INVESTIGATIONS ON SHOCK WAVE ATTENUATION BY DIFFERENT BARRIERS

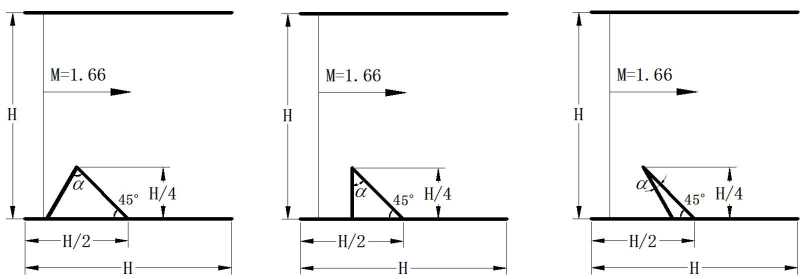
Sha Sha, Zhihua Chen[a)], Xiaohai Jiang & Junli Han
National Key laboratory of transient physics, Nanjing University of Sci. & Tec., Nanjing, 210094, China

Summary Shock waves passing three different triangle barriers are investigated numerically. Our numerical results clearly show that the interaction processes of the incident shock and the barriers, the corresponding pressure histories during the interaction have been obtained. It shows that a triangle with right-inclined windward side has the better effects on shock wave attenuation than the vertical and the left-inclined windward sides.

Shock waves or blast waves initiated by explosions would cause injuries to human and damage to structures and equipment. In recent decades, attenuation of shock waves has received increasingly attention due to its significant importance in many practical applications, such as prevention of explosion hazards and industrial safety. Barriers inside a tunnel with different sizes and shapes can cause the incident shock to be diffracted and reflected, generating flow fields with reflected and diffracted shocks, vortices, Mach steams and slip layers, some of them interact with each other making the flow field more complex, and the incident shock intensity can be reduced during this process.

Dosanjh[1] pioneered the investigation to observe and explain the chocking phenomenon in the supersonic flow immediately behind the obstacle. Britan et al.[2] investigated the attenuation of an incident shock with porous barriers of different geometries and porosities. Berger et al.[3] investigated the shock wave attenuation passing through different types of obstacles experimentally for both single-obstacle cases and multi-obstacle cases. In the present paper, three different types of triangle barriers were used to investigate their effects on the shock wave attenuation. The two-dimensional compressible LES Navier-Stokes equations by Faver filtering are used as the governing equations, which are solved using the finite volume method. A 5th-order WENO scheme is used to discretize the convective term and the two-order central difference scheme used for viscosity term.

The computational models and domains of the shock wave passing barriers with three different shapes inside a tunnel are shown in Fig.1. To investigate the effect of the slope of a triangle windward side (left side in Fig.1) on the shock wave attenuation, three triangles with the same height and slope of leeward (right) side are chosen. Their top corners α are taken as 75°, 45°, 15°, respectively. The Mach number of the inflow is 1.66. The computational boundaries of the top and bottom are chosen as reflecting boundaries; the right boundary is outflow condition. And the wall is taken as adiabatic. The high and low pressures on both sides of the incident shock are chosen to be 3 bar and 1 bar (P_0), respectively. Air was used as the working gas. The parameters are nondimensionalized using characteristic parameters (tube height H, and P_0 etc.).



(a) Case1 α =75° (b) Case2 α =45° (c) Case3 α =15°

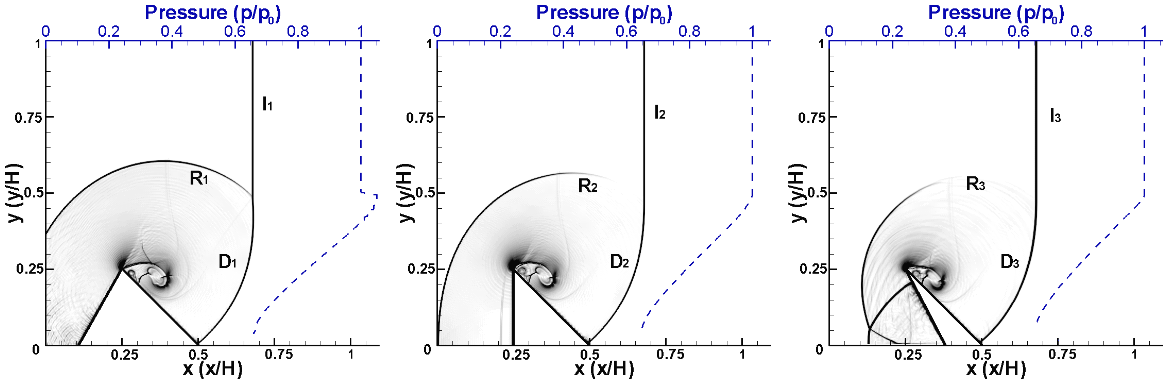
Fig.1 Computational model of this paper

NUMERICAL RESULTS AND DISCUSSIONS

Fig.2 presents the schlierens of the incident shock and the corresponding pressure distribution (dotted line) along the shock front of all three cases at t=0.046s. At this time, the incident shock waves have just passed the triangles, and the interaction processes of shock waves with three barriers are similar, the incident shock I_i (the subscript "i" denotes three different cases, i=1, 2,3) reflects on the left side of the barrier, the reflected shock R_i expands toward the front, then the bottom side of the incident shock is diffracted around the tip of the triangle barrier, an expansion fan is generated in pair with the diffracted shock D_i. However, the expansive wave is too weak to be shown in the Fig.2. The pressure distribution along the shock front of three cases is similar (dotted lines), and it is barely changed on the top side of the incident shock, still equals to the initial pressure. But below the interaction point of R_i and I_i, due to its diffraction and curve, the pressure decreases rapidly and become minimum near the bottom. However, there is a slight increase just down of the interaction point of R_1 and I_1, in Case1, which is different with other two cases. This is because that, the

a) Corresponding author. Email: chenzh@mail.njust.edu.cn

reflect shock is a compressive shock, and its interaction with the incident shock causes the pressure increase. However, In case 2 and 3, the downstream part of the reflected shock is very weak, so their interaction effects on the reflected shock R_i is very weak, thus, there is no increase in these two cases, and their highest pressure areas locate in front of the left side of the barrier.



(a) Case1 α =75° (b) Case2 α =45° (c) Case3 α =15°

Fig.2 The schlierens of the incident shock at *t*=0.046s and corresponding pressure distribution along the shock front

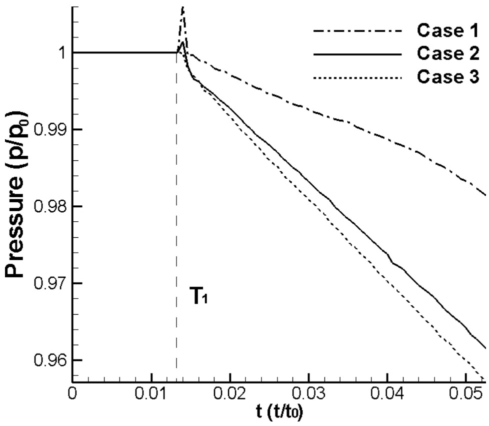


Fig.3 Mean pressure histories of the shock front.

The Mean pressure histories of the shock front are presented in Fig.3. At the first stage (before the interaction with the barriers), the pressure of the incident shock does not change. However, at time T_1 (the incident shock just reached the top corner of the barrier), the downstream of the reflected shock starts to merge with the incident shock. There is a pressure increase both in case 1 and case2, and the increase in case2 is less than case 1. While in case3, the mean pressure decreases directly. In the second stage, the mean pressure of shock front of all above three case starts to decrease, the attenuation order of three cases is case3>case2>case1, This is caused by the different strength of the downstream part of the reflected shocks, since the diffraction of shock along the right side of the triangle is the same.

CONCLUSIONS

In the present study, the interaction of an incident shock wave with three different triangle barriers is investigated numerically. The numerical results indicate that the direct reason of the incident shock attenuation is the effect of the interaction between the reflected waves and diffracted waves. After the incident shock passed the tip of the barriers, the bottom side of the incident shock starts to diffract and become curve, results to the pressure decrease accordingly. At the same time, the downstream part of the reflected shock merges with the incident shock, makes its pressure increase. Our investigations show that, when the slope of the leeward side and the height of the barriers are the same, the windward side of the barrier with right-inclination (case 3) has better pressure attenuation effect than that with either vertical (case 2) or the left-inclined sides (case 1).

References

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