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Numerical Simulation over a 2D Compression Ramp

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Abstract: To understand the aerodynamic interference effect of compression ramp on a launch vehicle at transonic and supersonic Mach numbers. Compression ramp are important factor of launch vehicle, and at the same time, they encounter local flow separation shock boundary layer interaction, flow unsteady and may leads to structural vibration failure. In this thesis, the flow field over various 2D compression ramp at high subsonic, transonic, are to be carried out to understand the flow field.

Key words: Compression ramp・Protrusion・Strap-on boosters・Semi-infinitedimensionless interactions

INTRODUCTION

To understand the aerodynamic interference effect of compression ramp on a launch vehicle at transonic Mach numbers. Compression ramp are important component of launch vehicle, and at the same time, they encounter local flow separation, shock boundary layer interaction, flow unsteady and may leads to structural vibration failure. In this paper, the flow field over various compression ramp at high subsonic, transonic are to be carrying out to understand the flow field around the ramp.

Therefore, in this paper, the compression ramp for the 2D are studied at high subsonic and transonic Mach numbers to understand the local flow field nature at the critical Mach number regimes faced by a launch vehicle. As stated before, the compression ramp can carry isolated pocket of separated flow with high sound pressure levels depending on the location, shapes, and sizes. The compression ramp on the rocket surfaces increases unsteady pressure fluctuations and leads to structure vibrations.

In this paper, numerical simulation of 2D Compression corner and their Pair effect of various ramp angles using Reynolds Average Navier Stokes (RANS) solver at transonic Mach number, turbulence model of two equation Realizable k-□ turbulence model. Forces, moment, co–efficient pressure, surface pressure distribution, flow field on the surface will be analysed. The compression ramp at various angles will be studied systematically by increasing the compression angle of protrusion with Mach number. This study will give an idea of the flow field and forces of various ramps and this study will be useful in shaping the location of the points of the compression ramp angle on the launch vehicle [1].

Configuration Study: The compression ramp configuration comprises of a blunt nose, sharp edge, semi cone, compression corner, Expansion corner, compression corner followed by expansion corner, etc. Typical view of the compression ramp of 25 deg ramp is shown in Figure 2.1

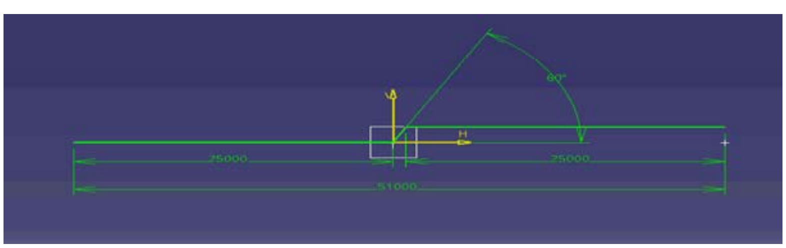

Fig. 2.1: Ramp angle of 60deg

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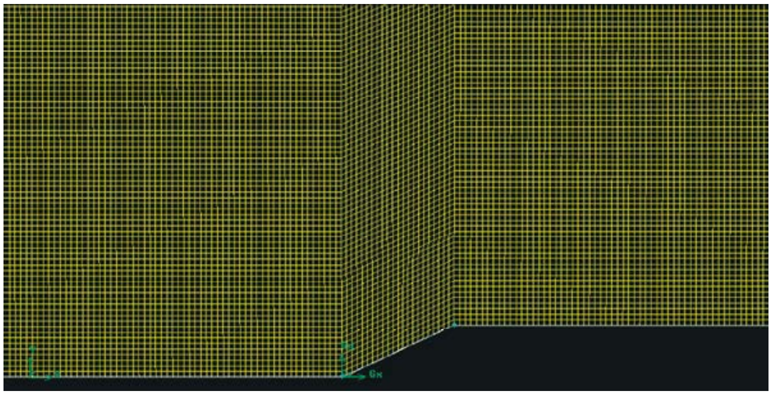


Fig. 3.1: Meshed View of Compression Ramp

The geometrical details of compression ramp are given in Fig 2.1. The compression ramp are mounted on a Flat surface are modelled. To study the wall proximity and interference effect's.

Meshing: The entire ramp was meshed with Quadrilateral mesh with an interval of 15. Quadrilateral meshing was done on the region over the Compression Ramp. Quadrilateral meshing was chosen because it was finer over the regions when compared to the tetrahedral mesh [2, 3].

RESULTS AND DISCUSSION

CFD simulations have been carried out for the various ramps configurations using *FLUENT RANS* solver with realizable *k-å* turbulence model at transonic Mach numbers. Simulations have been carried out for 2D compression ramps for transonic Mach numbers. The results have been analyzed after the convergence of the residuals and presented in this chapter [4].

2D Compression Corner

Convergence Plot: The *CFD* results were analyzed after the solution convergence for all the cases. The convergence plots of the residuals for few cases are shown in Fig. 4.1. The convergence plots indicate that the solutions are converged.

Surface Pressure Distribution over Compression Corner at Transonic Mach numbers (M=0.6-1.2): Figures 4.2 a to e show the ratio of local pressure to the free stream static pressure plots along the compression ramp (CR) (both ahead and behind) for ramp angles ranging from 8 to 60 degree. The compression ramp starts at X/H=0.

The general observations are (i) there is an upstream influence ahead of CR in terms of location and pressure rise. Maximum upstream influence is seen for Mach number 1.05 followed by 1.1 and 1.2. But, the maximum pressure rise is more for 1.2 followed by 1.1 and 1.05. For Mach numbers 0.95 to 0.6 the upstream influence and pressure rise gradually reduces and the values are less than at higher transonic Mach numbers (1.05 to 1.2).There is also downstream influence for all the CR and the influence on the downstream is highest for Mach number 0.95 [5].

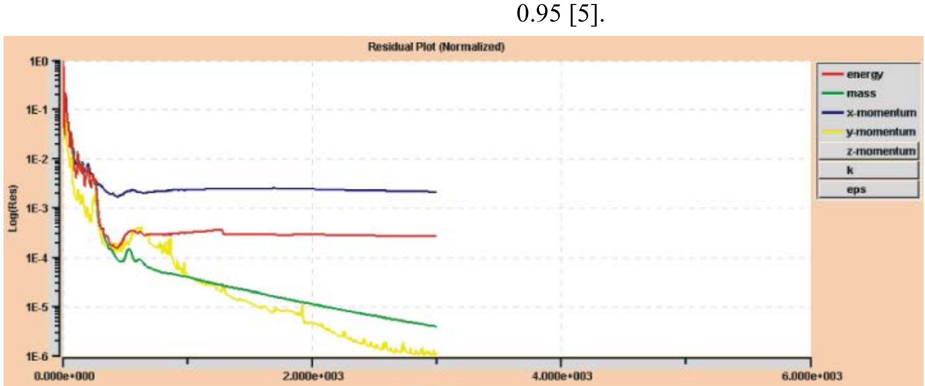
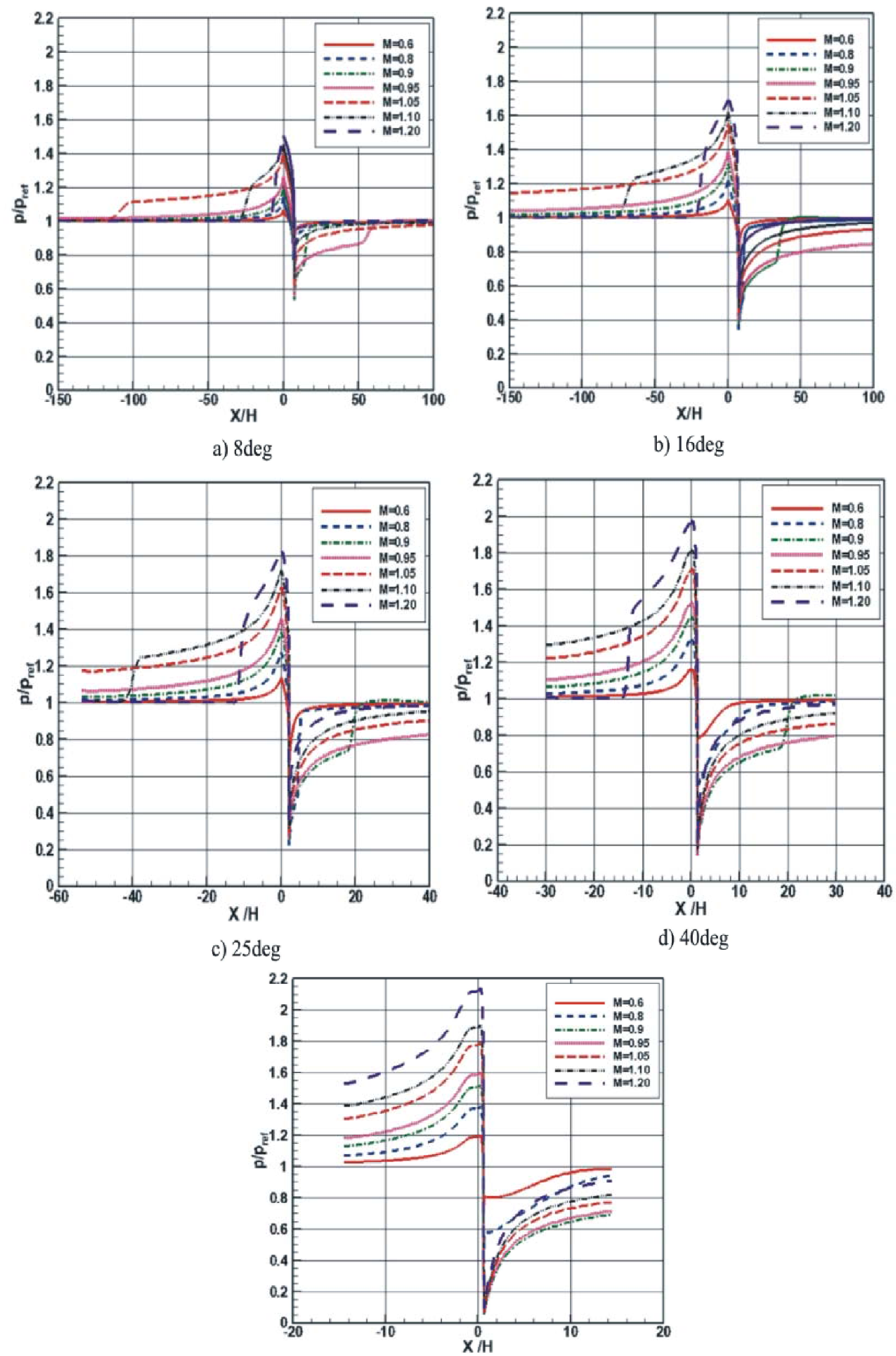


Fig. 4.1: 25deg Compression Corner at M=0.8



a) 8deg

b) 16deg

c) 25deg

d) 40deg

e) 60deg

Fig. 4.2: Pressure Distributions over Various Compression Corner at Transonic Mach number

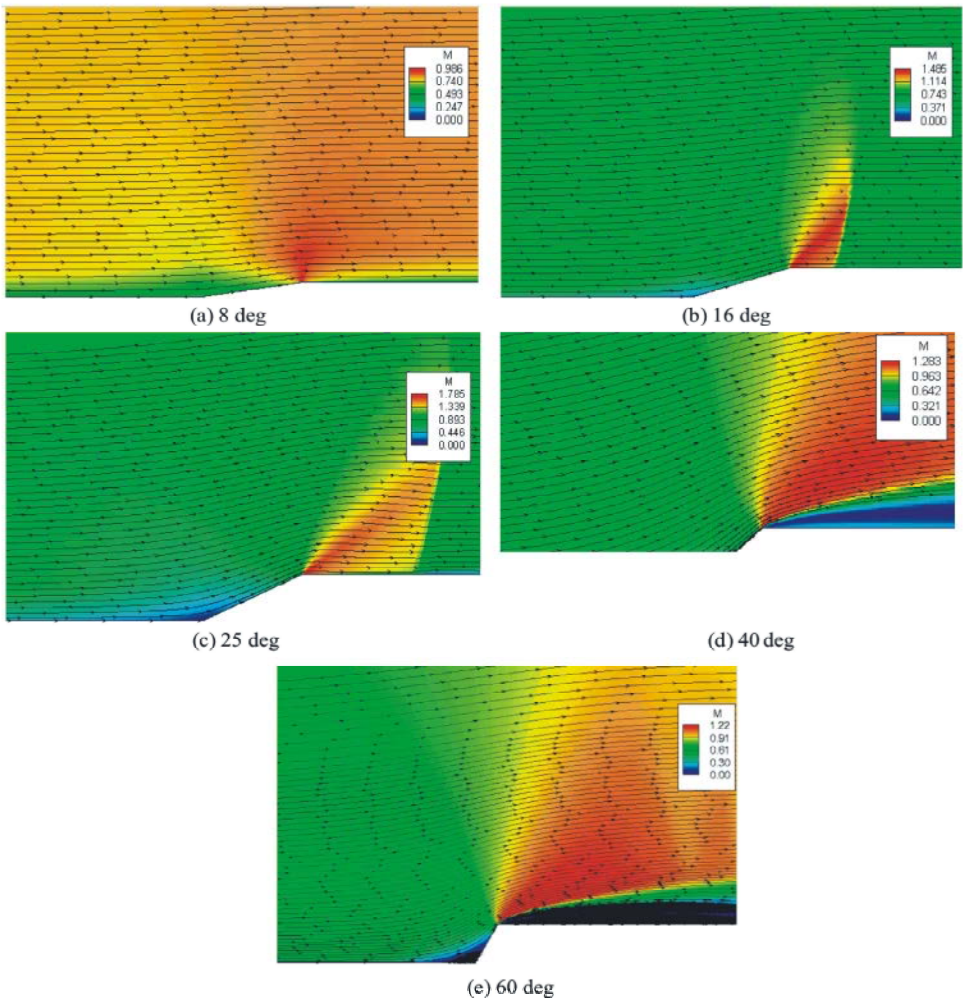


Fig. 4.3: Mach Palette with Streamlines for Various Compression Corner Angles at M=0.8

Mach Distribution and Streamlines for Compression Corner at M=0.8: Figures 4.3 a to e show Mach palette with streamlines for CR angles 8 to 60 degrees for Mach number 0.8 only. The salient features are (i) flow separation is observed in the compression corner from 25 to 60 degree and (ii) transonic shock is formed on the compression corners for ramp angles 16 to 40 degree.

CONCLUSION

Detailed turbulent CFD simulations for various compression ramps angle (8-90deg) for Mach numbers for transonic have been simulated using FLUENT solver and using multi-block structured grids. The turbulence closure is through realizable k-epsilon model. Compression ramps at transonic regime indicate that upstream influence and it highest for Mach number 1.05. Flow separation is observed in transonic Mach number at CR angle at greater than 25 degree. Peak pressure in transonic Mach number is highest at M=1.2; the location of Peak pressure at transonic Mach number is near ER corner beginning up to 25deg. [6]

Upstream influence is not felt as in transonic cases, effect of ramp is above. The drop in pressure rise increases in ramp angle but not as in 45 degree. The reattachment distance in general for all ER angles is maximum at M=0.95. Effects of turbulence model have been finalized after more studies.

Flow over a 2D protrusion exhibits rich flow features topologies such as separation and reattachment lines and junction vortices, wake vortices, and horseshoe vortices. With this study as comprehensive data base related to compression and expansion corner at subsonic to supersonic Mach number has been generated provably for the first time.

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