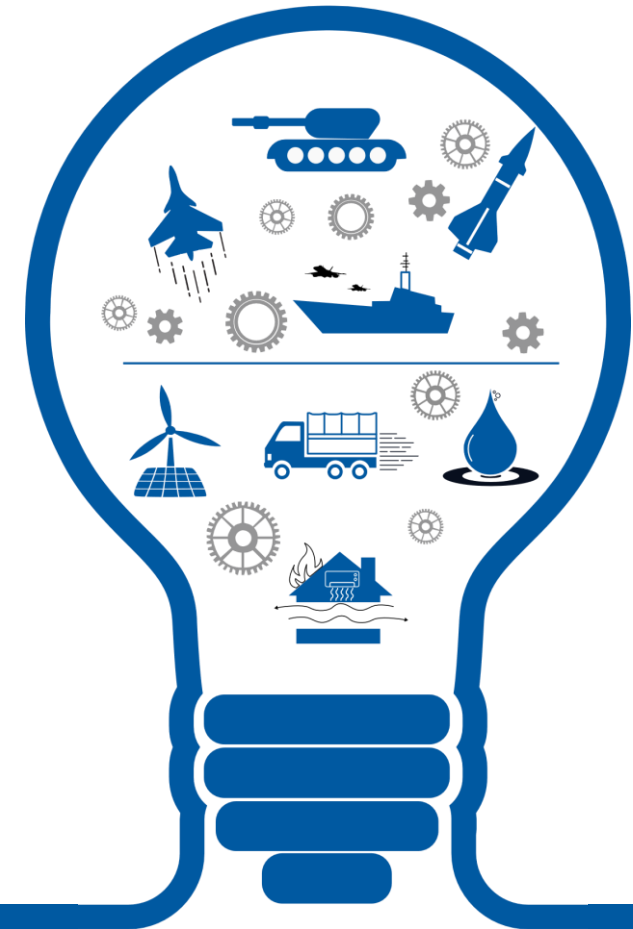


Missile aerodynamics

REFERENCE MANUAL

<http://labs.zeusnumerix.com/missile-aerodynamic-configurator/>



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Introduction

- To determine the aerodynamic characteristics of the missile with body and flare combination, body and surface combination
- Small diameter missiles have low drag
- Supersonic body drag is driven by nose fineness while subsonic drag is driven by wetted area
- L/D Is impacted by C_{D0} , body fineness, and lifting body cross section shape
- Flare Increases Static Stability
- Surfaces with large area and at high angle of attack have high normal force
- Canard control missiles are wingless and most are supersonic
- Larger tail area is required for neutral stability at high mach number



Governing Equations

- Body Zero-lift Drag coefficient: $(C_{D_0})_{Body} = (C_{D_0})_{Body, Friction} + (C_{D_0})_{Base} + (C_{D_0})_{Body, Wave}$
- Body Normal Force coefficient: $|C_N| = [|(a/b) \cos^2 \phi + (b/a) \sin^2 \phi|] [|\sin(2\alpha) \cos(\alpha/2)| + 2(l/d) \sin^2 \alpha]$
- Body Lift by Drag Ratio: $L/D = C_L/C_D = (C_N \cos \alpha - C_{D_0} \sin \alpha) / (C_N \sin \alpha + C_{D_0} \cos \alpha)$
- Body Aerodynamic Centre: $(x_{AC})_B / l_N = 0.63 (1 - \sin^2 \alpha) + 0.5 (l_B / l_N) \sin^2 \alpha$
- Flare Normal Force coefficient: $(C_{N_\alpha})_F = 2 [(d_F / d)^2 - 1]$
- Flare Aerodynamic Centre: $(x_{ac})_F = x_F + 0.33 l_F [2 (d_F / d) + 1] / [(d_F / d) + 1]$
- Static Margin for body-flare:

$$\frac{(x_{AC} - x_{CG}) / d}{[(C_{N_\alpha})_B + (C_{N_\alpha})_F]} = -\frac{\{(C_{N_\alpha})_B [(x_{CG} - (x_{AC})_B) / d] + (C_{N_\alpha})_F [(x_{CG} - (x_{AC})_F) / d]\}}{[(C_{N_\alpha})_B + (C_{N_\alpha})_F]}$$
- Surface Normal Force coefficient:

$$|(C_N)_{Surface}| = [4 |\sin \alpha' \cos \alpha'| / (M^2 - 1)^{1/2} + 2 \sin^2 \alpha'] (S_{Surface} / S_{Ref}), \text{ if } M > \{1 + [8 / (\pi A)]^2\}^{1/2}$$

$$|(C_N)_{Surface}| = [(\pi A / 2) |\sin \alpha' \cos \alpha'| + 2 \sin^2 \alpha'] (S_{Surface} / S_{Ref}), \text{ if } M < \{1 + [8 / (\pi A)]^2\}^{1/2}$$



Governing Equations

- Surface Normal Force: $N_{\text{surface}} = [(C_N)_{\text{surface}} (S_{\text{Ref}} / S_{\text{surface}})] * q * S_{\text{surface}}$
- Surface Aerodynamic Centre: $(x_{AC} / c_{MAC})_{\text{Surface}} = [A (M^2 - 1)^{1/2} - 0.67] / [2A (M^2 - 1)^{1/2} - 1], \text{ if } M > \sim 2$
 $(x_{AC} / c_{MAC})_{\text{Surface}} = 0.25, \text{ if } M < \sim 0.7$
- Surface Hinge Moment: $HM = N_{\text{Surface}} (x_{AC} - x_{HL})_{\text{Surface}}$
- Surface Zero-Lift Drag Coefficient: $(C_{D0})_{\text{Surface}} = (C_{D0})_{\text{Surface,Wave}} + (C_{D0})_{\text{Surface,Friction}}$
- Static Margin for body-surface:

$$\frac{(x_{AC} - x_{CG}) / d}{[(C_{N_{\alpha}})_{B} + (C_{N_{\alpha}})_{W} S_W / S_{\text{Ref}} + (C_{N_{\alpha}})_{T} S_T / S_{\text{Ref}}]} = - \{ (C_{N_{\alpha}})_{B} [(x_{CG} - (x_{AC})_{B}) / d] + (C_{N_{\alpha}})_{W} [(x_{CG} - (x_{AC})_{W}) / d] S_W / S_{\text{Ref}} + (C_{N_{\alpha}})_{T} [(x_{CG} - (x_{AC})_{T}) / d] (S_T / S_{\text{Ref}}) \}$$
- Normal Force coefficient for body-surface: $(C_N)_{\text{total}} = (C_N)_{\text{Body}} + (C_N)_{\text{surface}}$
- Zero-Lift Drag Coefficient for body-surface: $(C_{D0})_{\text{total}} = (C_{D0})_{\text{Body}} + (C_{D0})_{\text{surface}}$
- Drag force for body-surface: $D = C_D q S_{\text{Ref}}$



Web App - Usage

- User needs to enter all the input parameter details of missile aerodynamic configurator. Each parameter is described in next slide
- Upon execution, following output is generated:
 1. Zero-lift Drag coefficient, Normal Force coefficient, Aerodynamic Centre, Lift by Drag Ratio of the body
 2. Normal Force coefficient, Aerodynamic Centre of the flare
 3. Static Margin for body and flare combination
 4. Normal Force coefficient, Normal Force, Aerodynamic Centre, Hinge Moment, Total Zero-Lift Drag Coefficient of the surface
 5. Static Margin, Normal Force Coefficient, Zero-Lift Drag Coefficient, Drag force for body and surface combination



Input File Description

Parameter	Default	Unit	Description
specific heat ratio	1.4	-	specific heat ratio of air
altitude	6096	m	Altitude at which the missile is
Mach number	2	-	Mach number of the missile
angle of attack	40	degrees	Angle of attack of the missile
missile length	3.6576	m	Length of the missile
missile diameter	0.2032	m	Diameter of the missile
semi-major axis length/semi-minor axis length	1	-	Ratio of semi-major axis length to semi-minor axis length
major axis inclination angle wrt horizontal	0	degrees	major axis inclination angle wrt the horizontal plane of missile
missile nose length	0.48768	m	Length of the missile nose
center of gravity at launch	3.73126	m	Centre of gravity of missile at launch
Nose type	blunt	-	Type of missile nose(sharp or blunt)
Nose tip bluntness relative to missile diameter	10	%	Missile nose tip bluntness percent relative to missile diameter
nozzle exit area	0.00724	m ²	Area of the nozzle exit



Input File Description – Contd.

Parameter	Default	Unit	Description
Flare diameter	0.475	m	Diameter of the missile flare
flare length	0.3048	m	Length of the missile flare
number of surface planforms	4	-	Total number of surface planforms available
missile length ahead of surface MAC	1.7018	m	Length of the missile ahead of surface MAC leading edge
surface span	0.81788	m	Span of the surface
surface root chord	0.45	m	Root chord of the surface
surface tip chord	0.19	m	Tip chord of the surface
surface planform area	0.2369	m ²	Planform area of the surface
surface setting angle	0	degrees	Angle of the surface set wrt the longitudinal axis
max thickness of MAC	0.01486	n	Maximum thickness of MAC
surface leading edge sweep angle	45	degrees	Leading edge sweep angle of the surface
surface leading edge section total angle	10.01	degrees	Leading edge section total angle of the surface
missile length ahead of surface hinge line	1.78625	m	Length of the missile ahead of surface hinge axis



Output File Description

- These output summarizes the aerodynamic characteristics of the missile

Output Parameter	Unit	Description
Body Zero-Lift drag coefficient	-	Drag coefficient of the body at zero lift
Body Normal Force coefficient	-	Normal Force coefficient of the body
Body Lift by Drag Ratio	-	Lift by Drag Ratio of the body
Body Aerodynamic Centre	m	Aerodynamic Centre of the body
Flare Normal Force Coefficient	-	Normal Force coefficient of the flare
Flare Aerodynamic Center	m	Aerodynamic Centre of the flare
Static Margin for Body-Flare	m	Static Margin for body and flare combination
Surface Normal Force Coefficient	-	Normal Force coefficient of the surface
Surface Normal Force	N	Normal Force of the surface
Surface Aerodynamic Centre	m	Aerodynamic Centre of the surface
Surface Hinge Moment	N-m	Hinge Moment of the surface



Output File Description – Contd.

Output Parameter	Unit	Description
Surface Zero-Lift Friction Drag Coefficient		Friction Drag Coefficient of the surface at zero lift
Surface Zero-Lift Wave Drag Coefficient	-	Wave Drag Coefficient of the surface at zero lift
Surface Zero-Lift Drag Coefficient	-	Total Drag Coefficient of the surface at zero lift
Static Margin for Body-Surface	m	Static Margin for body and surface combination
Total Normal Force Coefficient for Body-Surface	-	Total Normal Force Coefficient for Body and surface combination
Total Zero-Lift Drag Coefficient for Body-Surface	-	Total Zero-Lift Drag Coefficient for Body and surface combination
Drag Force for Body-Surface	N	Total Drag force for Body and surface combination



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Thank You !



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