Depressed Aeroshell Forebody Geometries for the Generation of Lift

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Introduction

Several configurations of sectional deflections upon the forward facing geometry of a 70° cone-angle aeroshell were evaluated for their aerodynamic coefficients using modified Newtonian flow theory (γ = 1.4). Deflections (δ) are defined as the maximum change in cone-angle (±δ°) across the azimuthal polar coordinate φ. Forward deflections of 5, 10, and 15 degrees were separately evaluated upon both upper and lower surfaces; deflected areas subtended a φ range of 120°. Force and static stability aerodynamic coefficients were extracted from each geometry, plotted and evaluated against the 70° sphere-cone solution. All forward deflections increased the lift-drag ratio. Deflections upon the upper surface beget larger contributions to the lift-drag ratio while deflections upon the lower surface increased static stability.

Figure 1: Modeled Geometry

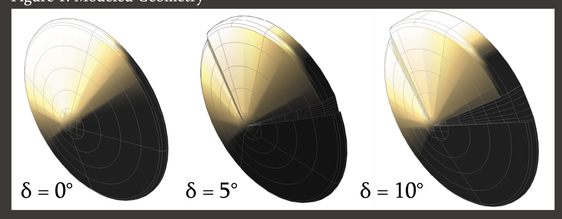
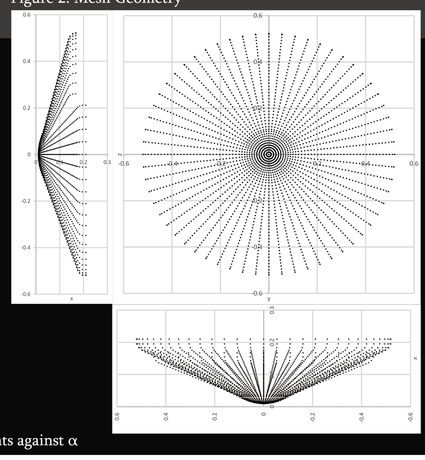


Figure 2: Mesh Geometry



Method

A program determining local pressure and aerodynamic coefficients in accordance to modified Newtonian flow theory was constructed in Excel. The initial 70° cone-angle geometry was parameterized and represented as a 2580-element mesh, codified to allow swift editing capabilities, and integrated within the modified Newtonian program. Illustrated in Figure 1 are geometries for zero (typical 70° spherical-cone), five, and ten degrees deflection upon the top; the views of Figure 2 depict the mesh for a deflection of 5 degrees. Two buffer zones, between the deflected and non-deflected portions, were allotted to each geometry, each spanning 2δ; the purpose of these regions is to maintain smooth, frontal geometry. All deflection areas (including buffer zones) subtend 120° of the azimuthal angle (30°-150° for top-deflections, 210°-330° for bottom-deflections). Geometries were analyzed over angles of attack (α) from 0° to 20°; sideslip angle (β) was not incorporated and is a suggested area of expansion for further study. For each composition of angle of attack α and deflection δ, unique local pressure coefficients were calculated upon each surface element. Decomposing each pressure coefficient into normal and axial force coefficients allowed analytical solution for the geometry's global lift, drag coefficients and L/D ratio. The moment coefficient was obtained from the summation of moments about the vehicle's nose.

Results

- Values for the normal and axial force coefficient across a positive α variation are portrayed in Figure 3; lift coefficient and the lift-to-drag ratio versus α are shown in Figure 4; lift-curve slope and moment coefficient against α in Figure 5. Each plot presents the modified Newtonian flow theory solution for a regular 70° sphere-cone (black), top/bottom 5° deflection (red), top/bottom 10° deflection (blue), top/bottom 15° deflection (yellow). Lower-surface curves are not complete as any further angle of attack (combined with δ) would drift the stagnation point off the geometry.
- All forward deflections were found to increase the lift-drag ratio: greater forward deflections resulted in a larger modification of the lift-drag ratio. For positive α, deflections upon the top surface contributed more towards a lift-drag ratio increase versus deflections upon the lower surface, whereas deflections upon the lower surface yielded a much more negative Cm-α slope. (c.f. Table 1, 5° deflection upper-surface L/D, Cm against 5° deflection lower-surface L/D, Cm). For negative α, this characteristic is swapped.
- Increasing the deflection angle tended to migrate the Cm-curve along the abscissa: deflection upon the top resulted in +α migration,
- Decreasing the azimuthal angle traversed by the deflected section tugged the solution towards the unaltered 70° sphere-cone without altering curve contour.
- While forward deflections upon the upper-surface increase the L/D ratio, they adversely impact static stability vs α trends. This can be mitigated in packaging considerations: a forward deflection can allow an increased static margin (distance between C.G. and N.P.) by moving the C.G. forward.
- No pre-entry spin-up with these configurations.
- Possible biconic section (stagnation point migrating off geometry no longer an issue).

Figure 3: Normal, Axial Force Coefficients against α

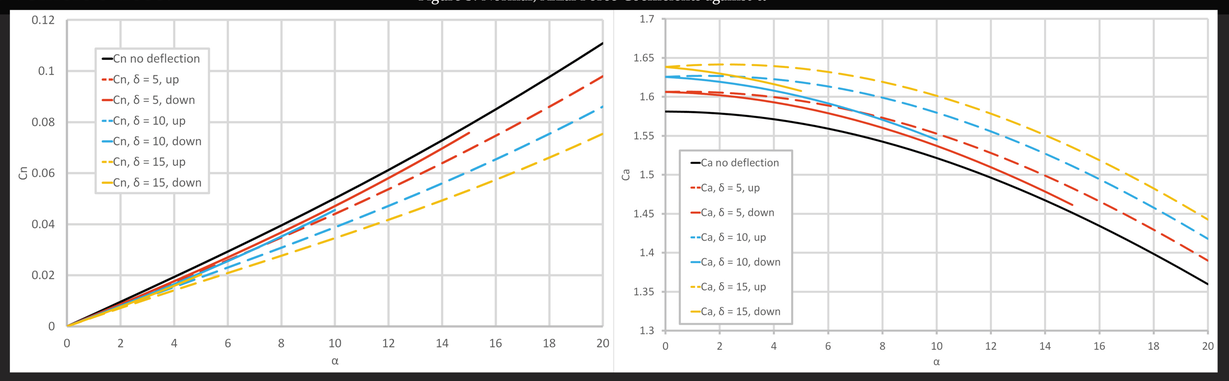


Figure 4: Lift Coefficient and L/D against α

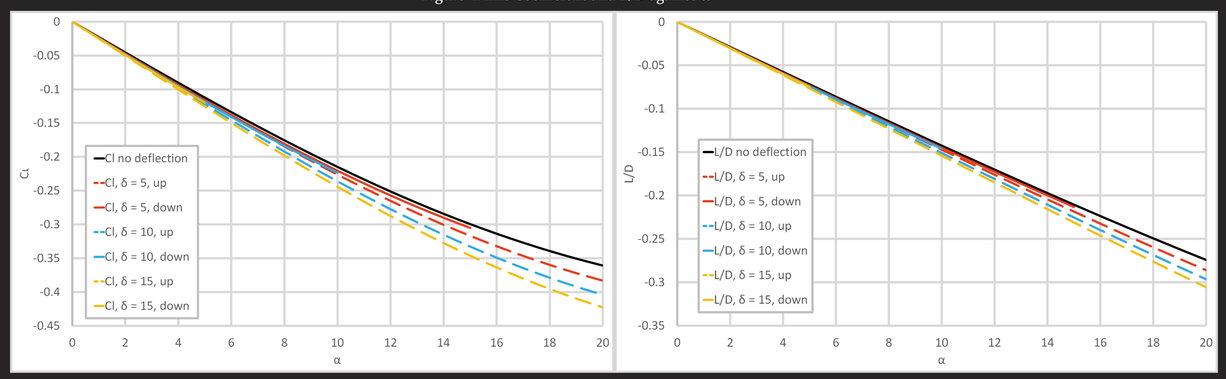
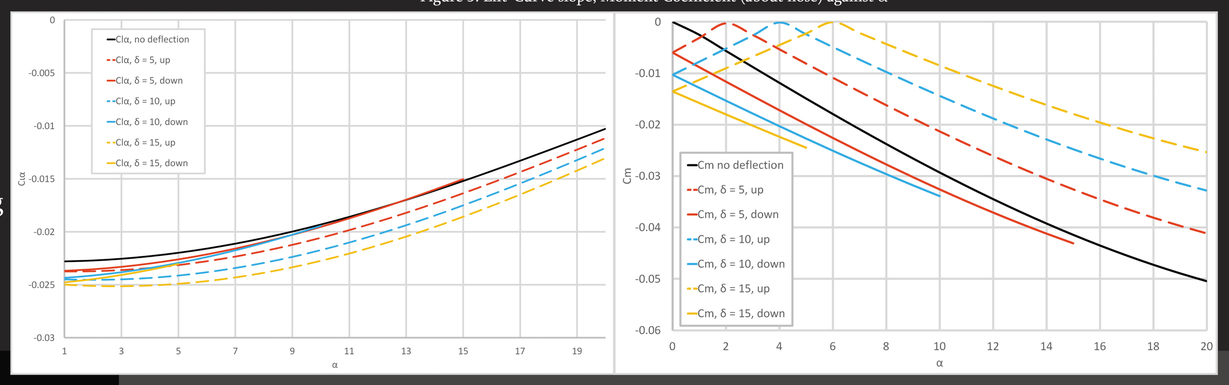


Figure 5: Lift-Curve slope, Moment Coefficient (about nose) against α



α = 11°	Cn	Ca	Cl	Cd	L/D	Δ L/D	Cm	α = 16°	Cn	Ca	Cl	Cd	L/D	Δ L/D	Cm
δ = 0°	0.05567	1.509467	-0.23337	1.492356	-0.15638		-0.03193	δ = 0°	0.085	1.434503	-0.3137	1.402362	-0.22369		-0.04349
δ = 5° up	0.048862	1.540908	-0.24605	1.52192	-0.16167	-0.00529	-0.02376	δ = 5° up	0.074692	1.465978	-0.33228	1.429776	-0.2324	-0.00871	-0.03455
δ = 5° down	0.052529	1.523971	-0.23922	1.505994	-0.15885	-0.00247	-0.03488	δ = 5° down							
δ = 10° up	0.042955	1.568192	-0.25706	1.547576	-0.1661	-0.00973	-0.01662	δ = 10° up	0.065406	1.494332	-0.34902	1.454473	-0.23996	-0.01627	-0.02659
δ = 10° down								δ = 10° down							
δ = 15° up	0.038116	1.590539	-0.26607	1.56859	-0.16963	-0.01325	-0.01051	δ = 15° up	0.05741	1.518747	-0.36344	1.475738	-0.24628	-0.02258	-0.01959
δ = 15° down								δ = 15° down							

Table 1: Aerodynamic Coefficients & L/D ratios for α = 11°, 16°; δ = 0°, 5°, 10°, 15°

Future Studies

- Expand analysis to include sideslip (β)
- Analyze deflection effects upon sphere-cones less than 70°, deflection areas subtending less than/greater than 120°.
- Hypersonic Pitch Damping analysis to obtain pitch damping coefficients and investigate dynamic stability indicators.
- Biconic applicability.
- Evaluation in supersonic, transonic, subsonic regimes.
- Define and analyze stability coefficients with set static margin and C.G. location.

Conclusion

- Forward deflections increase geometry's Lift-Drag ratio.
- Larger δ translates to greater Lift-Drag ratio.
- For positive α, Lift-Drag ratio dependent upon deflections on upper surface more than lower surface.
- For positive α, moment coefficient dependent upon deflections on lower surface more than upper surface.

Works Cited

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