International Journal of Engineering Research and Development
***e**-ISSN: 2278-067X, **p**-ISSN: 2278-800X, www.ijerd.com*
Volume 3, Issue 12 (September 2012), PP. 39-42

Computing Hypersonic Aerodynamic Coefficients

Ankit Mittal[1], Kanav Setia[2]
[1,2]*Indian Space Research Organization.*

Abstract— Finding Aerodynamic coefficients like coefficient of drag and moment about center of gravity on complex configurations is must for high speed scenarios like that of reentry. In modern era CFD is most extensively used to find out the coefficients, but this process is complex and time consuming. In this paper a code, viz. AeroCoef, is presented which is based on Newtonian theory, it gives reasonably good results of Hypersonic Aerodynamic Coefficients far more quickly and easily than a CFD simulation. The result section compares CFD result of Aerodynamic Coefficients on different bodies to the result obtained by AeroCoef, the results indicates that the code predicts the coefficient in no time with sufficient accuracy and is very useful to compare different configurations in very less time.

Keywords— Hypersonic flow, reentry bodies, Aerodynamic coefficients, Newtonian method, CFD.

I. INTRODUCTION

High speed flows (mainly hypersonic flows) are particularly the case in reentry scenarios, where drag acting on the vehicle and its moment about center of gravity CG is particularly important. A reentry body has to be slowed down from speeds as high as 7 km/s to around 20-30 m/s (in case of Lunar landing) by the action of aero-braking [1] i,e. the drag acting on the vehicle has to slow it down to very low speeds, hence, reentry bodies require high drag coefficient so as to slow down the module during the reentry phase otherwise the body will hit the ground at very high speeds and chutes will be of no use (because of very high dynamic pressure at high speeds), also the moment about CG is very important considering the stability of the vehicle, if the vehicle is not stable it will oscillate violently which will cause problem during the entry phase. Hence finding Aerodynamic coefficients on complex configurations accurately is must for a reentry and other high speed scenarios. In modern era CFD is most extensively used to find out the coefficients, this approach is time consuming and the accuracy depends on the boundary conditions, size of the domain, scheme used etc. The present approach predicts the hypersonic coefficients based on Newtonian theory by using the configuration of 3d axi-symmetric body.

II. THEORY

The present code is based on the Newtonian theory, laid by Sir Isaac Newton before the shock relations were developed. After the shock relations were developed it was proved that Newtonian method does not hold true for low supersonic Mach numbers, but is good enough for high supersonic or hypersonic Mach numbers. The small dependence of Aerodynamic coefficients on Reynolds number also makes the theory more suitable.

Newton assumed that the flow consist of large number of fluid particles, which collide a surface and moves tangent to the surface. In this procedure the momentum of fluid particles normal to the wall become zero, while the moment tangent to wall remains conserved [2]. The shock relation proves that the momentum parallel to shock direction remains conserved not the momentum tangent to wall. At hypersonic speeds the shock angle is very small and it nearly tends to the flow turning angle, and hence the Newtonian hypothesis applies to and only applies to high speed hypersonic flows. More information on Newtonian method can be found in [2].

$$Cp = 2\sin^2\theta$$

Where θ is the angle between the tangent (at the point on the body) and the flow velocity direction.

III. METHODOLOGY

All To verify the code, firstly the actual hypersonic coefficient of drag on known shapes such as sphere, 70 deg aeroshell (Viking mission), Apollo configuration, is compared to the result given by AeroCoef. Then a CFD simulation is ran on a blunt reentry configuration and the Cd from that result is compared to the Cd from our code. The conditions on which the CFD simulations were run are given below.

Free stream conditions: M=23.4, T=224K, P=11 pa.

Boundary conditions:
Inlet: Supersonic Inlet (conditions equal to free stream conditions).
Outlet: Supersonic Outflow.
Wall: No slip isothermal wall at (300 K)
Far_field: Farfield condition**(**conditions similar to free stream conditions)

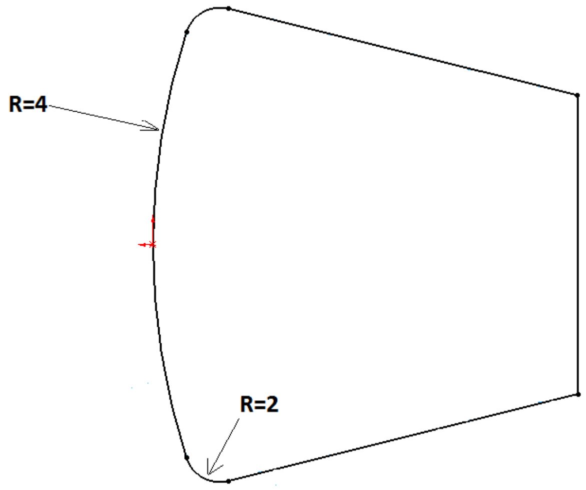

Figure 1: Tested Body

IV. RESULTS

As discussed in methodology, the result obtained by AeroCoef was compared to the CFD results obtained on the same body. The diameter of the tested body is 2.8 m. The simulation is conducted at angle of attack 0 deg, and free stream Mach number of 23 with perfect gas assumption. Figure 2 shows the Mach contours, while figure 3 shows pressure contours.

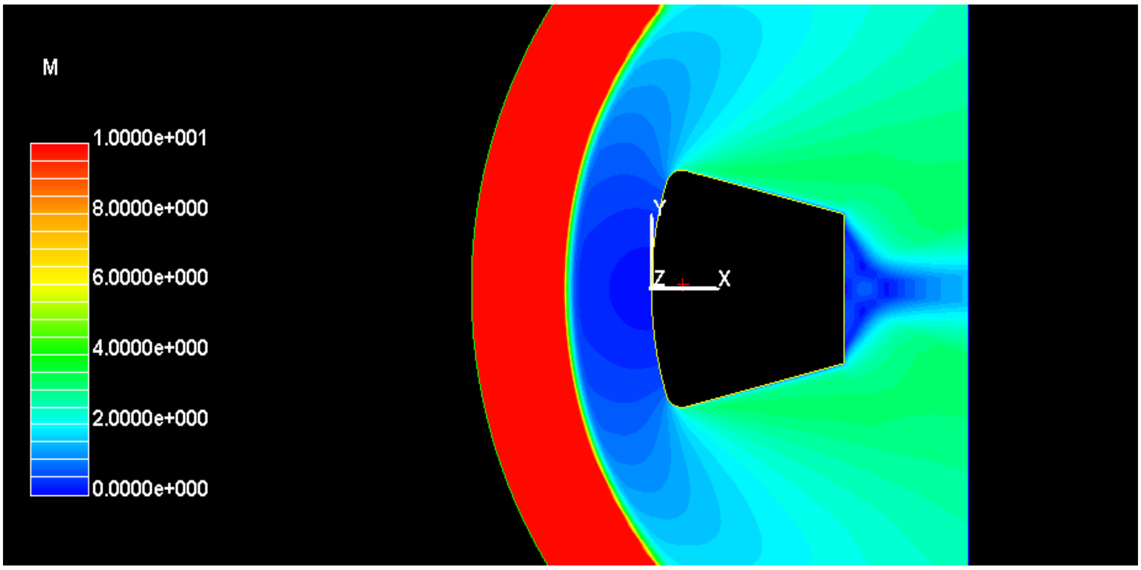

Figure 2: Mach contours on the tested body

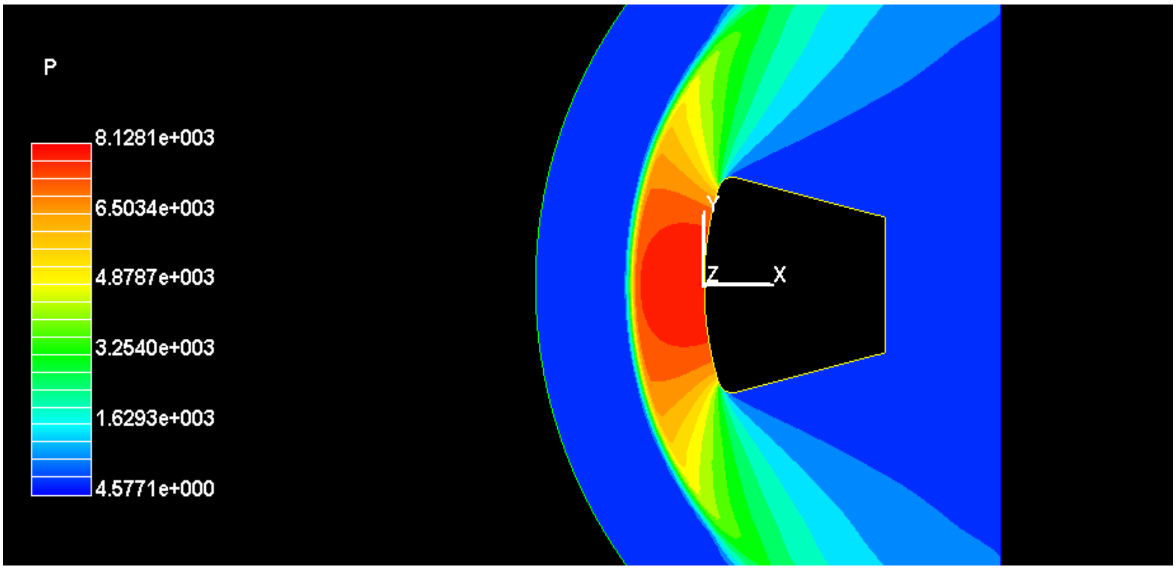

Figure 3: Pressure Comparison

Table I: Results comparison

Body	**Cd (CFD/Experimental)**	**Cd (AeroCoef)**
Tested body	1.61	1.64
70 deg aeroshell (Viking mission)	1.68	1.6527 (Ref 2)
Apollo crew module	1.57	1.598
Sphere	1	0.9718

Apollo configuration at different angles of attack, and the AeroCoef results are compared to actual Apollo configuration results [3]. Figure 4(a) shows the Cm about CG on Apollo configuration with CG at coordinates [825.72, -228.056, 0] (in mm); both the results match very well and shows that the trim angle of attack for Apollo configuration is nearly -31 deg (for the assumed CG). Figure 4(b) shows L/D with angle of attack for the two approaches, again the data matches very well with the maximum difference of 5% and trim L/D is 0.46.

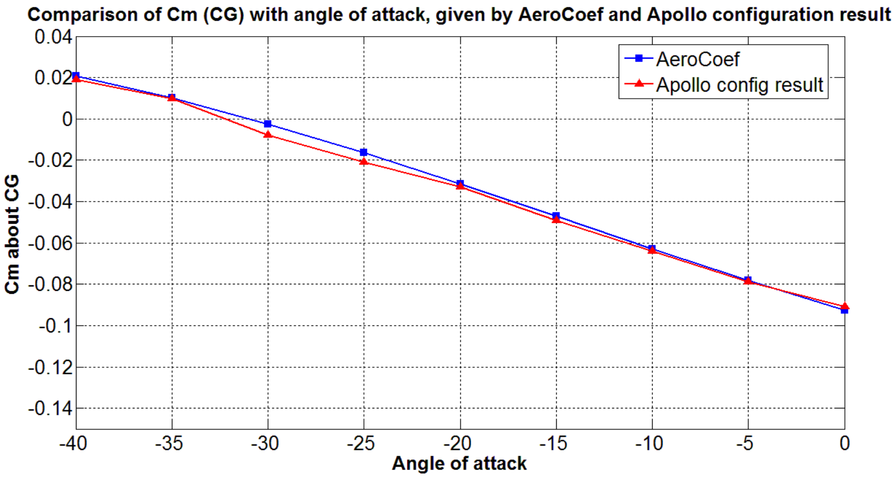

Figure 3: Cm comparison

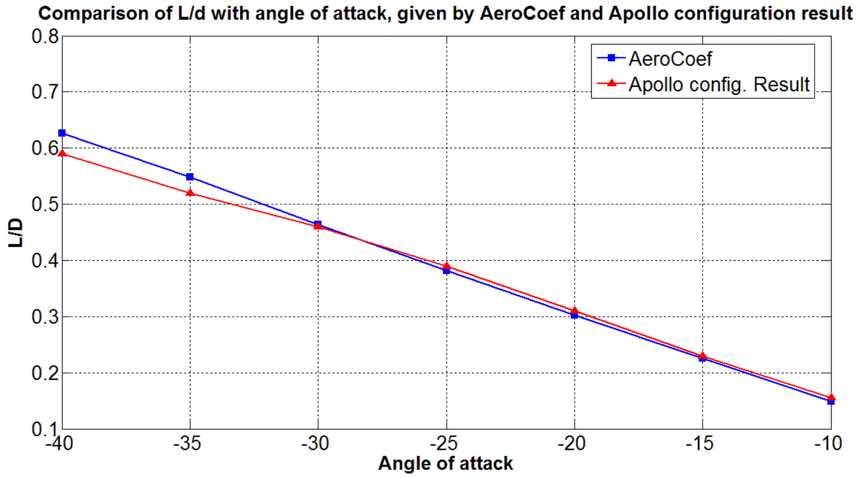

Figure 4(b): L/D comparison

V. CONCLUSION

The above code presents a very easy way and much less time consuming way to compare the Aerodynamic coefficients on the complex reentry bodies with reasonable accuracies. The code is validated for many cases and is proved that at hypersonic Mach numbers AeroCoef works quickly and reasonably well. Cm about center of gravity, L/D and hence the stability of the vehicle can be checked to sufficient accuracy and quickly by the above presented code.

REFERENCE

[1]. Braun, R.D. and Manning, R.M. *Mars Exploration Entry, descent and Landing Challenge*, IEEAC #0076, December9, 2005.

[2]. Anderson, J.D.: *Hypersonic and High Temperature Gas Dynamics*, second edition AIAA.

[3]. Kamal M. Shweyk, B.F. Tamrat, and Abdi Khodadoust. *Parametric Shape Study of Capsule-Type Vehicles uring Atmospheric Re-entry*, AIAA Atmospheric Flight Mechanics Conference and Exhibit 21 - 24 August 2006, AIAA 2006-6140.

[4]. Kenneth D. Korkan and Gerald M. Hanley. *Apollo command module aerothermodynamic characteristics at hyperbolic Earth entry velocities*, JOURNAL OF SPACECRAFT AND ROCKETS 1966, 0022-4650 vol.3 no.8 (1274-1281).