EFFECT OF STRINGER ON OVERALL AERODYNAMIC COEFFICIENT OF A TYPICAL LAUNCH VEHICLE

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ABSTRACT

Surface stiffener known as stringers is one of the important structural aspects on the external surface of the launch vehicles. It provides the required structural stiffness to the vehicle stages and it also likely to influence the local aerodynamics. In this paper, the effect of stringers on the multi-body launch vehicle aerodynamics is studied at M=0.5 and 1.2 through numerical simulations. The stringers seem to decrease the compression and suction pressures at the end of inter-stages. It also increases the overall normal force coefficient of the vehicle by 4 to 5% and moves the centre of pressure location forward.

Keywords: launch vehicle, CFD, validation, aerodynamic coefficients, angle of attack, Mach number

INTRODUCTION

Aerodynamic characterisation of a launch vehicle is important for structural design and also for the control and guidance designs. To meet the functional requirements protrusion like retro rockets, ullage rockets, propellant feed lines, destruction systems, stringers are provided. Their effect on the overall aerodynamic characteristics are also studied in general through numerical methods and wind tunnel testing. Reference 1 reports the effect of skin stringers on aerodynamics of Epsilon launch vehicle at M=1.5 through both numerical methods and experimental studies. Some of the launch vehicle design have stringers as stiffeners on the external surface of the inter-stages of the vehicle. The stringers have corrugated or hat type external surface. The effect of aerodynamic characterises of the stringers are critically important for the local structural design and also on the overall aerodynamic coefficients.

CONFIGURATION

Figure 1 shows the launch vehicle configuration with stringers on the inter-stages considered for the present numerical simulations. The interstage structure of the launch vehicle is constructed as a cylindrical shell with external hat type stringers. Stringers are located at three segments and total length of the stringers is 4.8D. The projection height of the stringer is 0.01D. Total length of the vehicle is 15.87D, where, D is the reference diameter of the launch vehicle.

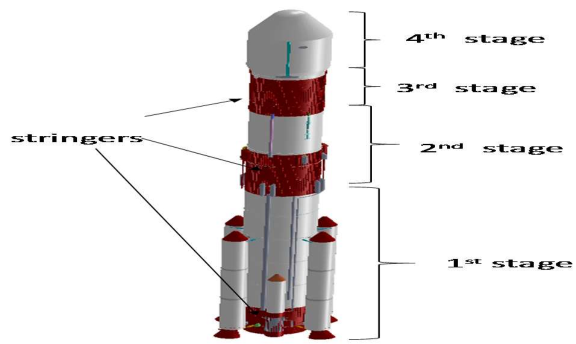

FIGURE 1: VIEW OF THE TYPICAL LAUNCH VEHICLE

DETAILS OF CFD SOLVER, GRID AND SIMULATION CONDITIONS

Computational grid around the body was generated using commercial software *Pointwise* [2]. Quad dominated surface mesh along with tetrahedral volume grids were generated around the body. The first cell non-dimensional height 'y^+' for without stringer case is 1 where solve to wall boundary condition is used and for with stringers the y^+ is 30 where solve to wall boundary condition is used. The solve to wall is being simulated for the stringer cases presently and the results will be updated. Fig. 2 shows the farfield domain size and the surface triangles along with boundary conditions. The spherical control volume diameter is 170D. Figure 3 shows the zoomed view of surface grid over stringer and no stringer cases. Zoomed view of the grid in symmetry plane in the vicinity of stringer is shown in Fig. 4. There are approximately 30 million cells generated in the volume which consists of prism layers near the wall with a growth ratio of 1.2. Flow field simulations were performed using commercial CFD solver 'CFD++' Ref. 3. The turbulence is modelled using realizable k-ε model.

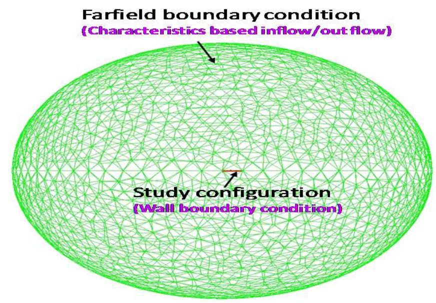

FIGURE 2: FARFIELD DOMAIN AND BOUNDARY CONDITIONS

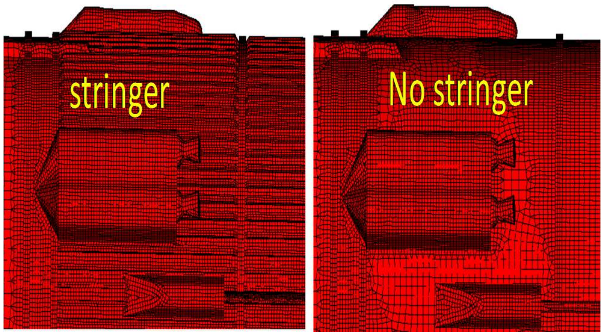

FIGURE 3: SURFACE MESH WITH AND WITHOUT STRINGERS

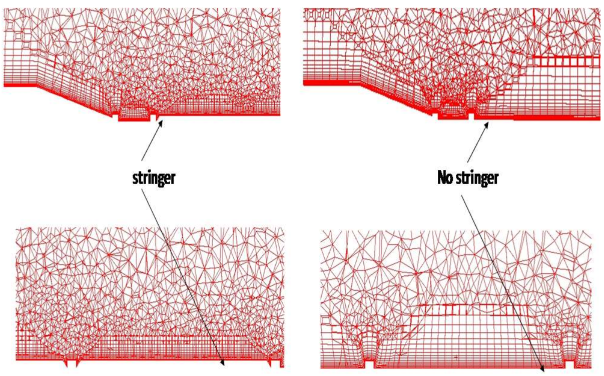

FIGURE 4: PRISM LAYER IN THE VICINITY OF THE STRINGER AND WITHOUT STRINGER

RESULTS AND DISCUSSION

CFD simulations were carried out using CFD++ solver at M=0.5 and M=1.2 with angle of attack of 4 deg. The normalized residuals of mass, momentum, energy, turbulent kinetic energy and turbulent dissipation are shown in Fig. 5 for M=1.2 for with stringer and without stringers. The residual fall is better for with stringer case due to the nature of wall function approach. Figure 6 shows the convergence of normal force coefficient at M=0.5 for stringer and without stringer cases. With stringer normal force coefficient is higher compared to no stringer case. Figure 7 shows the surface Cp palette at M=0.5. A closer look reveals, slightly high pressure on the hat section sides. The stringers also reduce compression and suction pressures at the inter-stage ends in comparison with no stringers case. Overall, through the surface palette information, the effect of stringers looks subtle, nevertheless, their effect is felt on the overall aerodynamic coefficients. Table 1 gives the overall normal force coefficients and centre of pressure locations for with and without stringers configurations. The configuration with stringers increases the normal force coefficient by 4 to 5% for the Mach number range studied and the effect on the centre of pressure moves forward by a maximum of 0.2D. The effect is pronounced at higher Mach number of 1.2. The increase in the normal force coefficient can be indirectly attributed to the increase in the surface area due to the stringer shape. Therefore, accounting the effect through increase in the diameter, which accounts only the stringer height may not be a correct approach. Nevertheless, the effect of increased diameter also has to be studied in future to bring out its effect.

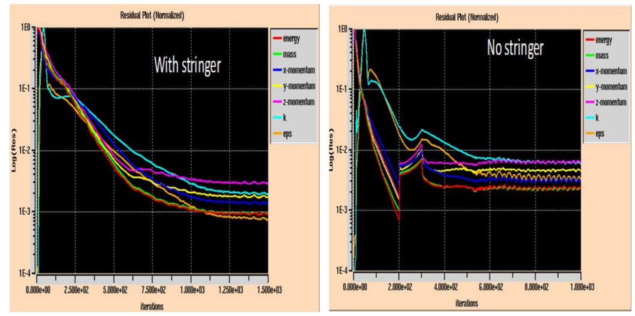

FIGURE 5: CONVERGENCE HISTORY FOR EQUATION K-E TURBULENCE MODEL AT M=1.2

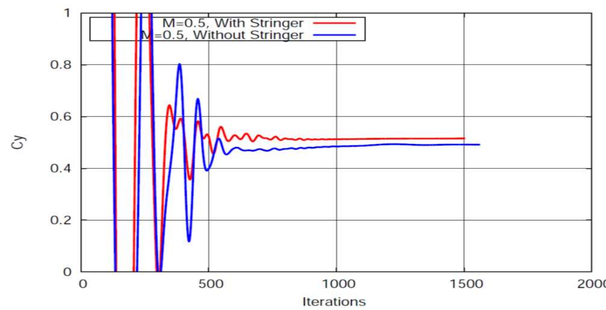

FIGURE 6: CONVERGENCE OF NORMAL FORCE COEFFICIENT AT M=0.5

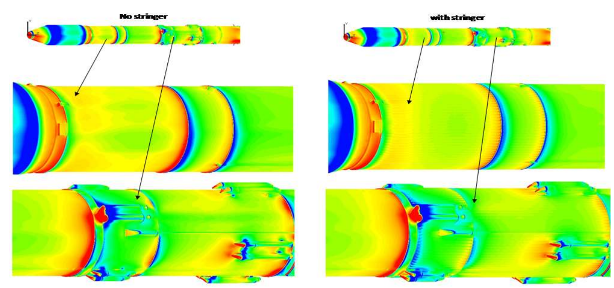

FIGURE 7: CP PALETTE COMPARISON AT M=0.5 – WITH AND WITHOUT STRINGER

CONCLUSION

The stringers are unavoidable features of a typical launch vehicle and their effect on the aerodynamics is studied at M=0.5 and 1.2 using CFD++ solver with k-e realizable turbulence models over an unstructured grid with prism layers. The flow field palette indicates that the stringers reduce the compression and suction pressures on the inter-stage edges. The flat surface of the hat section also faces slightly higher pressure.Overall, the stinger increases the normal force coefficient of the vehicle by 4 to 5% and the centre of pressure moves forward by a maximum of 0.2D. The increase in the normal force coefficient and centre pressure is higher at M=1.2.

REFERENCES

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[2] Pointwise Ver. 18.1.

[3] CFD++ User's manual 8.1.