUSSION

As a result we have achieved the supersonic Mach number through all the three processes. According to this Mach number, the velocity and time is calculated and plotted in graph. Shock tube is an investigating device used to investigate the shock wave phenomenon. There are two sections. “Driver and Driven section" separated by an Aluminium foil at different pressure .Thus the main aim of this project was to design and develop a simple, yet efficient shock tube. When the experiments were successful it was proved that the design was successful in all aerodynamics and structural aspects as far as simulation is concerned.

REFERENCES

1. Transient Measurements in a shock tube(Georgia Institute Of technology), 1998
2. Shock Tube Experiment, University of Michigan aerospace lab, November 2005.
3. Shock tube laboratory, Mechanical and Aerospace Engineering Laboratory, Department of Mechanical and Aerospace Engineering, Rutgers: The State University of New Jersey, 1996
4. Scott Guirlinger, jeffkobelak, John keuttler,revised by dr. Gary L. Catchen, Supersonic Flow : shock tube, May 6, 2002.
5. Dr. Dick Desautel (originally developed by Mr. Roger Gliege ,Shocktunnel experiments ,Revised by Dr. Nikos J. Mourtos, 1992.
6. C J Barton and D A Holder, Convergent Shock Tube: New Design, First Results, ,British Crown Copyright 2004 / MOD, Published with the permission of the controller of Her Britannic Majesty’s Stationery Office, 1997.
7. Al-Falahi Amir, Yusoff M. Z, N. H. Shuaib, Yusaf T, Flow Instability in Shock Tube Due to Shock Wave-Boundary Layer-Contact Surface Interactions, a Numerical Study,1994.
8. Zekai Hong, David F. Davidson, Ronald K. Hanson, Contact surface tailoring condition for shock tubes with different driver and driven section diameters,shcok waves,2009.
9. Ted A. Erikson, Armour research Foundation of Illinois Institute of Technology, Technologucenter, Chicago, 16, shock tube testing,1959.
10. J. Kasahara, University of Tsukba, Z.Liang, S.T.Bowne,J.E.Shepherd, California Institute of Technology, Impulse generation by an open Shock tube,Revised on February 28, 2008.
11. Wisconsin Shock tube calculator, available on the internet.
12. Author Lukaseiwich ,Experimental methods of Hypersonics, Gas Dynamic Series, Volume 3, 1953.

13. Dr.E.Rathakrishnan, IIT Kanpur GasDynamics, Tata-Wiley publishers, 2005.

14. John Bertin, Hypersonic Aerothermodynamics, AIAA education series,1994