Numerical Simulation of Conical and Spherical Shock Interaction: Hysteresis Investigations

J.D. Parisse, J. Giordano, and D.E. Zeitoun

1 Introduction

In the literature, we can find lot of analytical or numerical studies about shock wave interaction. However, in the major part of this work, the two dimensional assumption is used [1]-[4]. Although we know that in real flight conditions the interaction is at least axisymmetrical or three dimensional, we have also chosen to deal with axisymmetrical interaction. Indeed, the comprehension of the axisymmetrical phenomena is needed before taken into account a more realistic three dimensional case. Thus, in the present paper, we have numerically studied the interaction between a shock generated by a conical ring and a shock generated by a sphere (respectively called the conical and spherical shock). A schematic description of the study case is given by the figure 1. The inlet conditions are: $M = 4.96$, $T = 77\ K$ and $P = 1700\ Pa$. The preliminary results on this topic have been presented in [5] and [6].

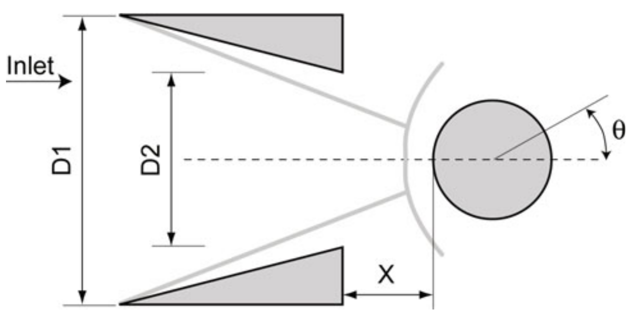

Fig. 1 Schematic description

In a first section of this paper, the numerical code used for the simulations will be presented. Then, several geometry cases will be studied and for the most interesting

J.D. Parisse · J. Giordano · D.E. Zeitoun
Aix Marseille Université, IUSTI/UMR CNRS 6595, Technopôle de Château Gombert, 5 rue Enrico Fermi, 13013 Marseille, France.

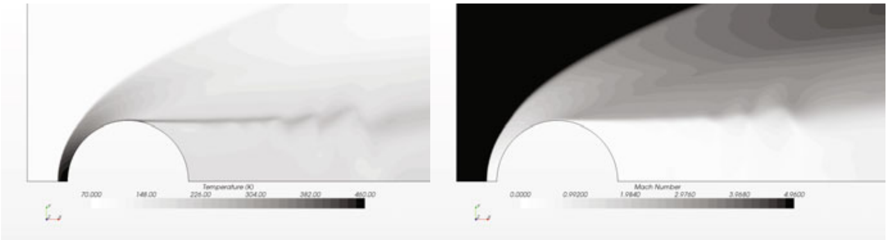

Fig. 2 Preliminary results for a sphere alone

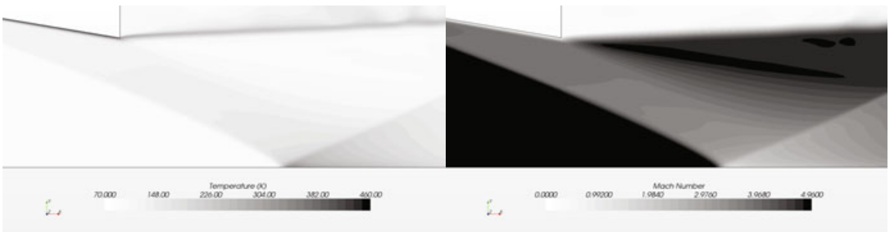

Fig. 3 Preliminary results for a the conical ring alone alone

one hysteresis phenomena will be investigated. Eventually, we will conclude and give some perspectives of this work.

2 Numerical Method

To solve the laminar Navier-Stokes equations in the axisymetric case, the commercial code STARCCM+, from CD-ADAPCO is used. STARCCM+ has ben chosen for his versatility, his accuracy and to be used in 3D in a future work. These capabilities are demonstrated in Figures 2 and 3 which show that the code is able to capture strong discontinuity as sock waves. Moreover, this code is able to describe fine structures like boundary layers, slipping lines and after body wake.Besides, this code is efficient to deal with moving mesh and, as consequence here, allows us to characterize hysteresis phenomena.

For the calculations the mesh used is a seven block one of 100×100 of Q_4 cells, the minimum cell size is 10^{-5} m. As a first step, we have chosen to used the the steady solver with AUFS Riemann solver, the CFL coefficient use for the implicit solver is equal to 3.0. All the solid part of the calculation domain are supposed to be adiabatic wall.

3 Results

Taking into account our previous work [5] and [6] the sphere diameter has been set to 15 mm and the X distance range from 12.5 mm to 17.5 mm. To investigate hysteresis phenomena calculation have been for X varying from 12.5 *mm* to 17.5 *mm* and back to 12.5 *mm*.

Figure 4 and 5 respectively show the Mach number and Temperature iso-values at different positions for the forward and backward motion. As it has already been demonstrated, [5] and [6], this two figures show that the shock wave

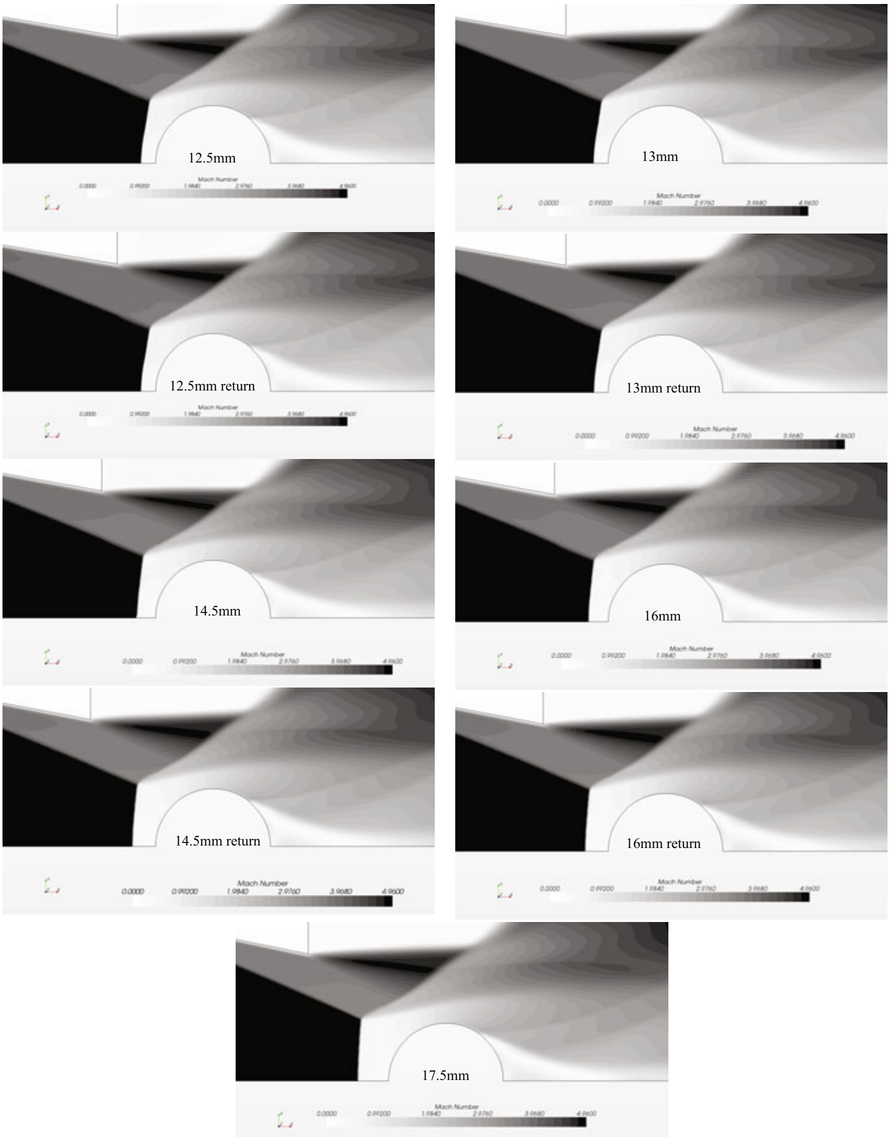

Fig. 4 Mach number isovalue for different positions for the forward and backward motion

Fig. 5 Temperature isovalue for different positions for the forward and backward motion

becomes straighter as the increasing of X. This shock wave modification leads to an increasing of the average temperature over the sphere surface without any notable modification of the maximum temperature. For this sphere diameter the shock interaction looks like a Mach inverse one: the slipping line diverges from the symmetry axis.

With the taken into account of the sphere motion, we are able to consider hysteresis phenomena. Thus, we have found that the shape and the position of the shock wave are slightly modified. We can seen that the shock is straighter on the way back and that the stand off distance is greater when the sphere is on its return path. The shock is also more stable on the way back. For the temperature, there is a decreasing in the second case but the variations are quite small. The slipping line is not really affected by this hysteresis, this logical as its location is due to the sphere size.

So, there is an hysteresis for that kind of shock wave interaction. It is important to notice that the differences between the two cases are much more important for the biggest value of the X distance.

4 Conclusion and Perspectives

This works has shown the capability of STARCCM+ to deal with shock wave interaction for quite high Mach number value. Moreover, it has mainly demonstrated that there is hysteresis phenomena for this conical-spherical shock wave interaction. Nevertheless, we have to get a closer look to stability problem. To deal with this problem some explicit unsteady calculations will be done and some investigation about the turbulence will be carried out using the Spalart-Allamaras model [7] with the Catris and Aupoix's correction [8] to take into account compressibility effects.

A more detailed description of the heat exchange between the fluid and the solid boundary of the fluid domain must be done. The adiabatic wall assumption is to rough to have a fine understanding of these interactions. To do so, will use STAR-CCM+ capabilities to solve heat transfer equation in solid and to couple it with the fluid.

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