Comparison of Inviscid Flux Schemes and Turbulence Models on SU2 for Roll Induction Mechanism of Subsonic Missiles with Wrap-around Fins

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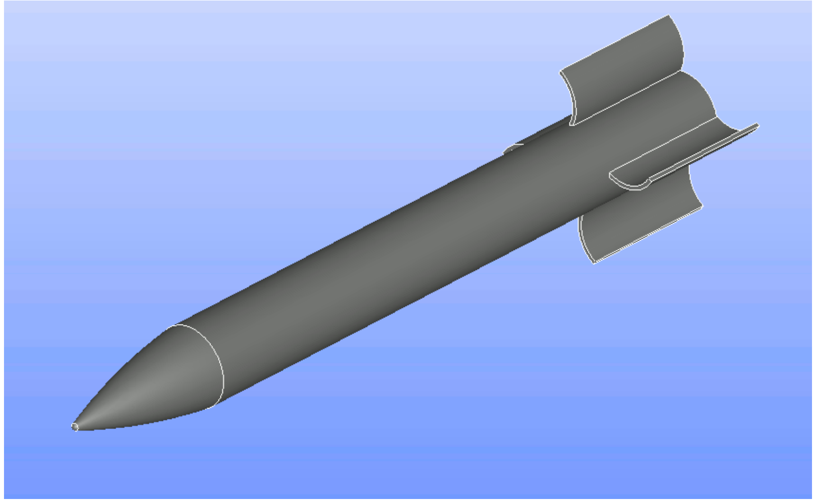
Missiles with Wrap-around Fins

Wrap-around fins:



Dahlke F1 Wrap-around Missile Geometry

Pros:

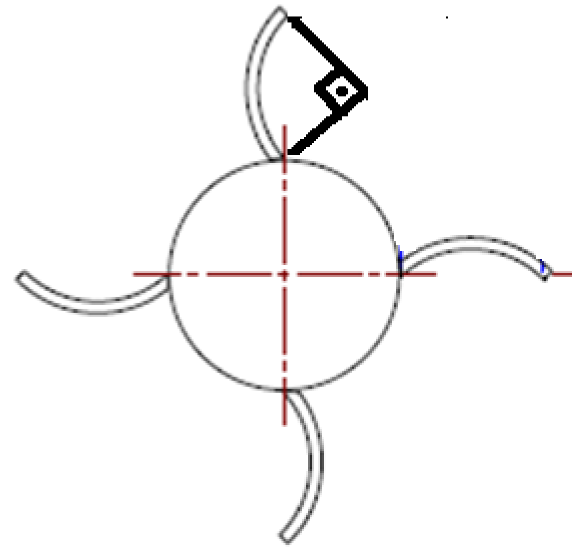
- Packaging advantage for tube launched missiles
- The same aerodynamic stability characteristics with projected planar counterpart

Cons:

- The roll induction at zero angle of attack
- The roll sign inversion at 5-8 degrees total angle of attack
- $I_{xx} << I_{yy}$ causes $O(\omega_x) \cong O(\omega_y)$

(C.W. Dahlke, 1976)

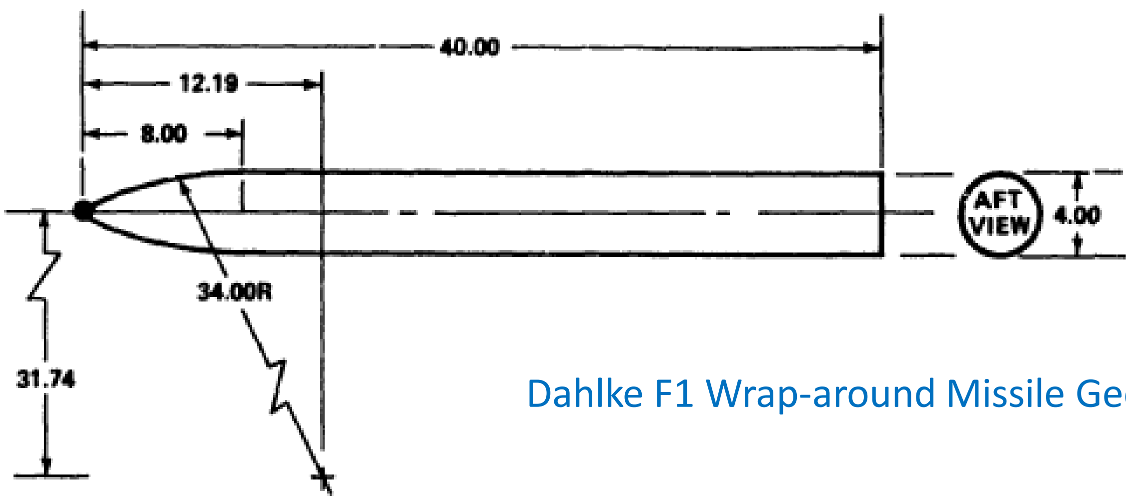
Wrap-around Fin: Dahlke F1

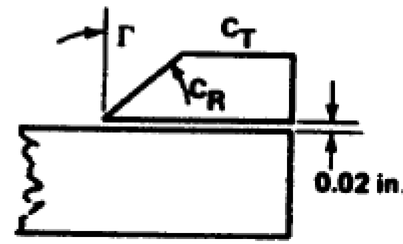


Wrap-around fins:

Geometry:

- Secant Ogive nose geometry
- 90^o Fin Angle
- No Sweep Angle ($c_T = c_R$)





SWEPT LEADING EDGE

Dahlke F1 Wrap-around Missile Geometry

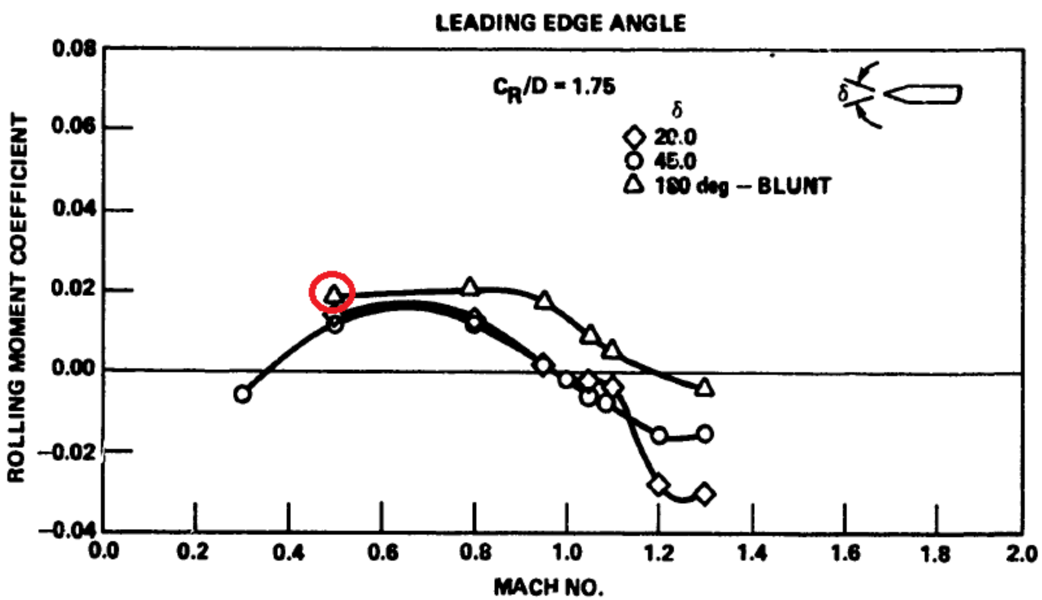
(C.W. Dahlke, 1976)

Wind Tunnel Experiments

Wrap-around fins:

Experimental Data:

- F1 fin geometry with blunt leading edge is chosen to compare the CFD results.
- $C_{Mx} = 0.00183$ @ $M_{a\infty} = 0.5$



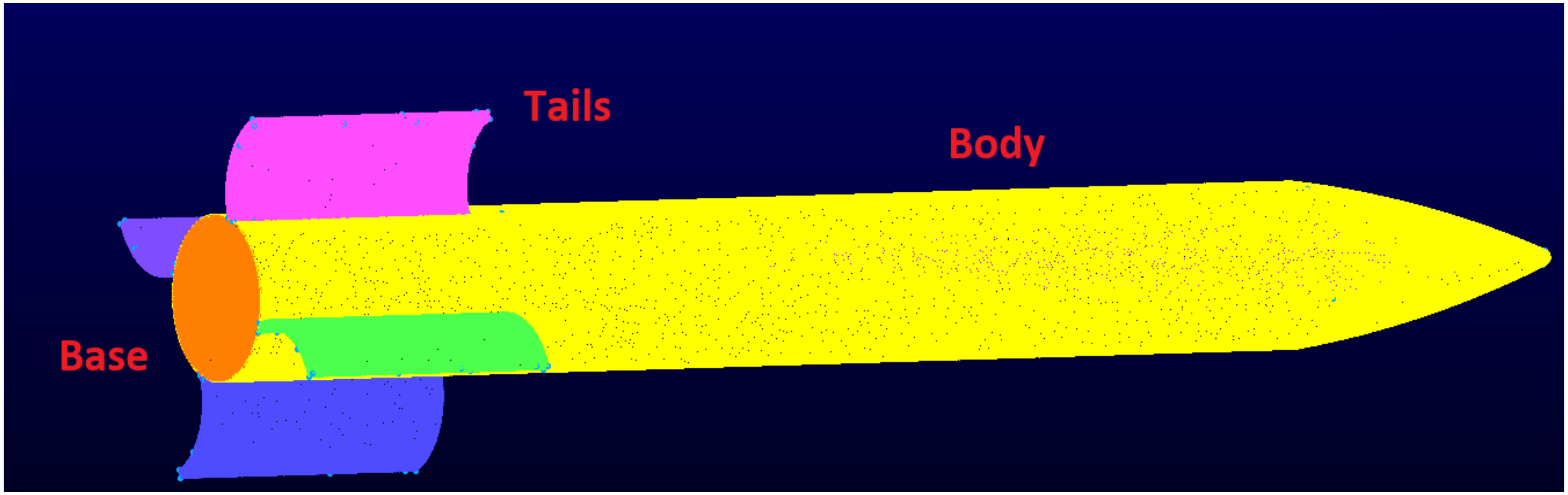
Dahlke F1 Wind Tunnel Results
at 0° angle of attack

(C.W. Dahlke, 1976)

Grid Generation

Grids:

- Grids are generated by using Pointwise Grid Generation Software.
- Same unstructured surface mesh on the body, tails and base.
- Grid resolution is increased by sources on nose, tails and wake regions.



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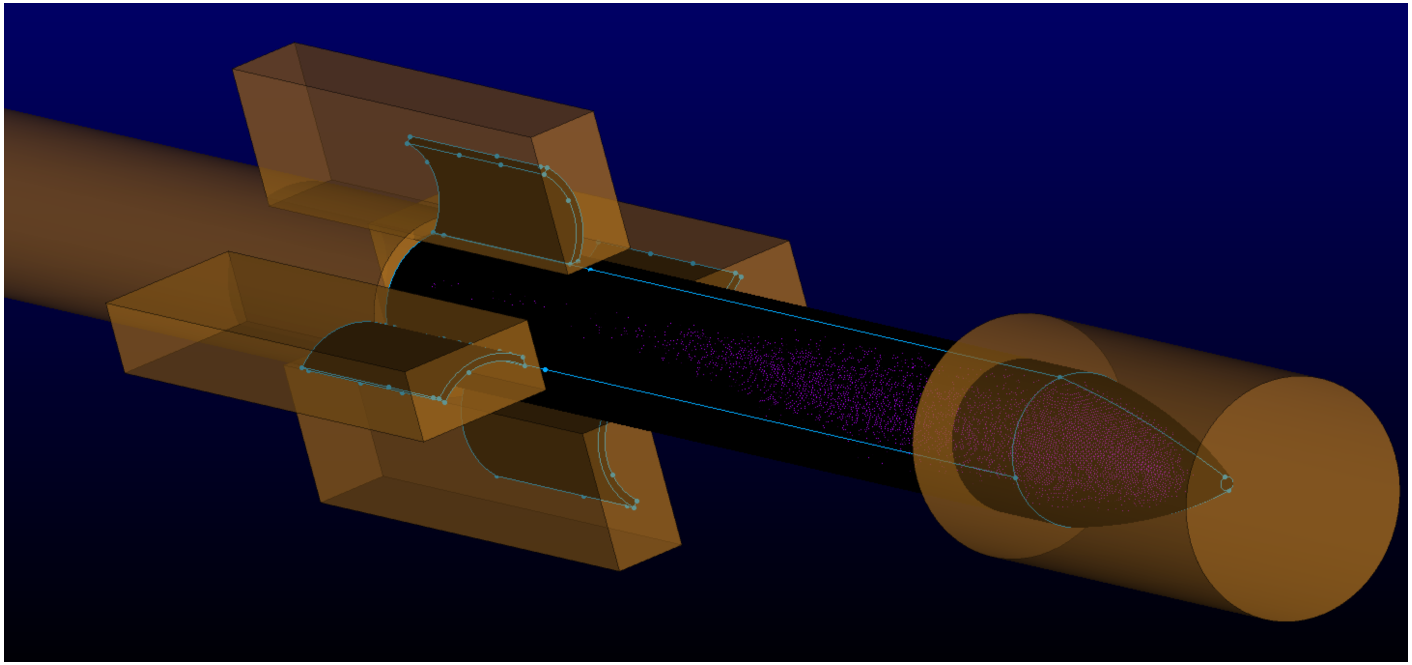


Grid	# of cells
1	15 M
2	26 M
3	31 M

CFD Simulations by using SU2 7.1.1

Numerical Approach:

- Turbulence Models: Spalart Allmaras and k-ω (SST)
- Convective Numerical Methods: AUSMPLUSUP2 and JST
- Green Gauss for spatial gradients
- Euler implicit time discretization
- FGMRES linear solver with ILU(0) preconditioner

BCs:

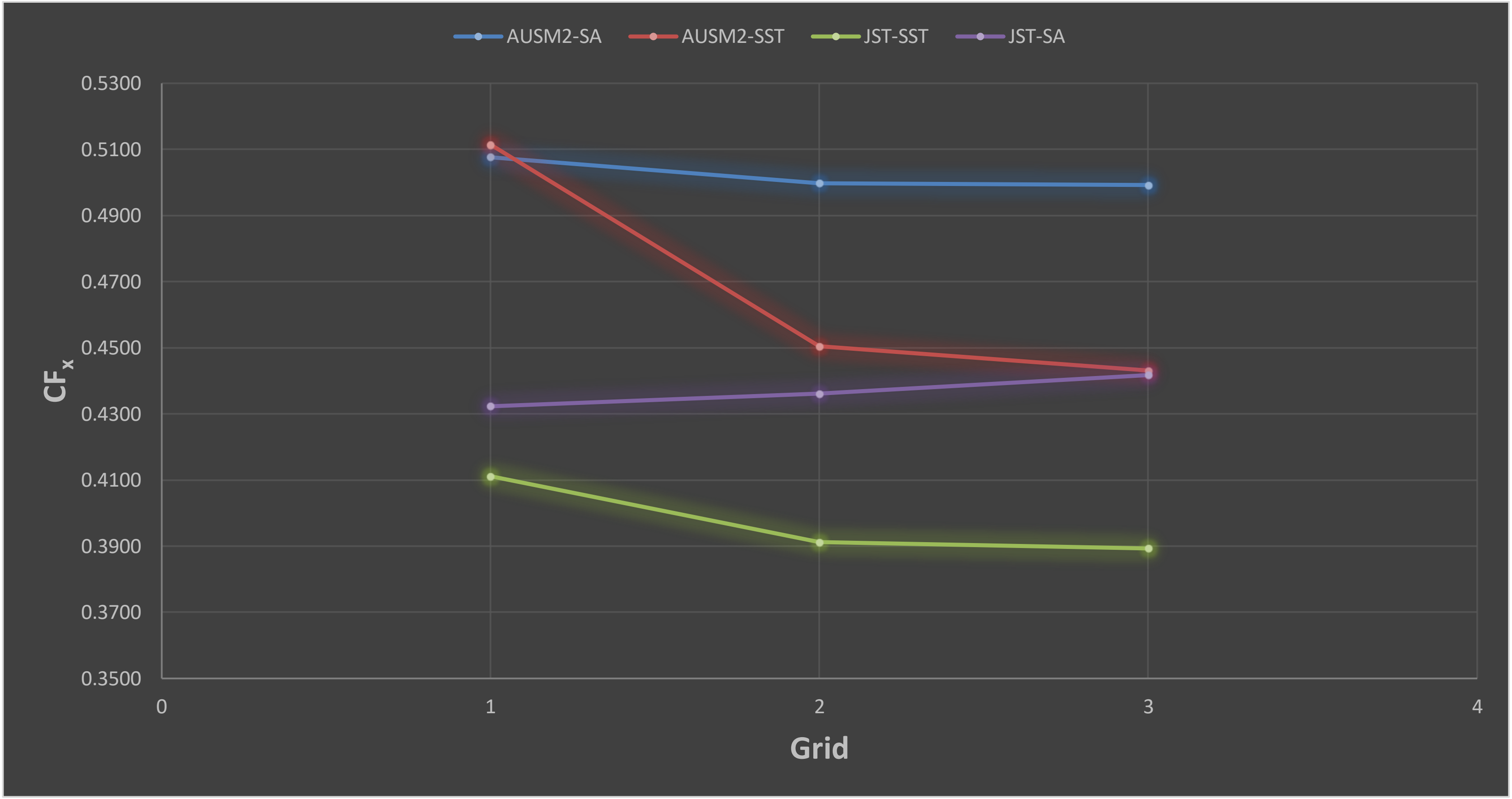
- Farfield BC on the outer domain
- Adiabatic Wall BC on body surface

Freestream:

- $P_\infty = 101325$ Pa
- $T_\infty = 293.15$ K
- $M_\infty = 0.5$

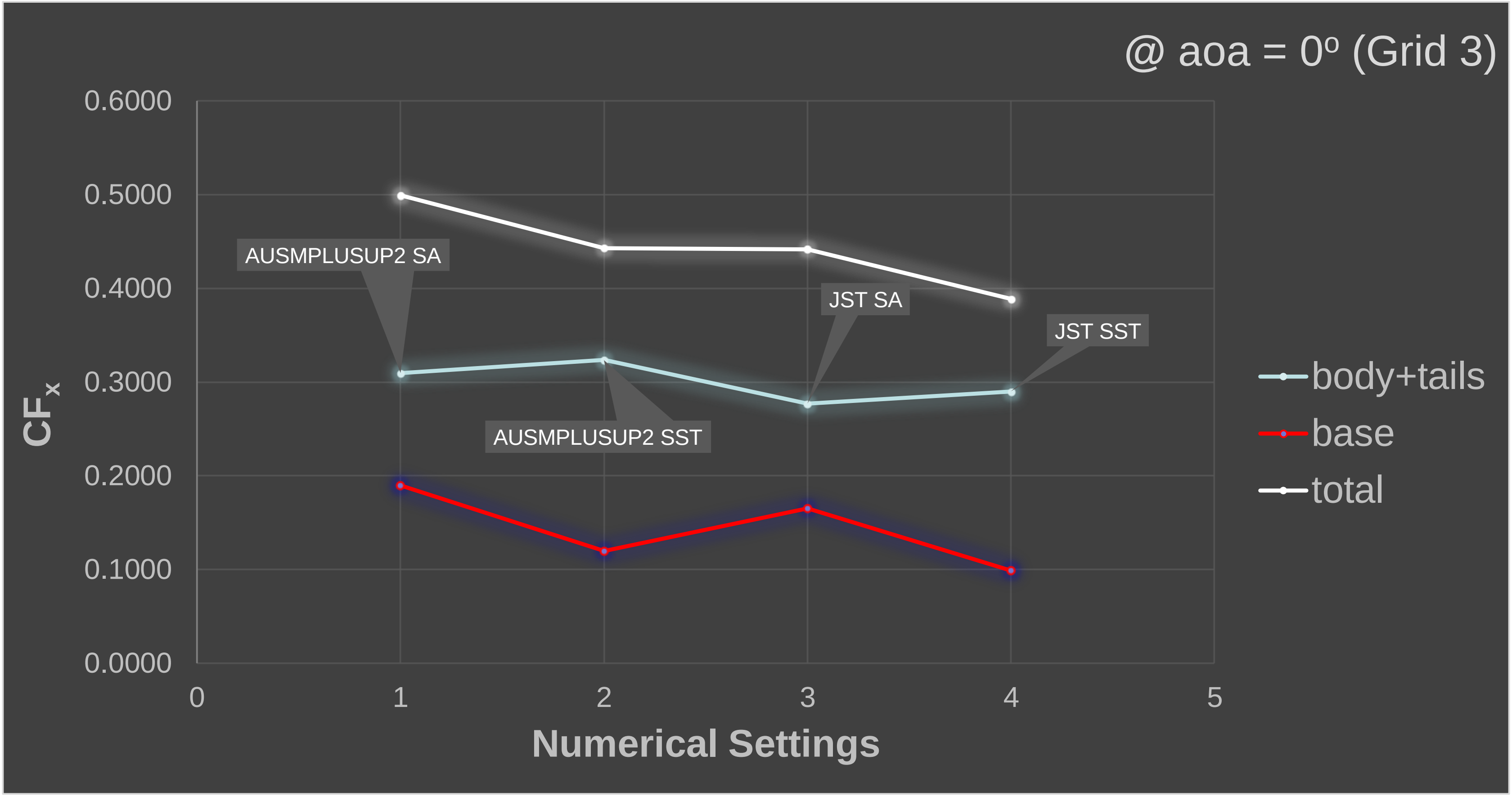
RESULTS

- **Different Turbulence Models**: Spalart Allmaras causes **larger axial force** than k-ω SST



RESULTS

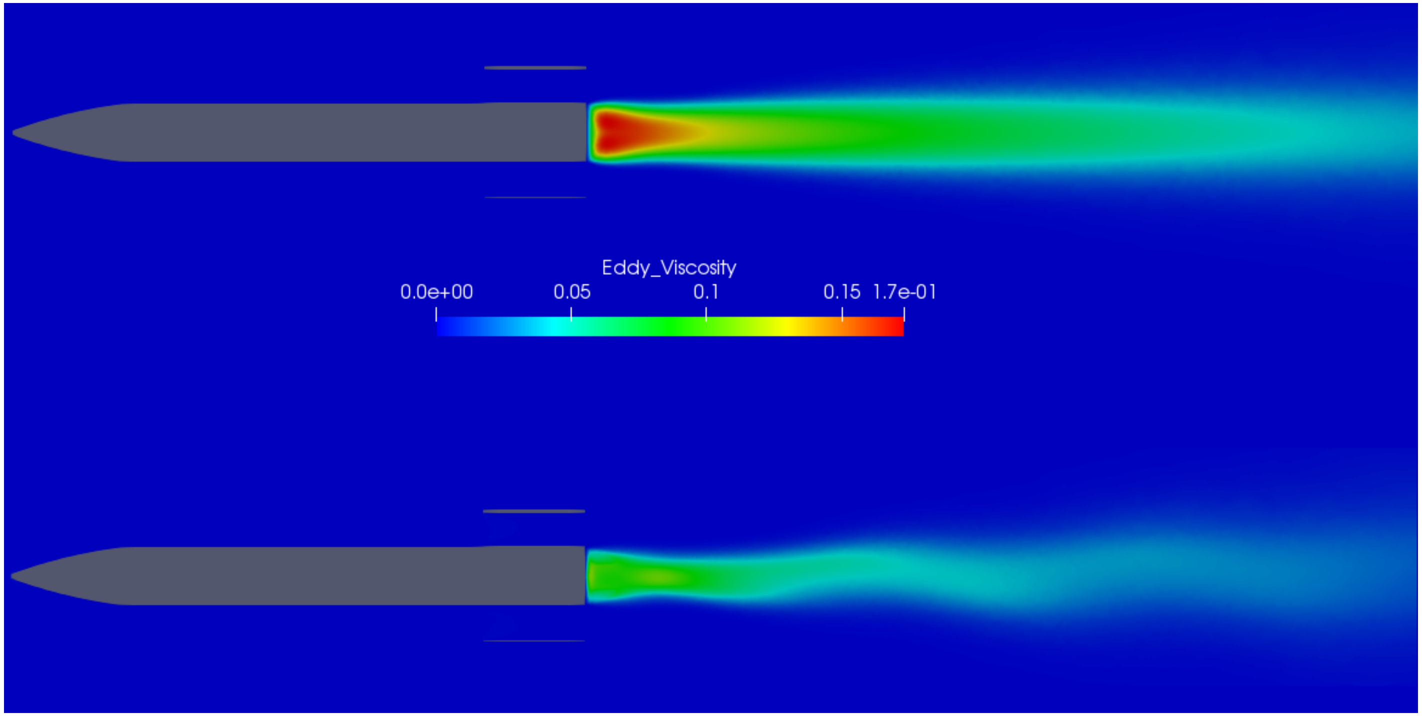
- **Different Numerical Methods: Axial force difference** is dominated by the **base drag** contribution



RESULTS

- Eddy viscosity contours for different methods for Grid 2

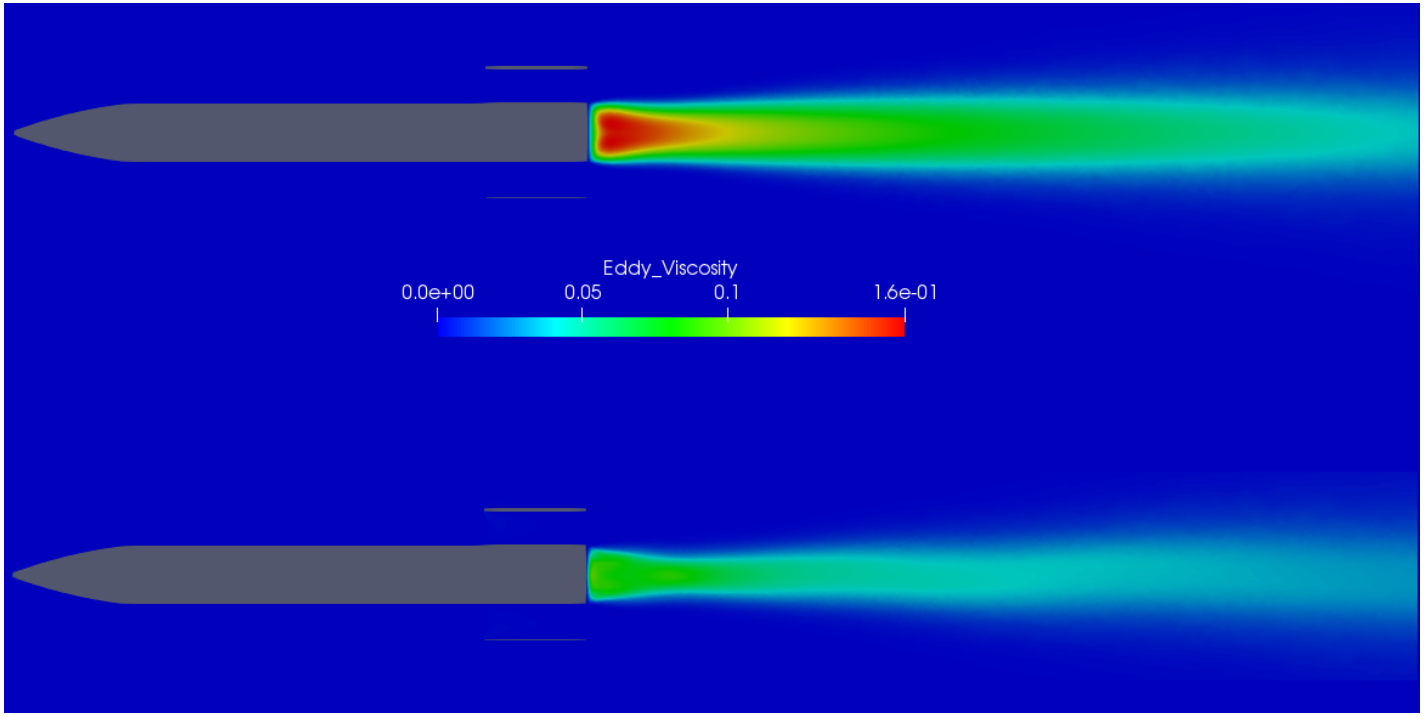
AUSMPLUSUP2
(SA upper, SST lower)



RESULTS

- Eddy viscosity contours for different methods for Grid 2

JST
(SA upper, SST lower)

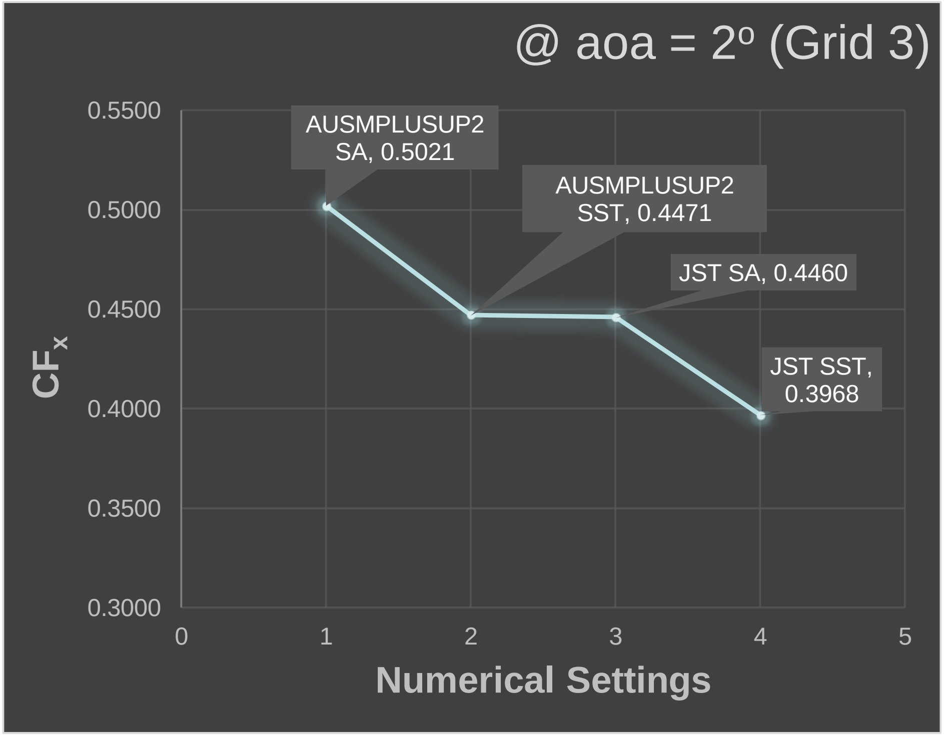


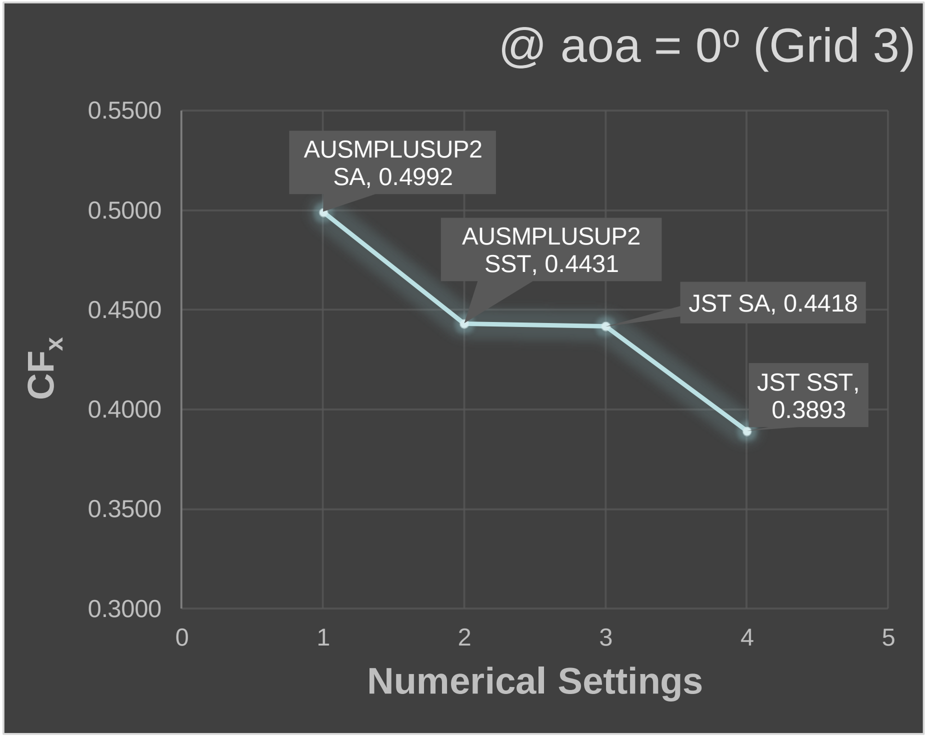
RESULTS

- JST-SA shows better accuracy with the wind tunnel results for pitching moment, as well as the better grid independency

RESULTS

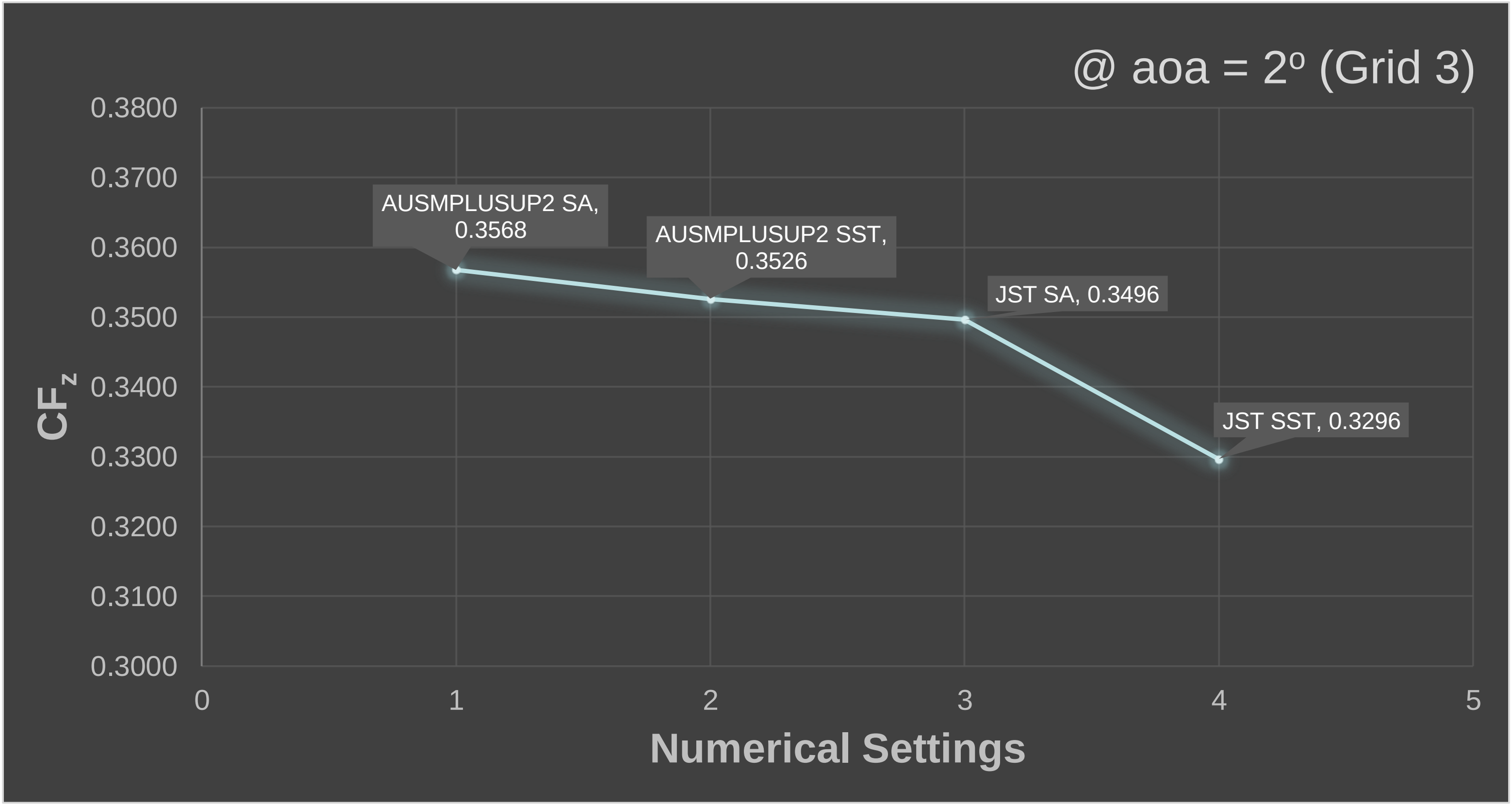
- AUSMPLUSUP and SA tends to generate **larger axial force** than that of their counterparts





RESULTS

- AUSMPLUSUP and SA tends to generate **larger normal force** than that of their counterparts



Summary/Conclusions

- CFD simulations with SU2 for missiles with wrap-around fins were done for different cases.
- AUSMPLUSUP and SA causes **larger force coefficients** due to lower diffusive contribution and **larger eddy viscosity generation**, respectively.
- JST-SA shows better accuracy with the experimental data
- JST and SA are more **easily converged** than their counterparts
- **Roll moment induced** by wrap-around tails as expected from theory are captured.

Acknowledgement

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Q & A

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