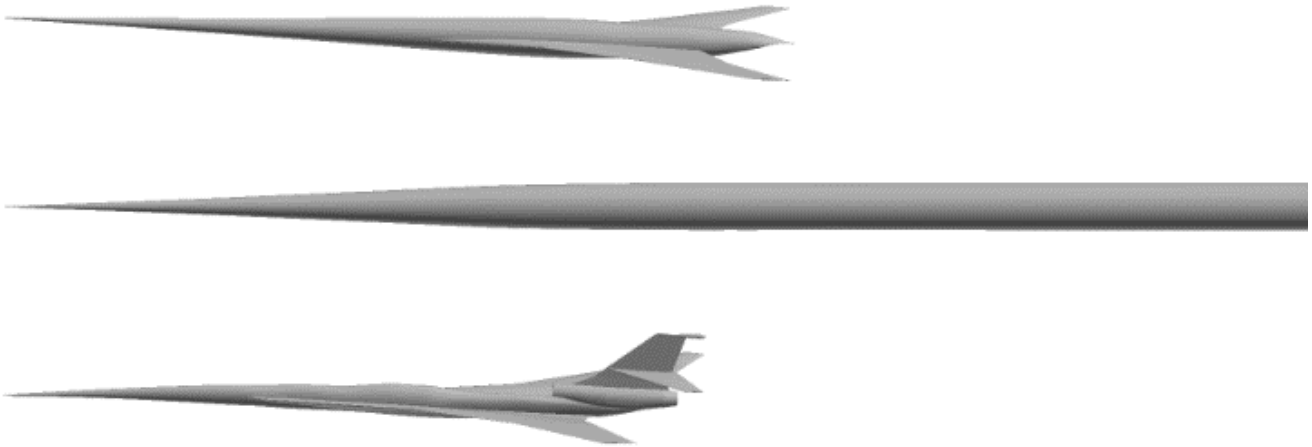
Near-field Pressure Signature Prediction by JAXA



Hiroaki ISHIKAWA (ASIRI)

Yoshikazu MAKINO (JAXA)

Atsushi UENO (JAXA)

Yohei KASUGA (University of Tokyo)

Outline

I. Summary of cases analyzed

II. Flow solver / Computing platform

- ✓ Flow solver (TAS)
- ✓ Computing platform : JSS2

III. JWB

- ✓ Design method and Wind tunnel test schedule
- ✓ Flow solver convergence
- ✓ Limiter function
- ✓ Results

IV. AXIE

V. C25D

VI. Comparison

- ✓ AXIE, JWB, C25D

VII. Conclusion

Summary of cases analyzed

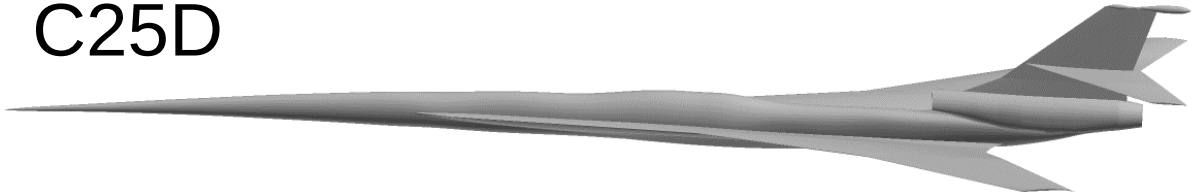
Model	Providor	viscousity	mesh	Grid Spacing(Resolution)					
axie	SBPW	inviscid	mixed	2.56	2	1.6	1.28	1	
			tetrahedra	2.56	2	1.6	1.28	1	
jwb	SBPW	inviscid	tetrahedra	1	0.83	0.7			
c25d-flowthru	SBPW	inviscid	mixed	2	1.6	1.28	1	0.8	0.64
			tetrahedra	2	1.6	1.28	1	0.8	

Propagation (optional) analysis are carried out for above cases.

JWB

axie

C25D



Flow solver/Computing Platform

CFD solver

Solver	TAS
	Tohoku university Aerodynamic Simulation
developer	Tohoku university & JAXA
Mesh	Unstructured mesh
	cell-vertex finite volume
discretization scheme	HLLEW
spatial accuracy	2nd order
limiter function	Venkatakrishnan
time integration	LU-SGS implicit method
Equation	Euler

Details will be presented by Knamori (tommrrow).

Propagation(Optional)

Xnoise : Burgers equation
MPnoise : Multi-pole method
Boom metre : Loudness estimation

Computing Platform

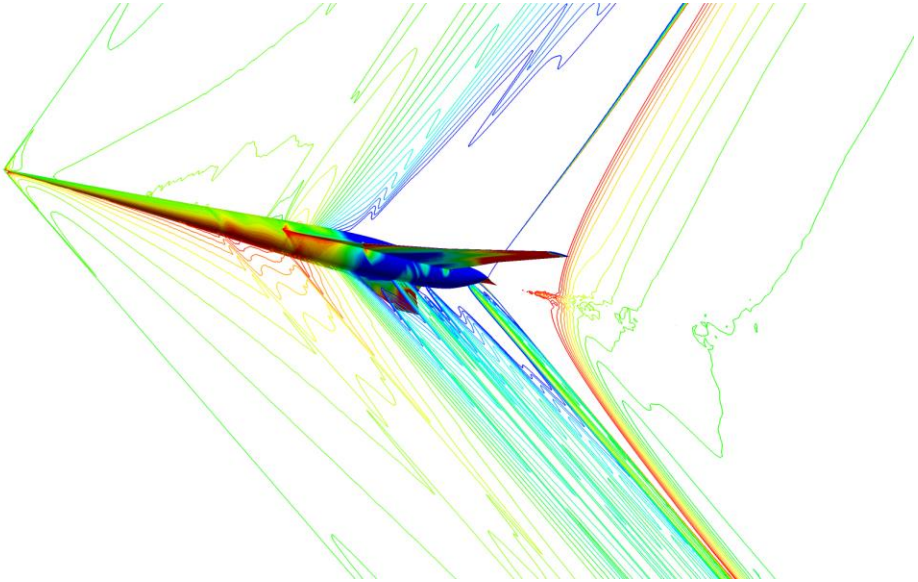
JSS2 SORA-MA

- JAXA Supercomputer System generation 2
- Fujitsu Supercomputer PRIMEHPC FX100
- Architecture: Scalar machine
- Processor Type = SPARC64 Xlfx (32 cores/node)
- Nodes/System = 3,240 nodes
- Memory/Node = 32GiB
- Memory/System = 101.25TiB
- Peak Performance = 3.495 PFLOPS

3-400 processors x 2-3.5h for SBPW2

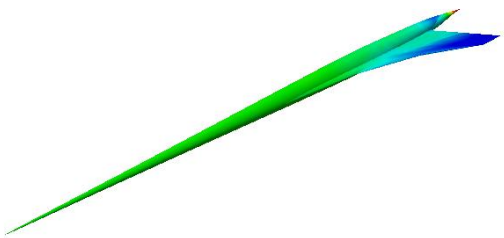
JWB

viscousity	mesh	Grid Spacing(Resolution)		
inviscid	tetrahedra	1	0.83	0.7



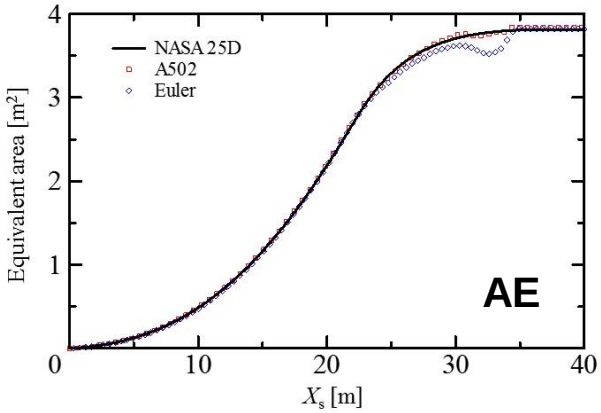
JAXA Wing Body (JWB) designed

- Step 1; Equivalent area (AE) based optimization
  - Euler analysis to evaluate lift component of equivalent area.
  - Free-form deformation (FFD) to optimize body shape.

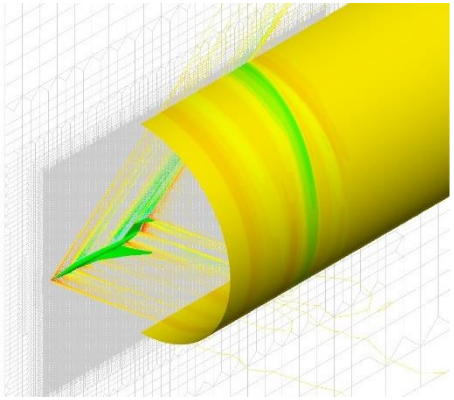


Euler analysis

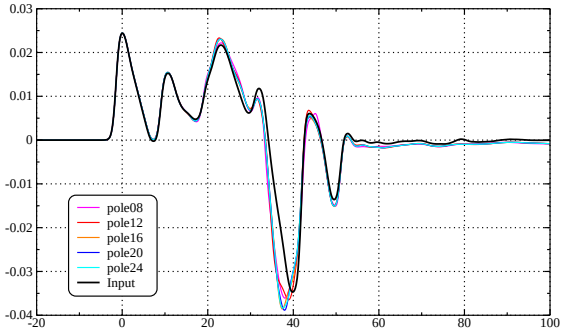
AE_lift
AE_volume



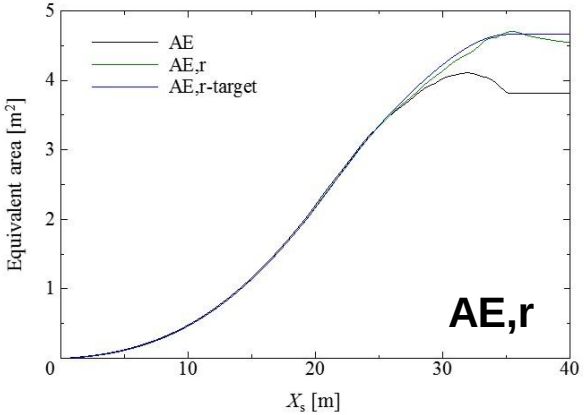
- Step 2; Reversed equivalent area (AE,r) based optimization
  - Euler analysis to evaluate near-field pressure distribution.
  - Multi-pole analysis to consider pressure propagation in circumferential direction.



Euler analysis

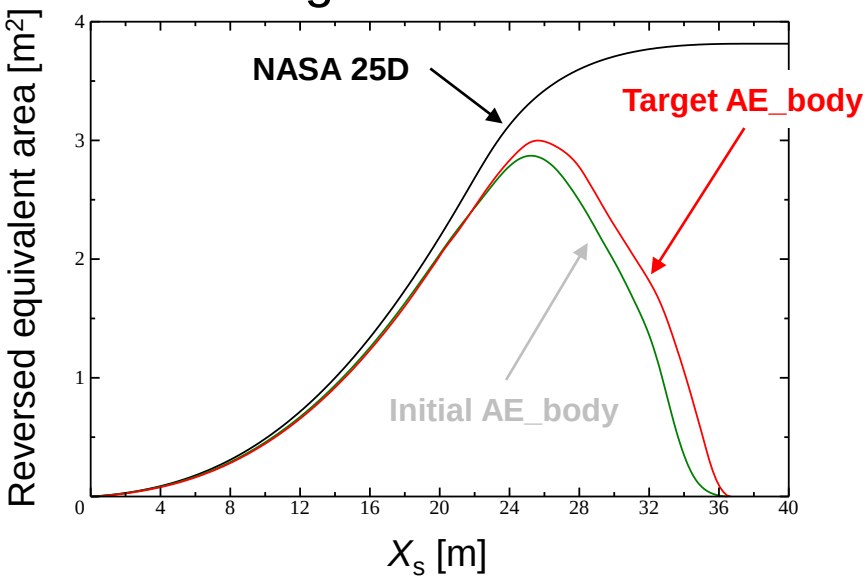


Multi-pole analysis



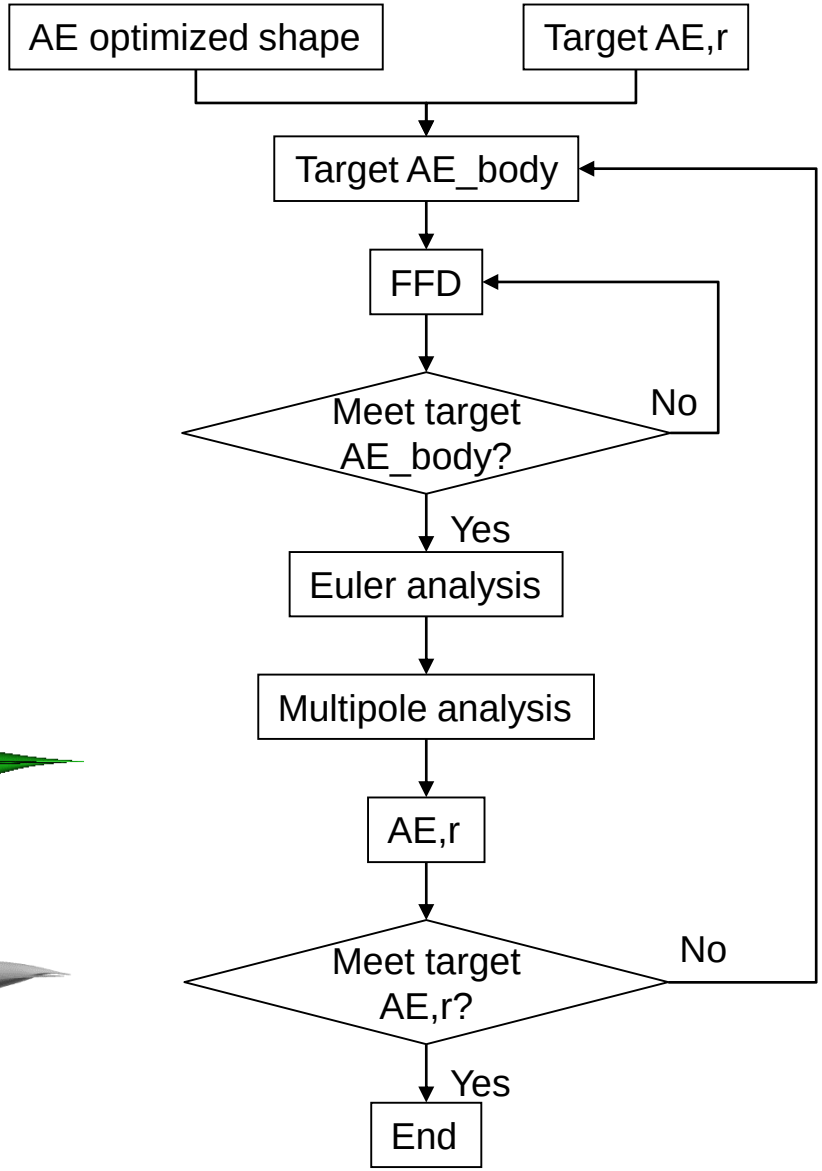
JAXA Wing Body (JWB) designed

- Optimization of body shape to meet NASA 25D
  - Wing was fixed.



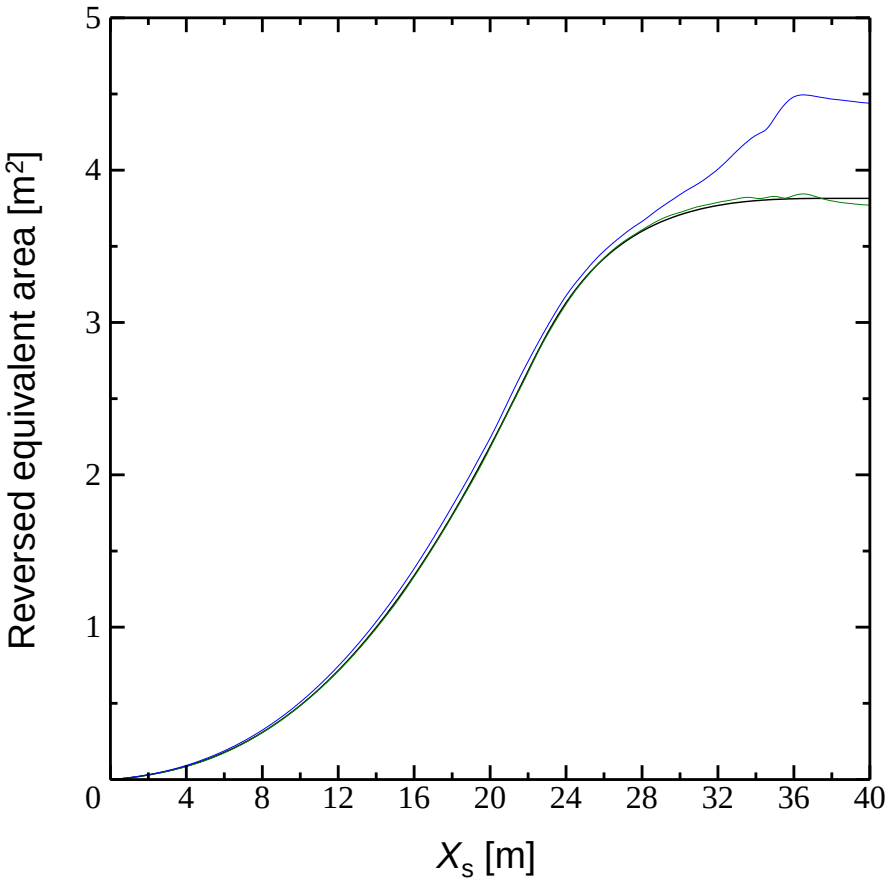
Initial shape

Designed shape

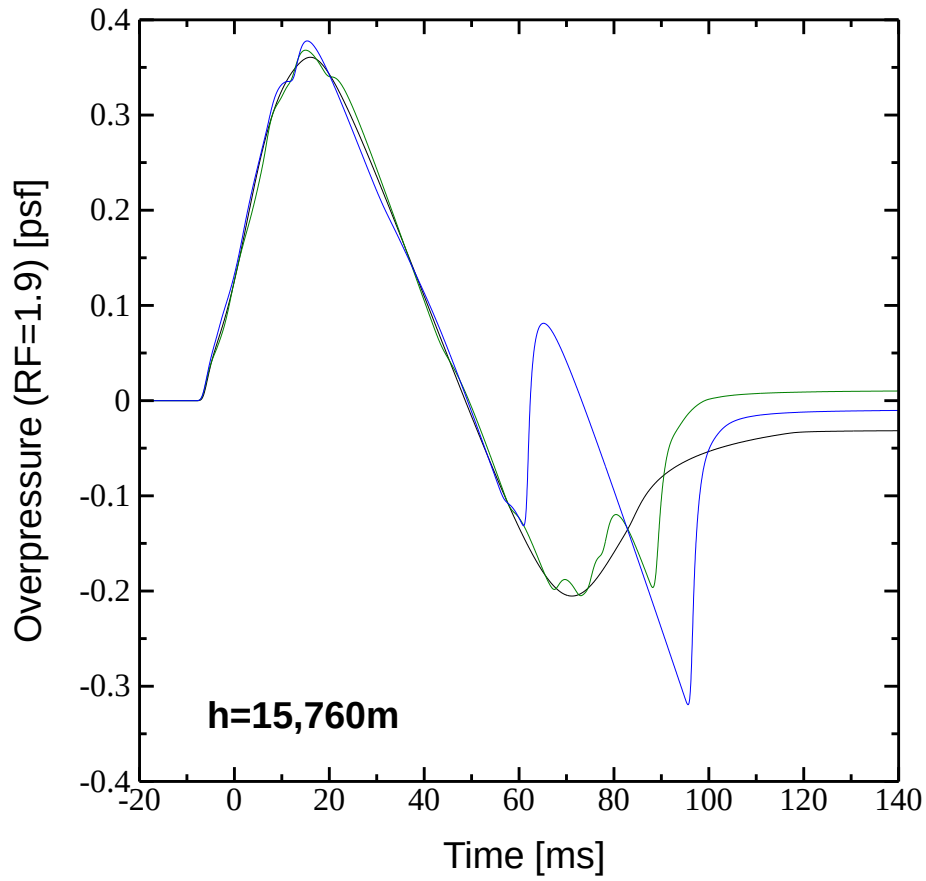


JAXA Wing Body (JWB) designed

75.1 PLdB; NASA 25D
84.7 PLdB; AE optimized
78.9 PLdB; AE,r optimized



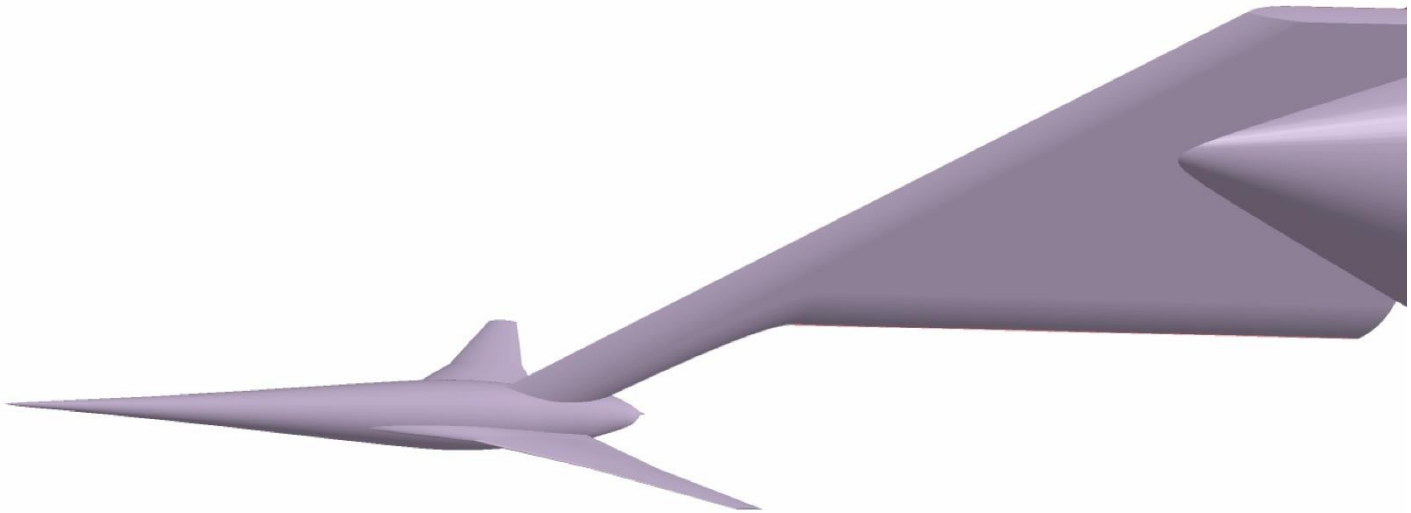
Equivalent area



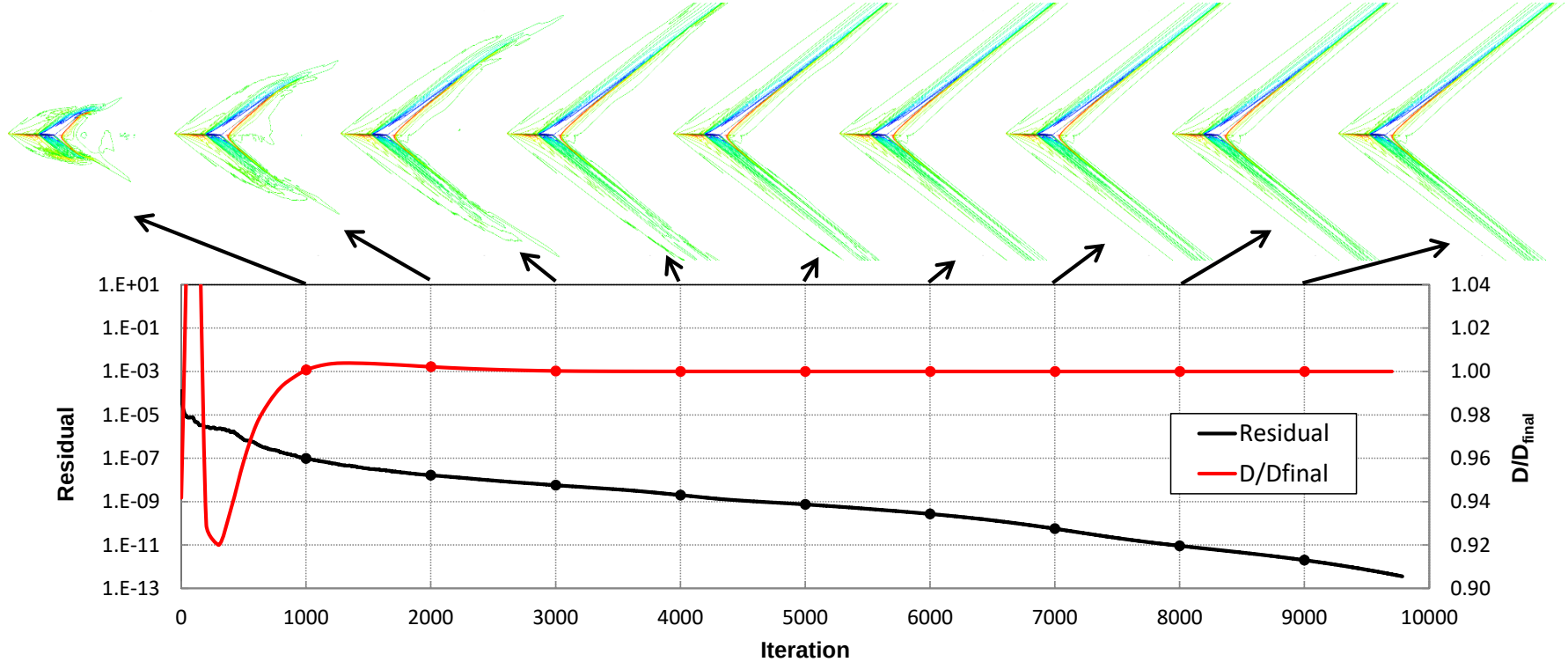
Boom signature at ground

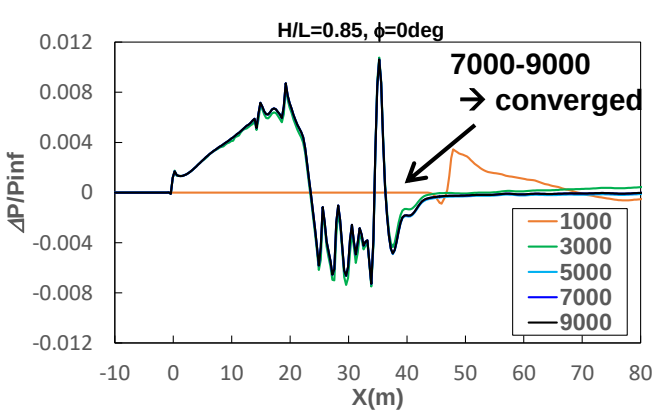
Wind tunnel test

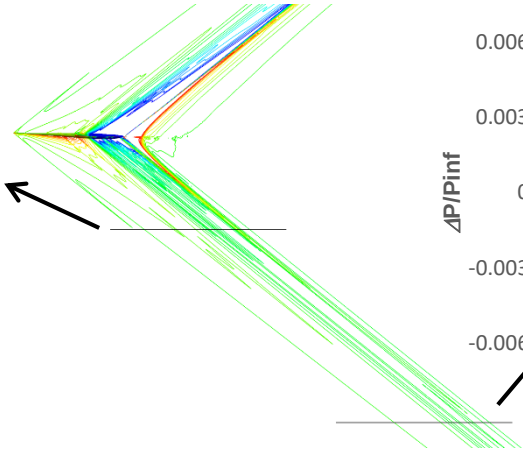
Wind Tunnel Testing will be held in 2 weeks.

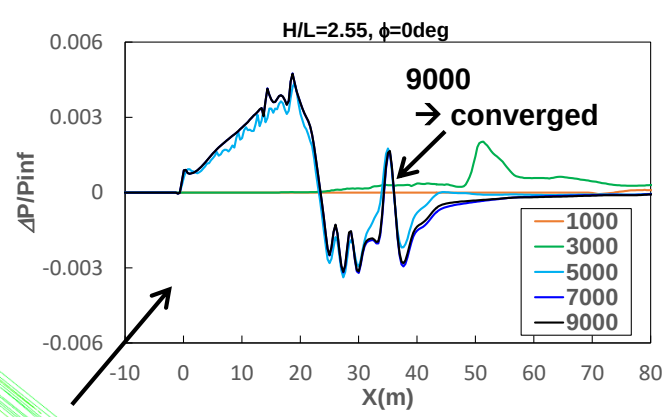


Flow solver convergence









Limiter Function

Venkatakrishnan limiter (AIAA 93-080)

$$\Phi_{i+1/2} = \frac{1}{\Delta_-}\left[\frac{\left(\Delta_+^2 + \varepsilon^2\right)\Delta_- + 2\Delta_-^2\Delta_+}{\Delta_+^2 + 2\Delta_-^2 + \Delta_-\Delta_+ + \varepsilon^2}\right]$$

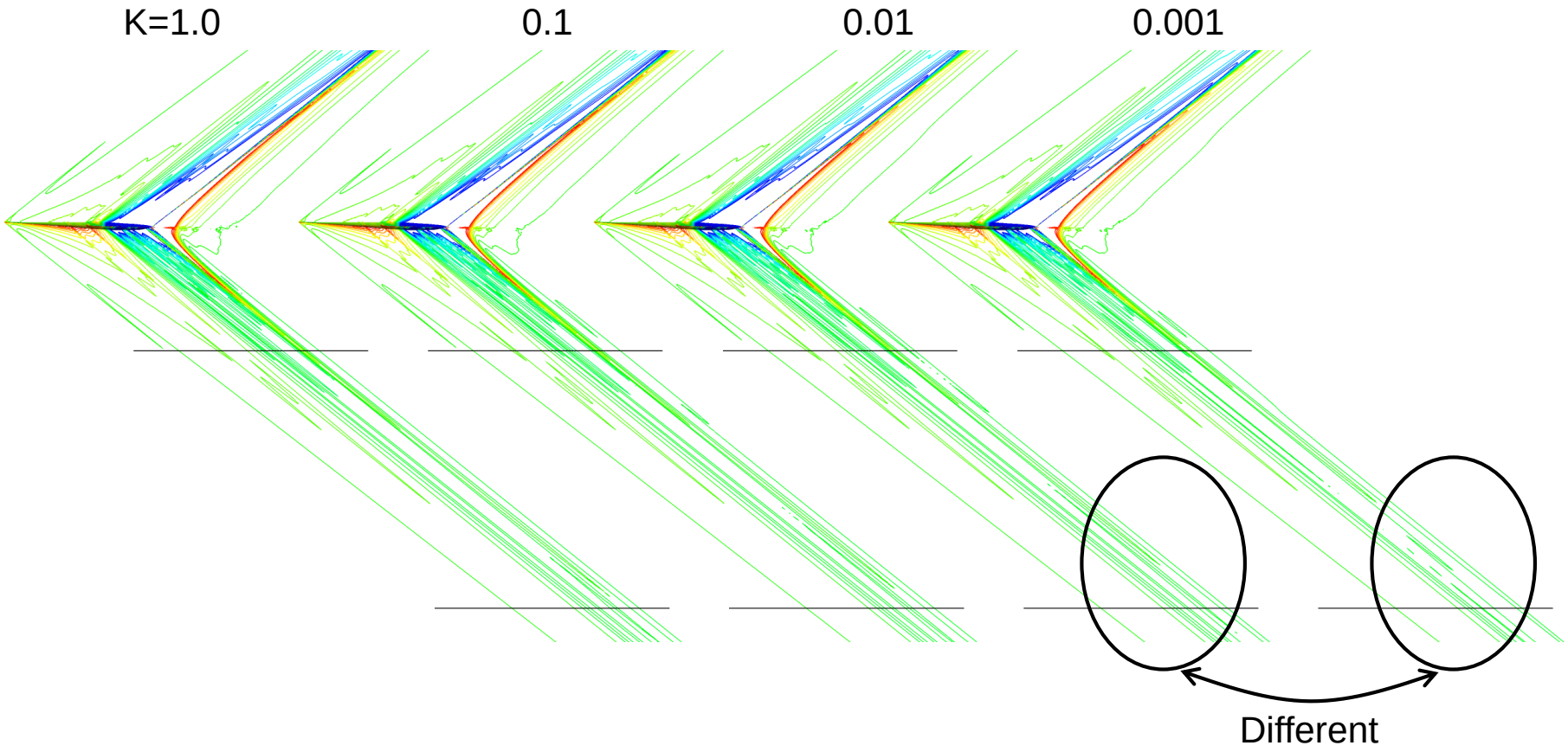
$$\varepsilon^2 = \left(K\overline{\Delta}\right)^3$$

where $\overline{\Delta}$ is an average grid size and K is a constant (limiter factor).

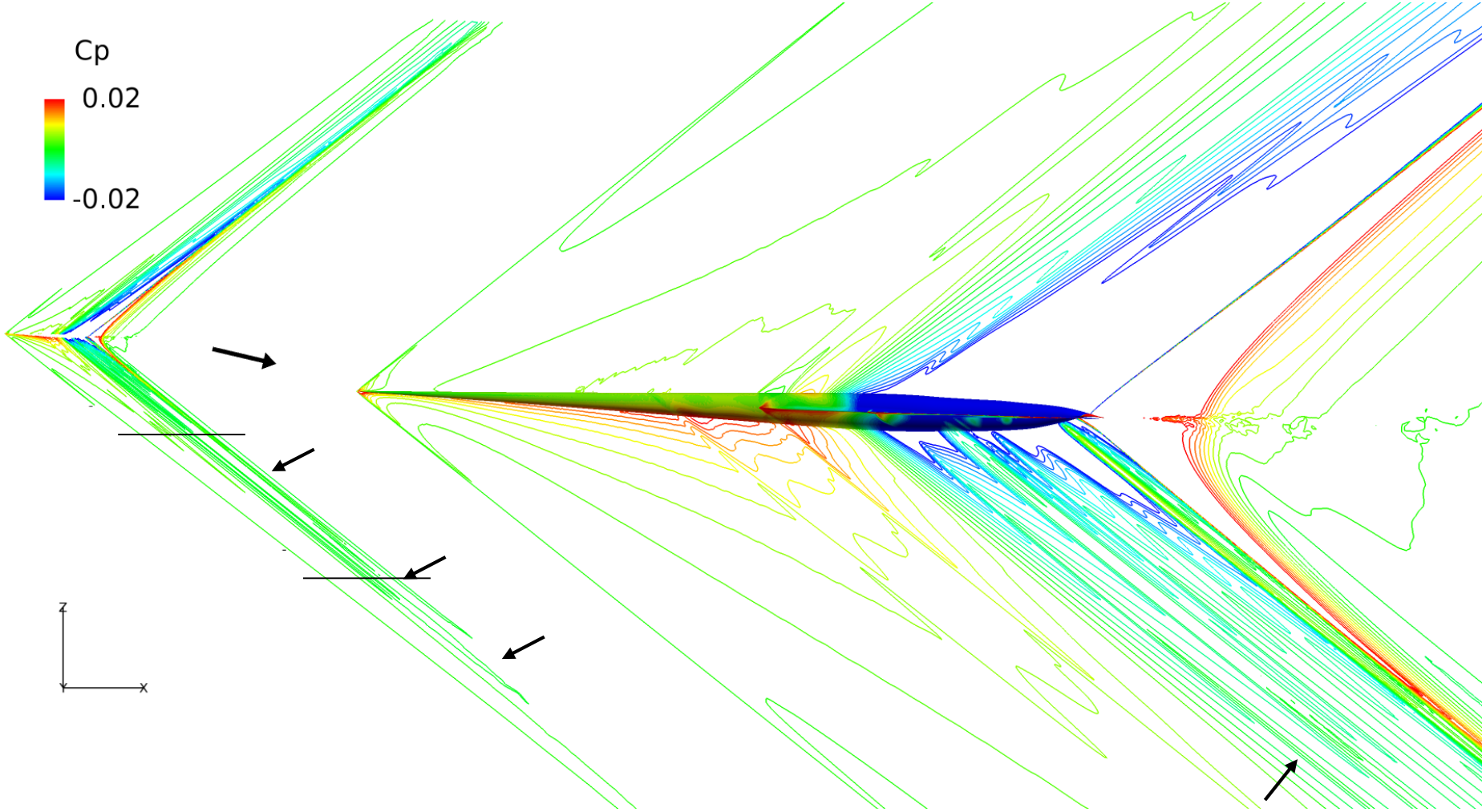
Limiter factor, K

K	Stability	Accuracy	Provided data
1	Low	High	JWB
0.1	⇕	⇕	
0.01			C25D
0.001	High	Low	AXIE

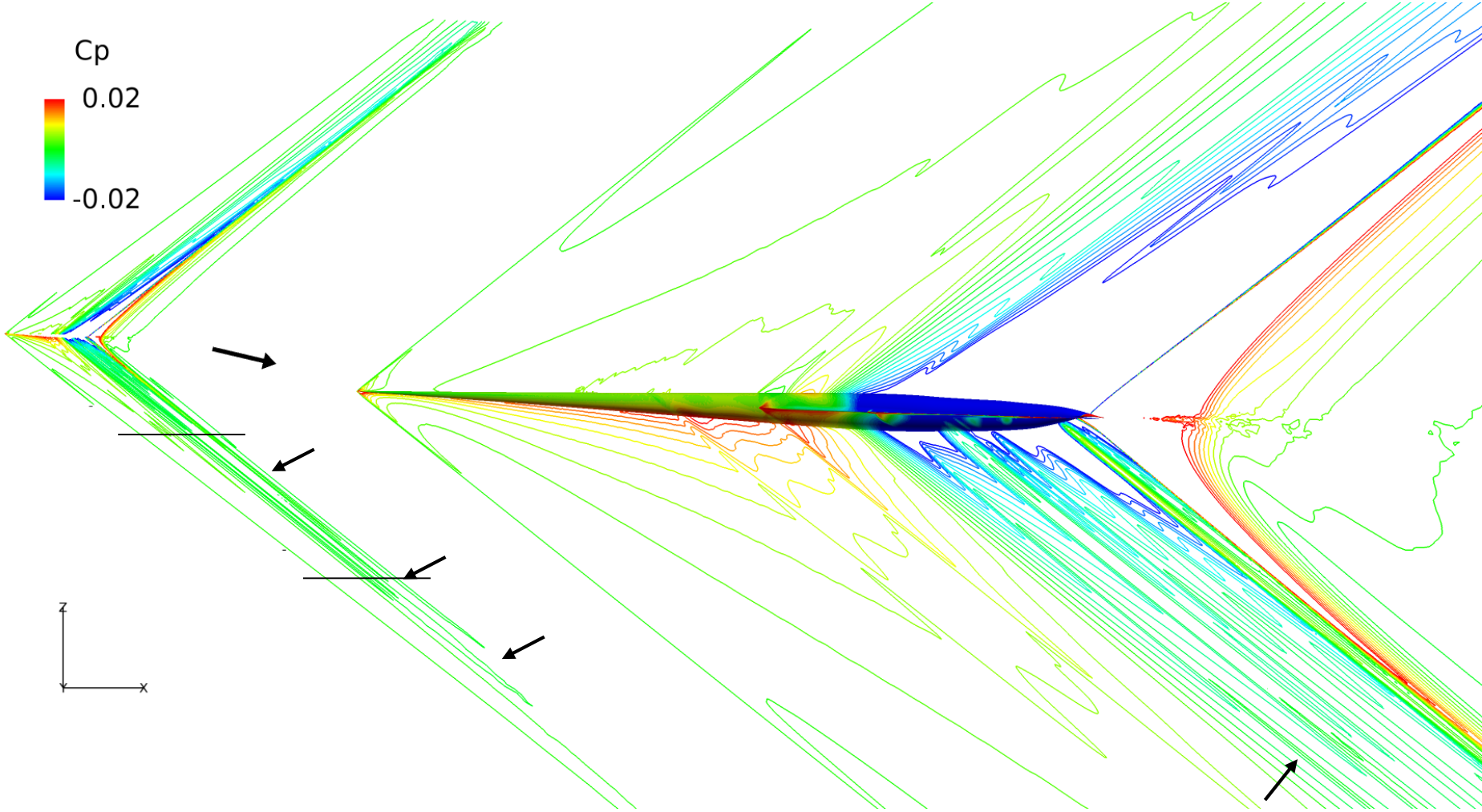
Limiter Function



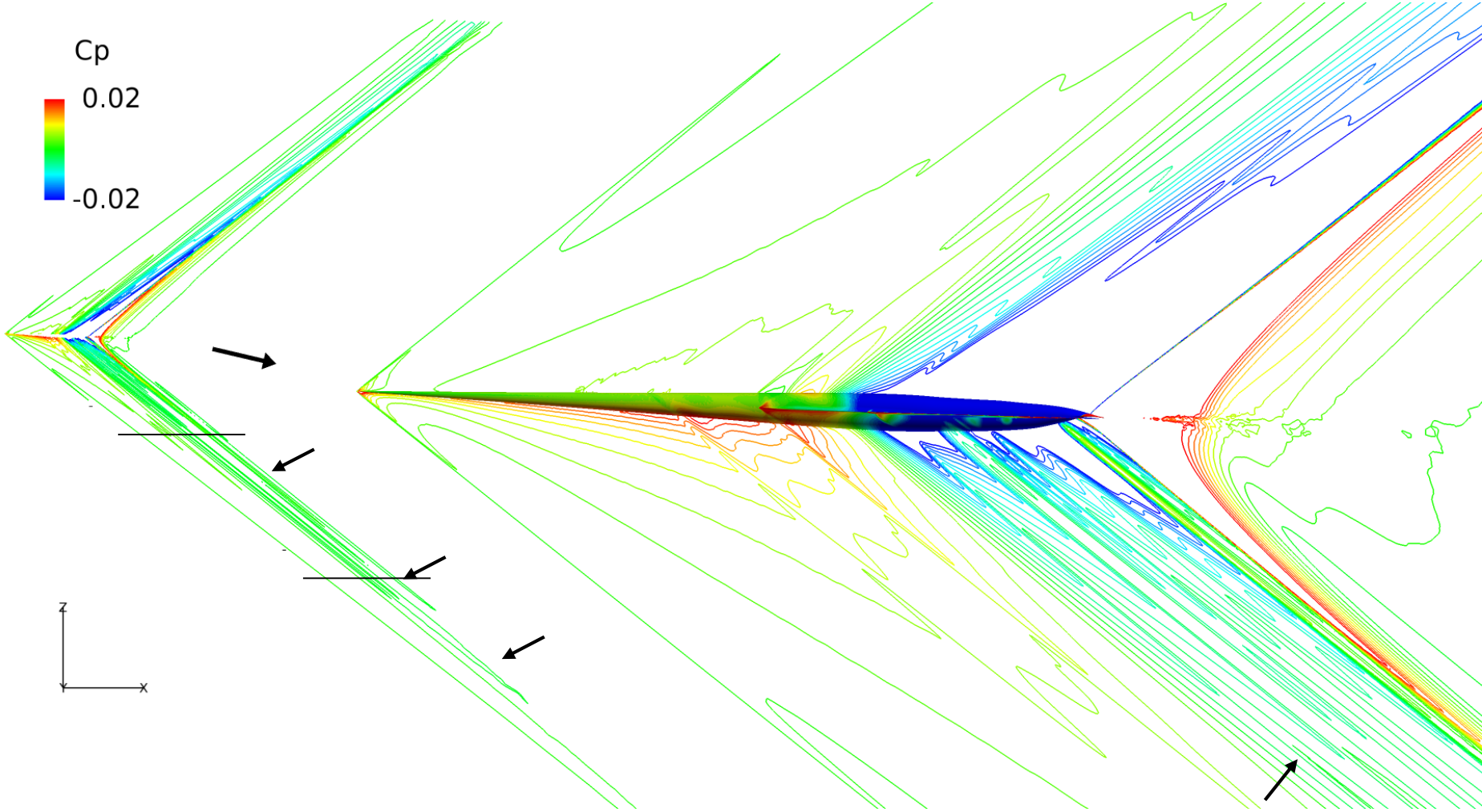
Limiter Function :K=1.0



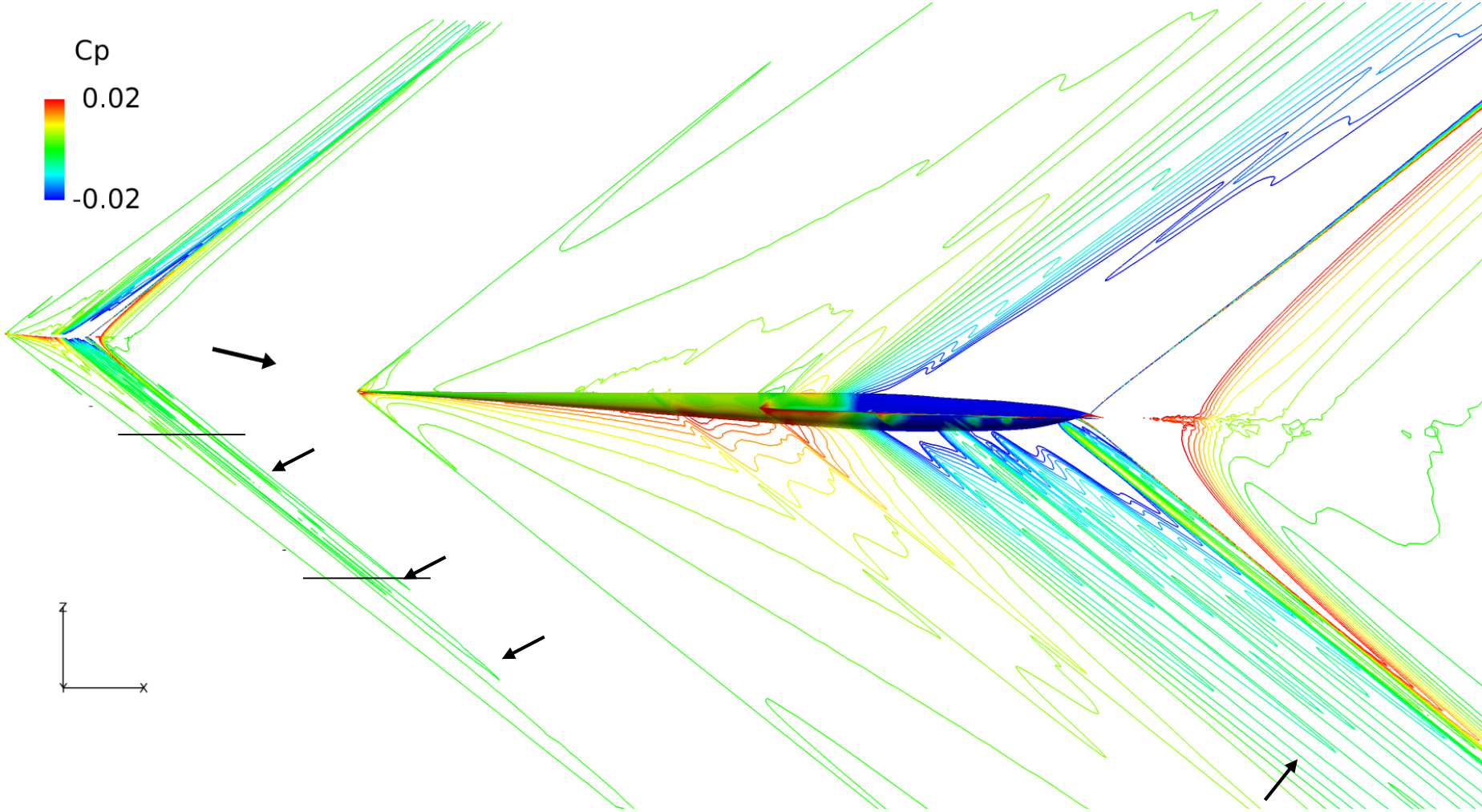
Limiter Function :K=0.1



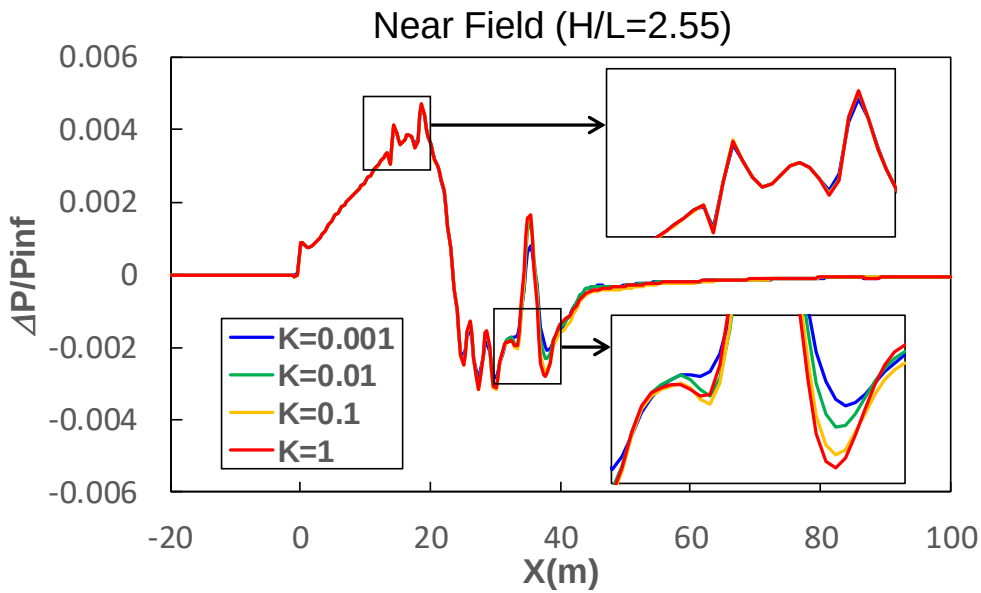
Limiter Function :K=0.01



Limiter Function :K=0.001



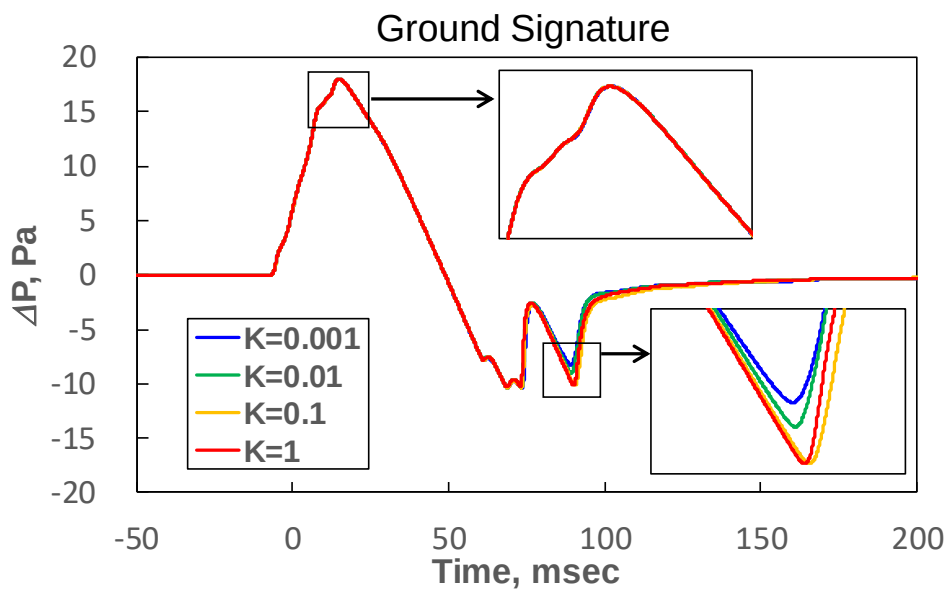
Limiter Function

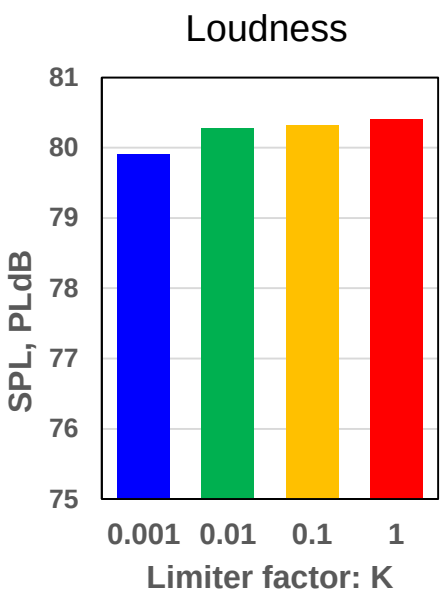


Front shocks → same

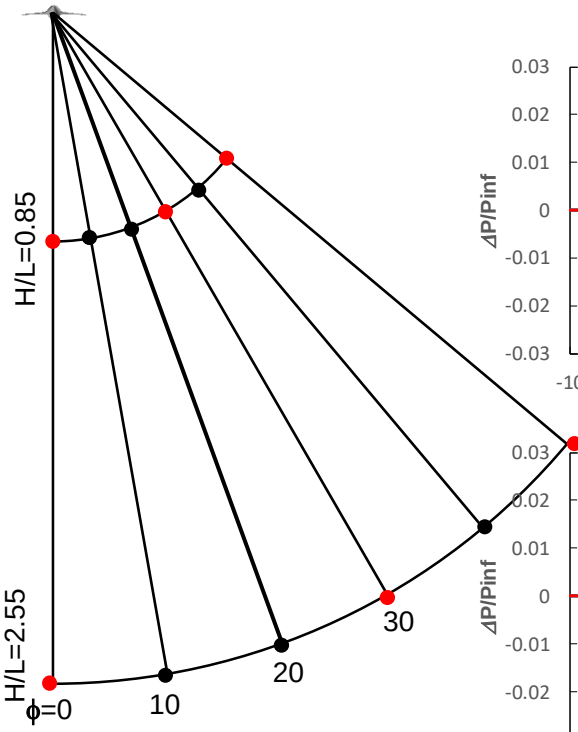
Aft shocks → different
K=0.001 → blunt
K=1 is sharp and same as K=0.1

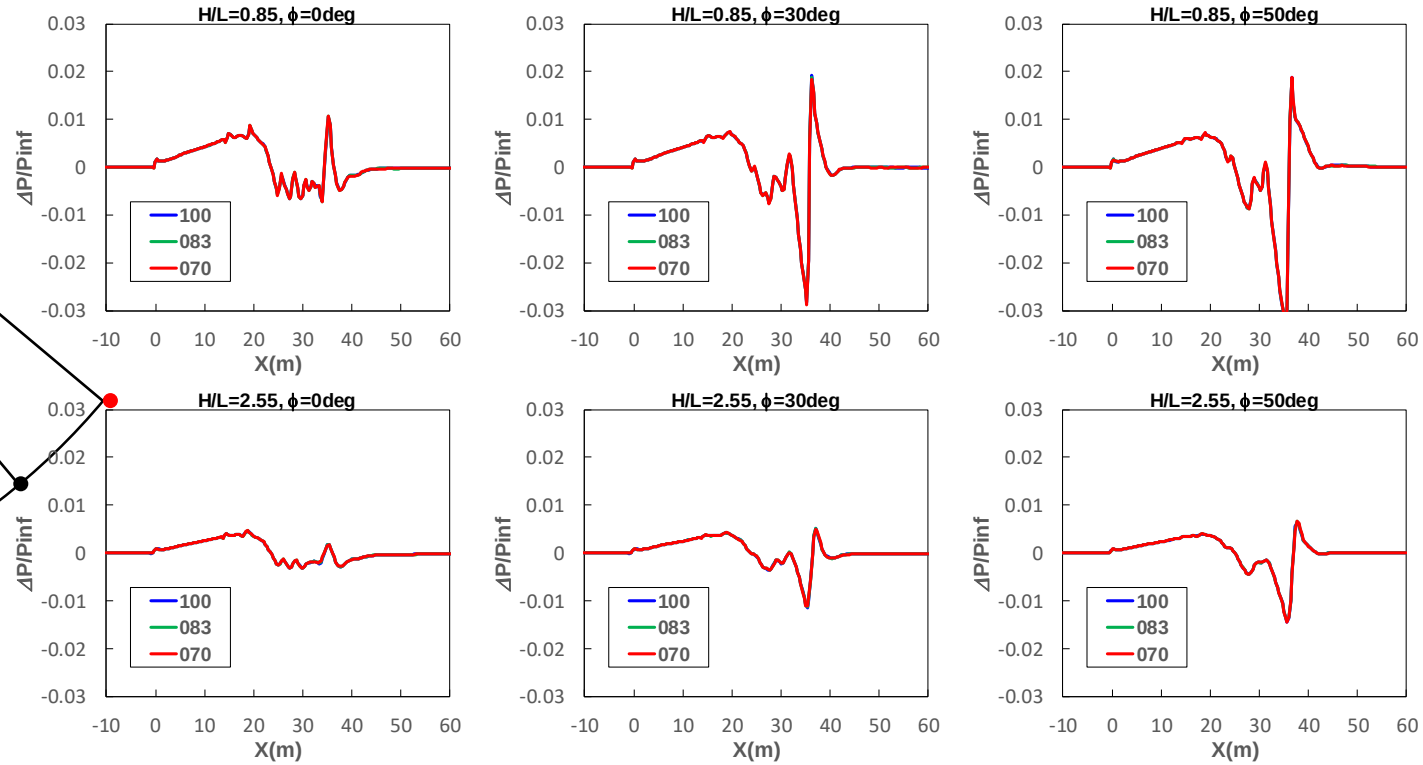
K=1 is used for JWB simulation.





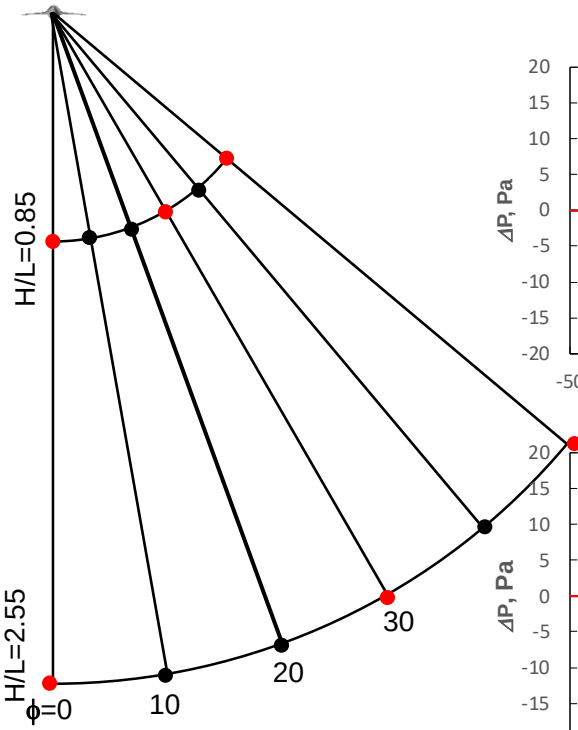
Near field



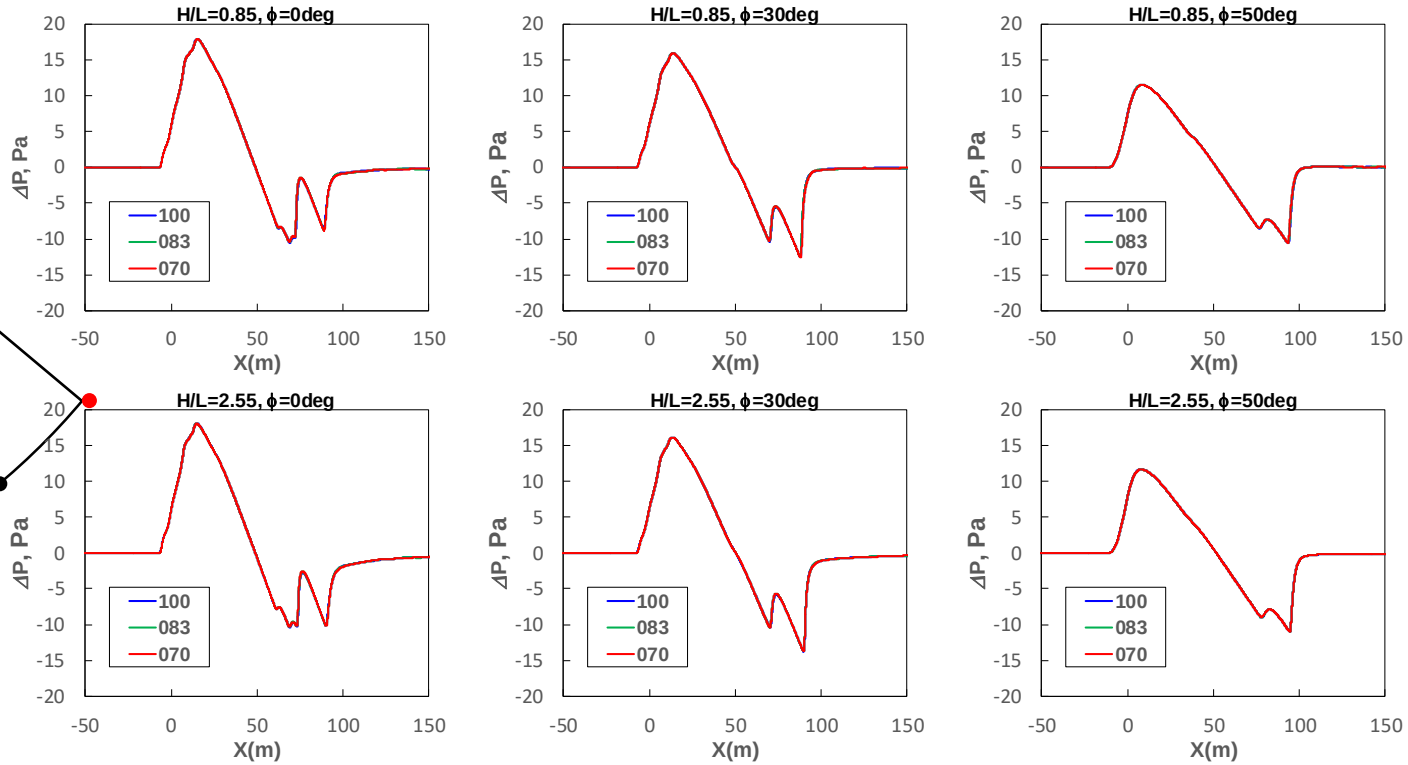


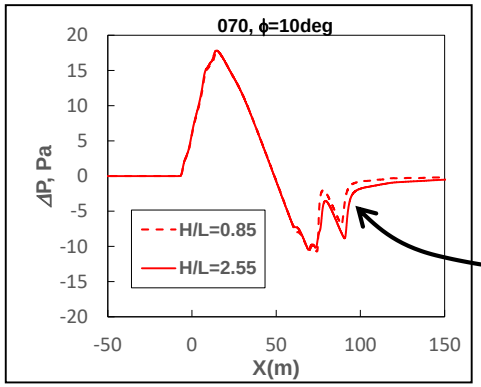
Grid dependency is not observed among 100 – 070.

Ground & Loundness

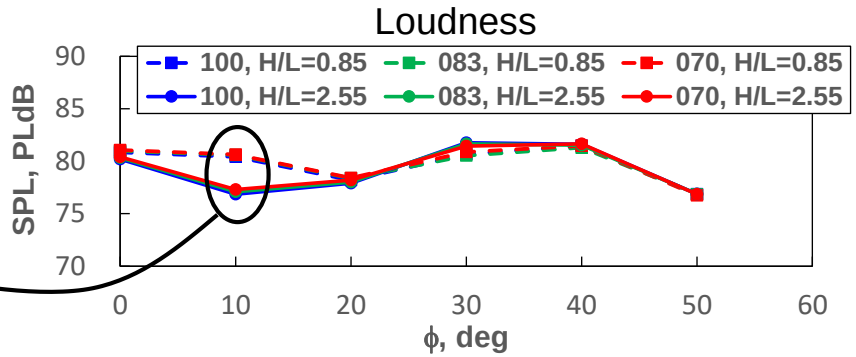


Ground Signature



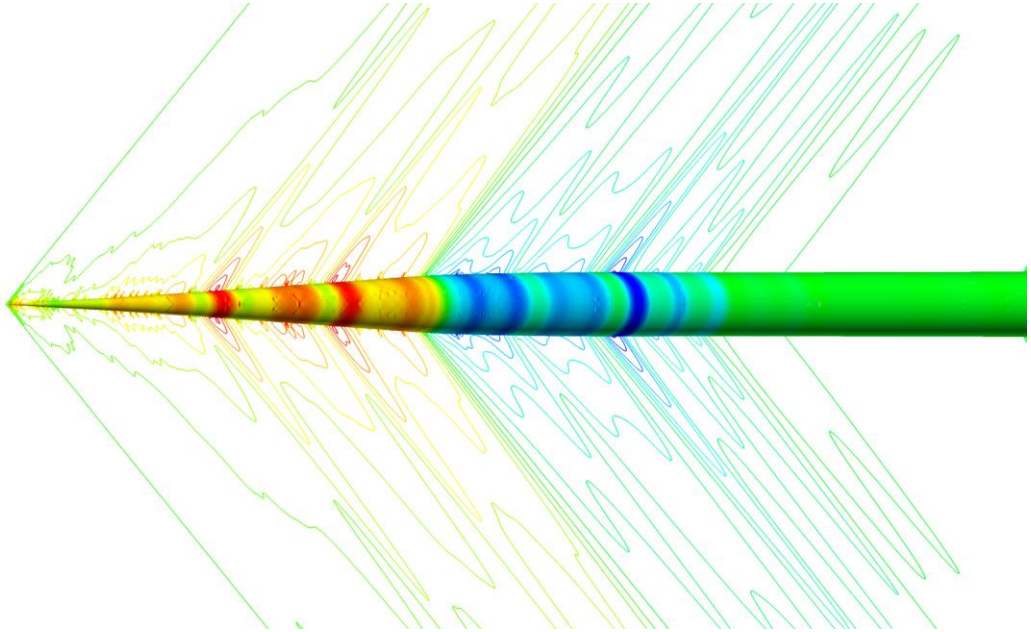


Loudness

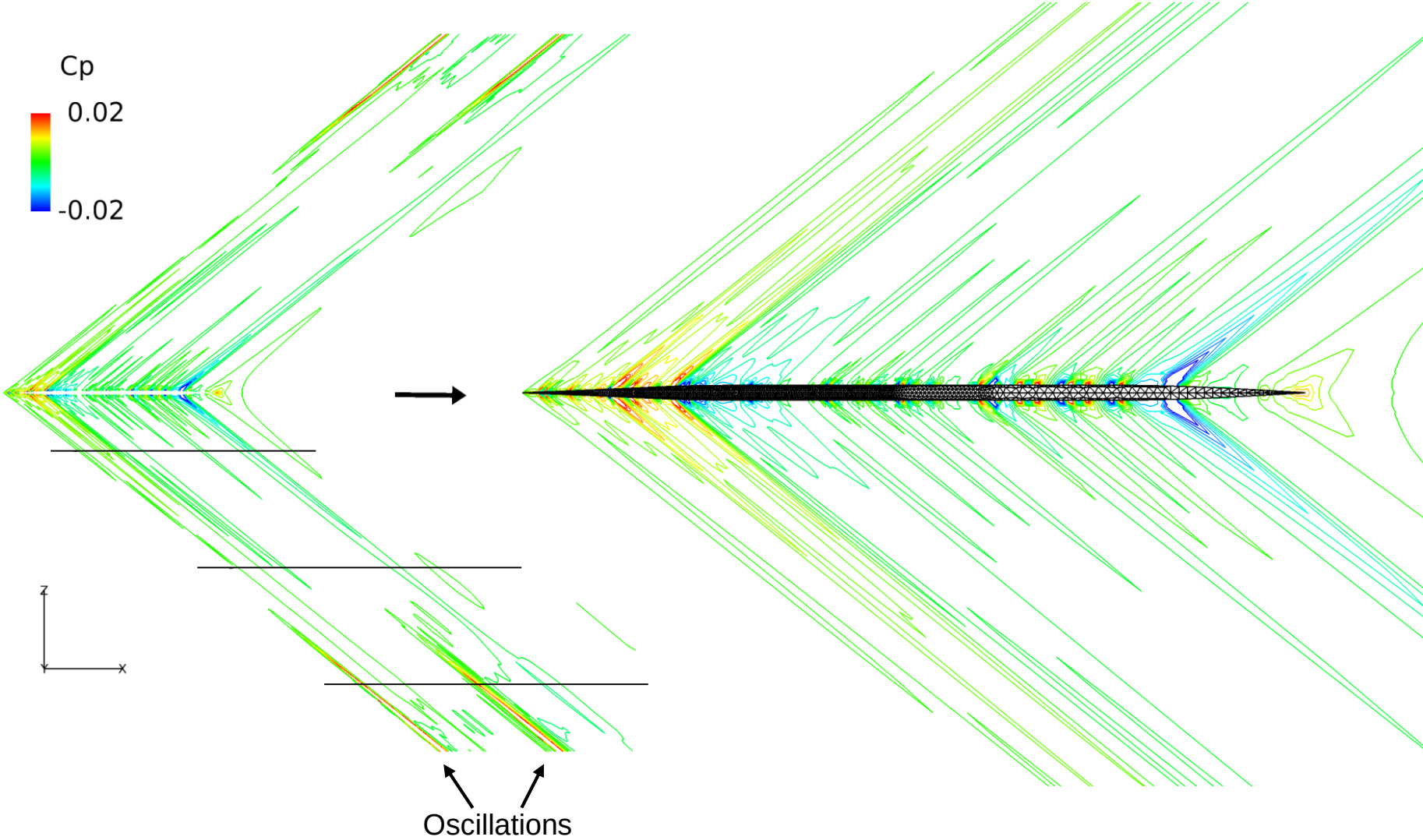


AXIE

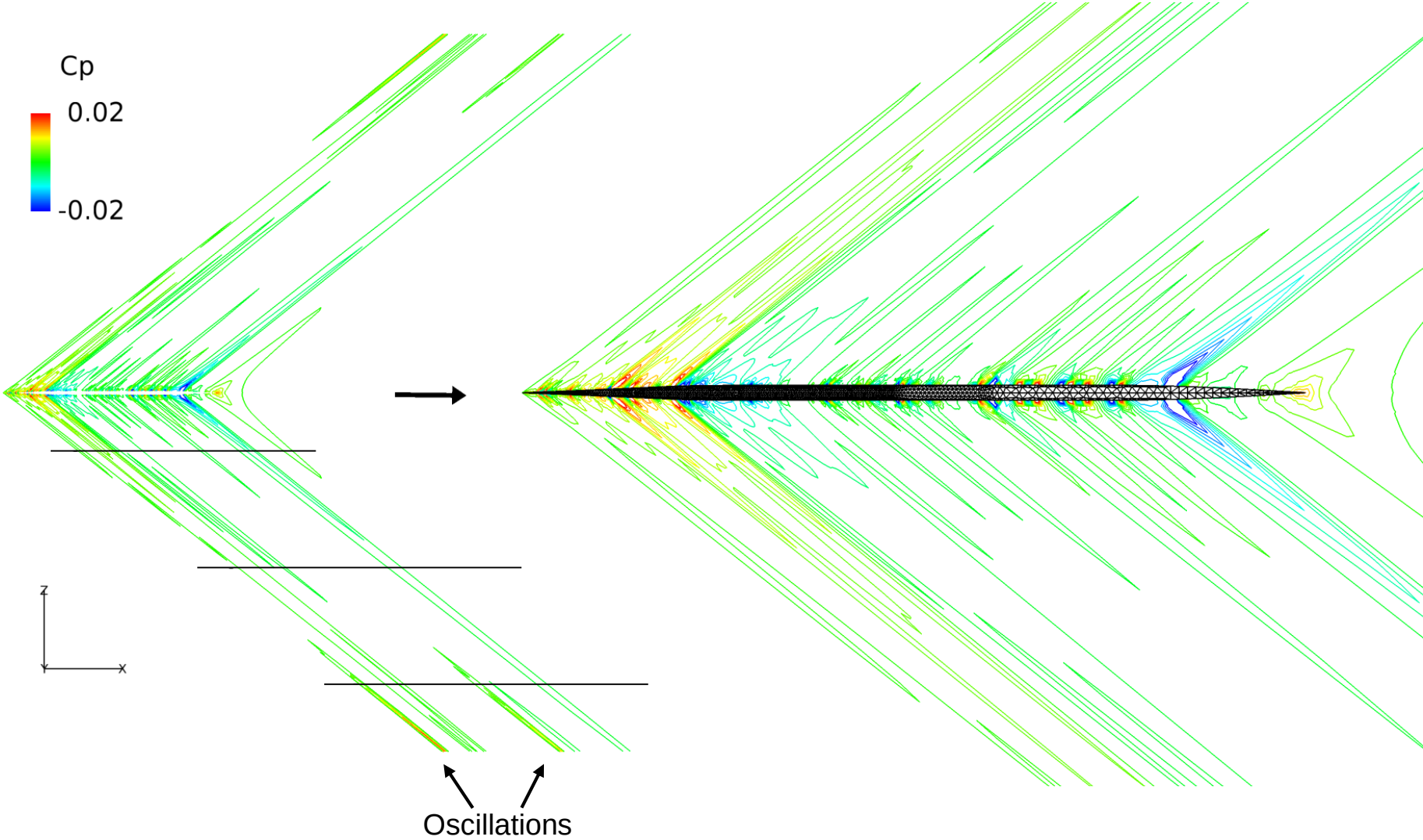
Model	Providor	viscousity	mesh	Grid Spacing(Resolution)				
axie	SBPW	inviscid	mixed	2.56	2	1.6	1.28	1
			tetrahedra	2.56	2	1.6	1.28	1



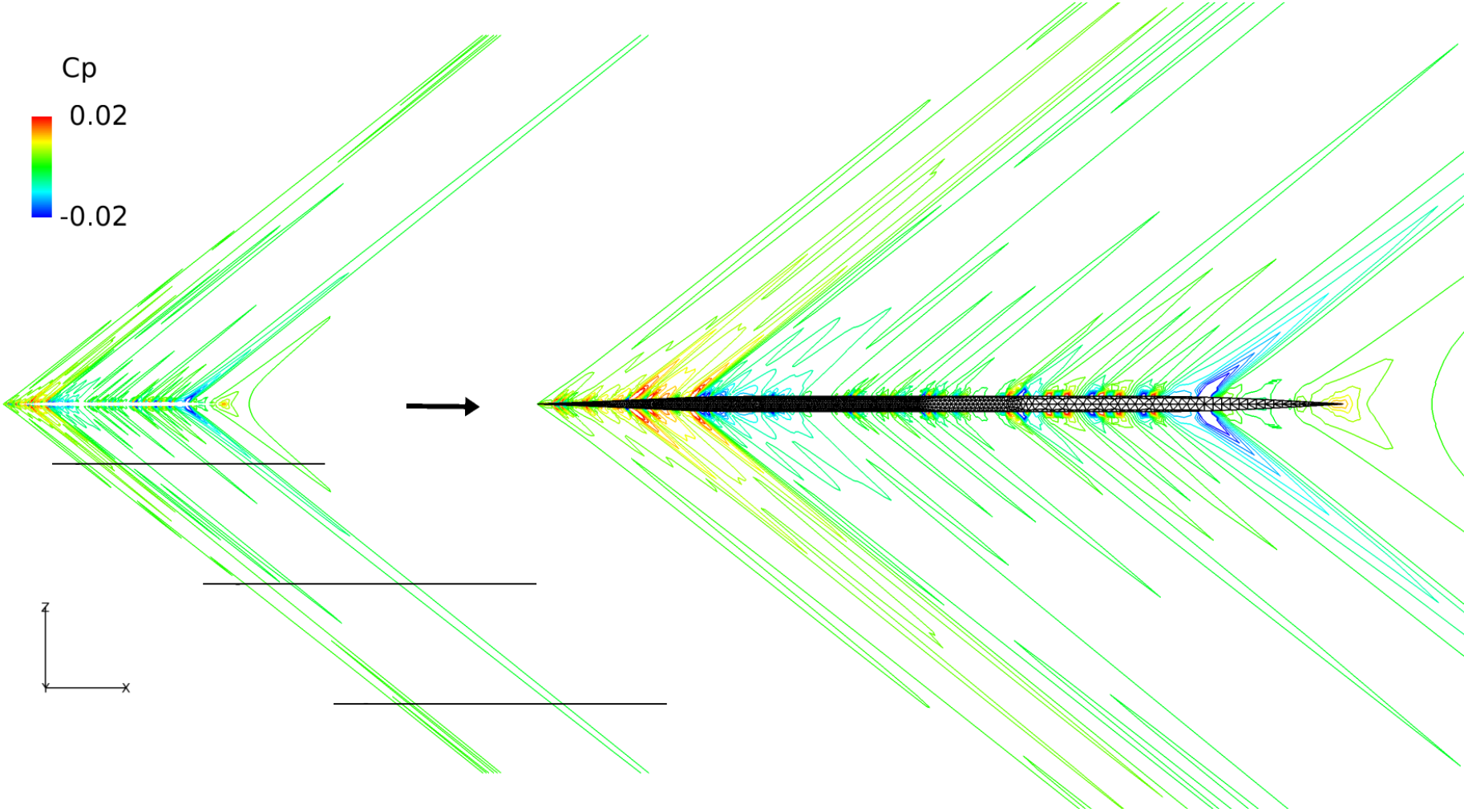
Limiter Factor, K=0.1



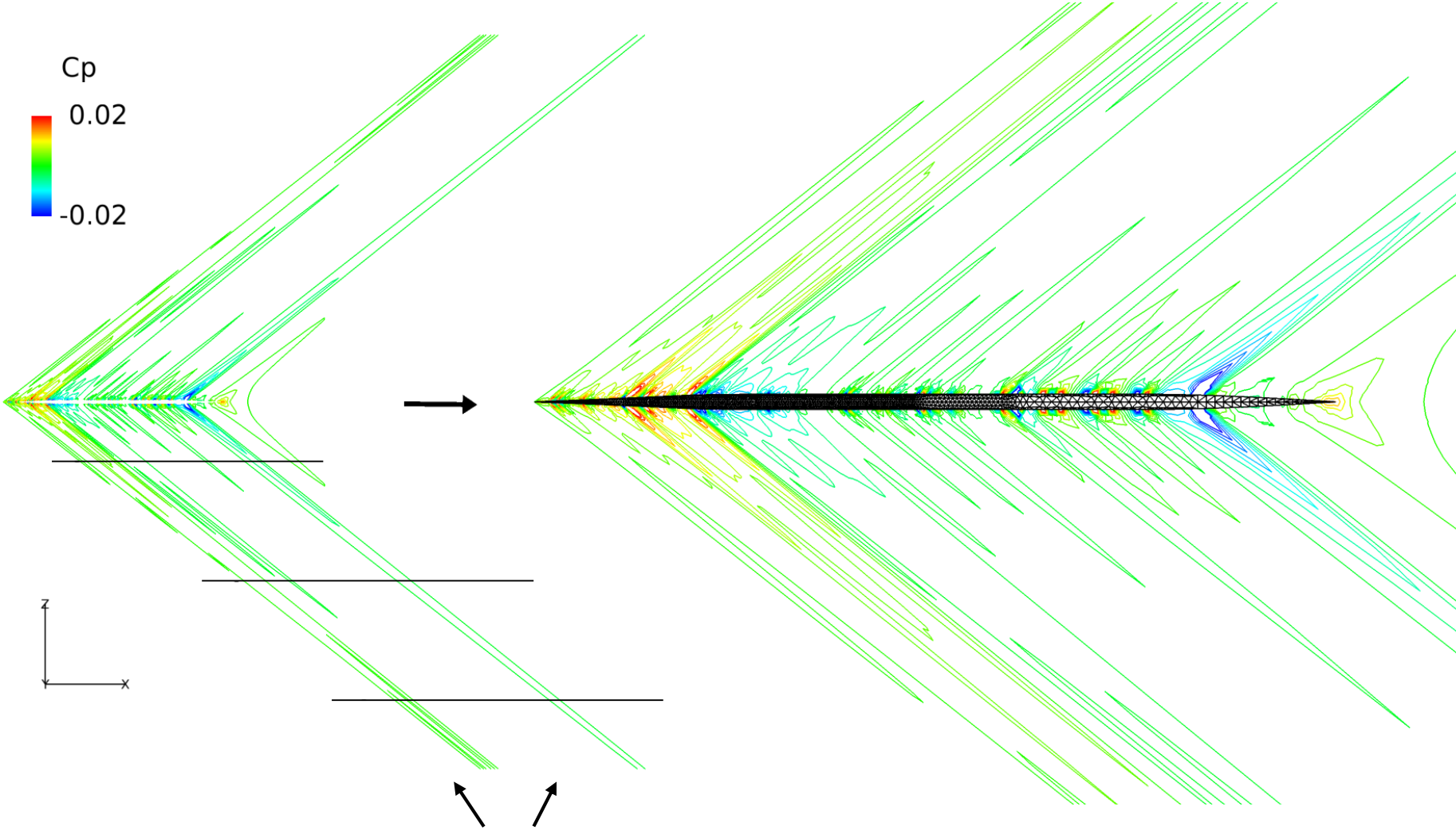
Limiter Factor, K=0.05



Limiter Factor, K=0.01

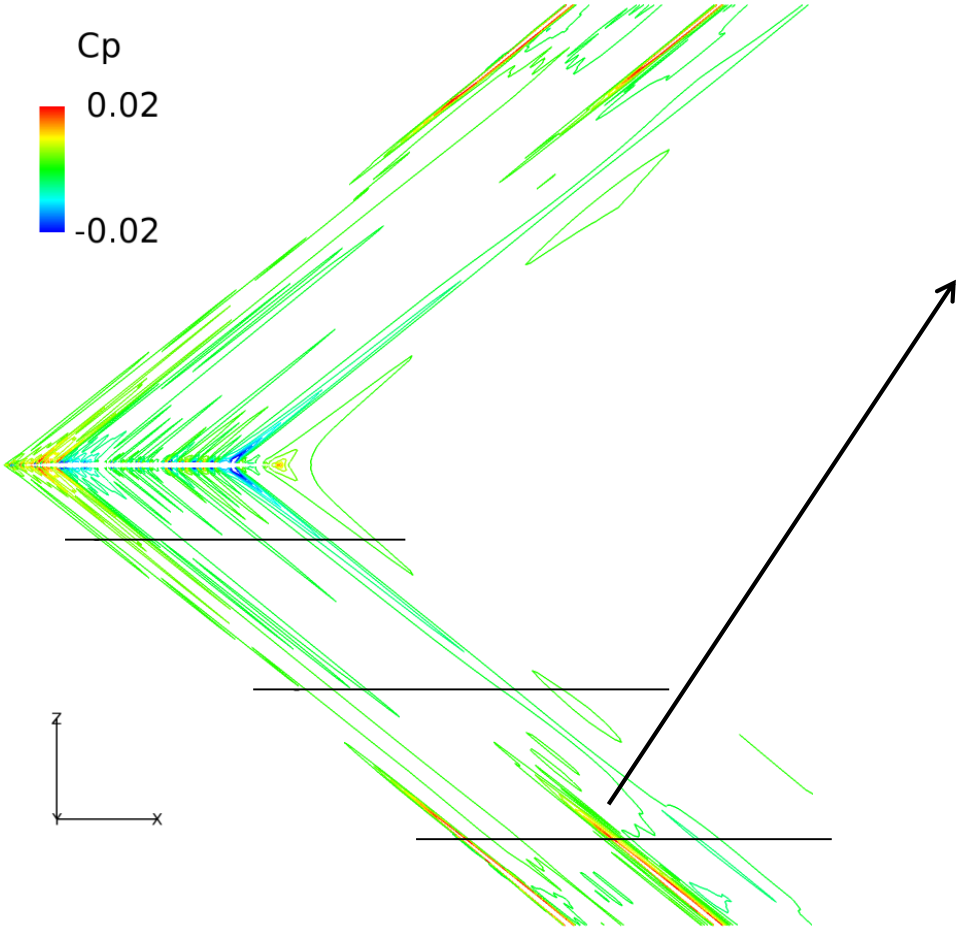


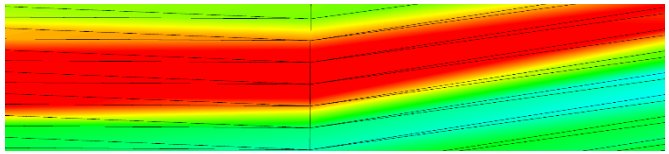
Limiter Factor, K=0.001

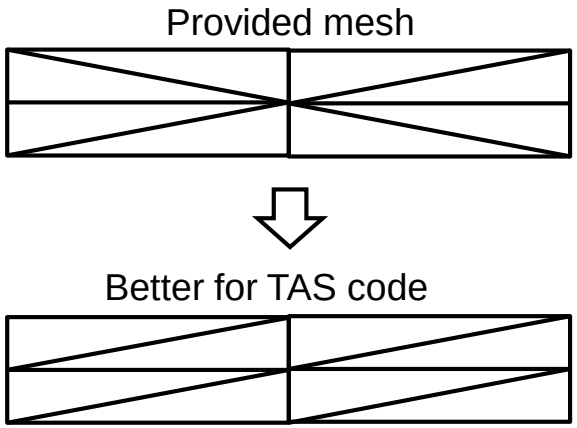


Oscillations disappear.
K=0.001 is used for AXIE.

axie-inv-mixed-256, K=0.1

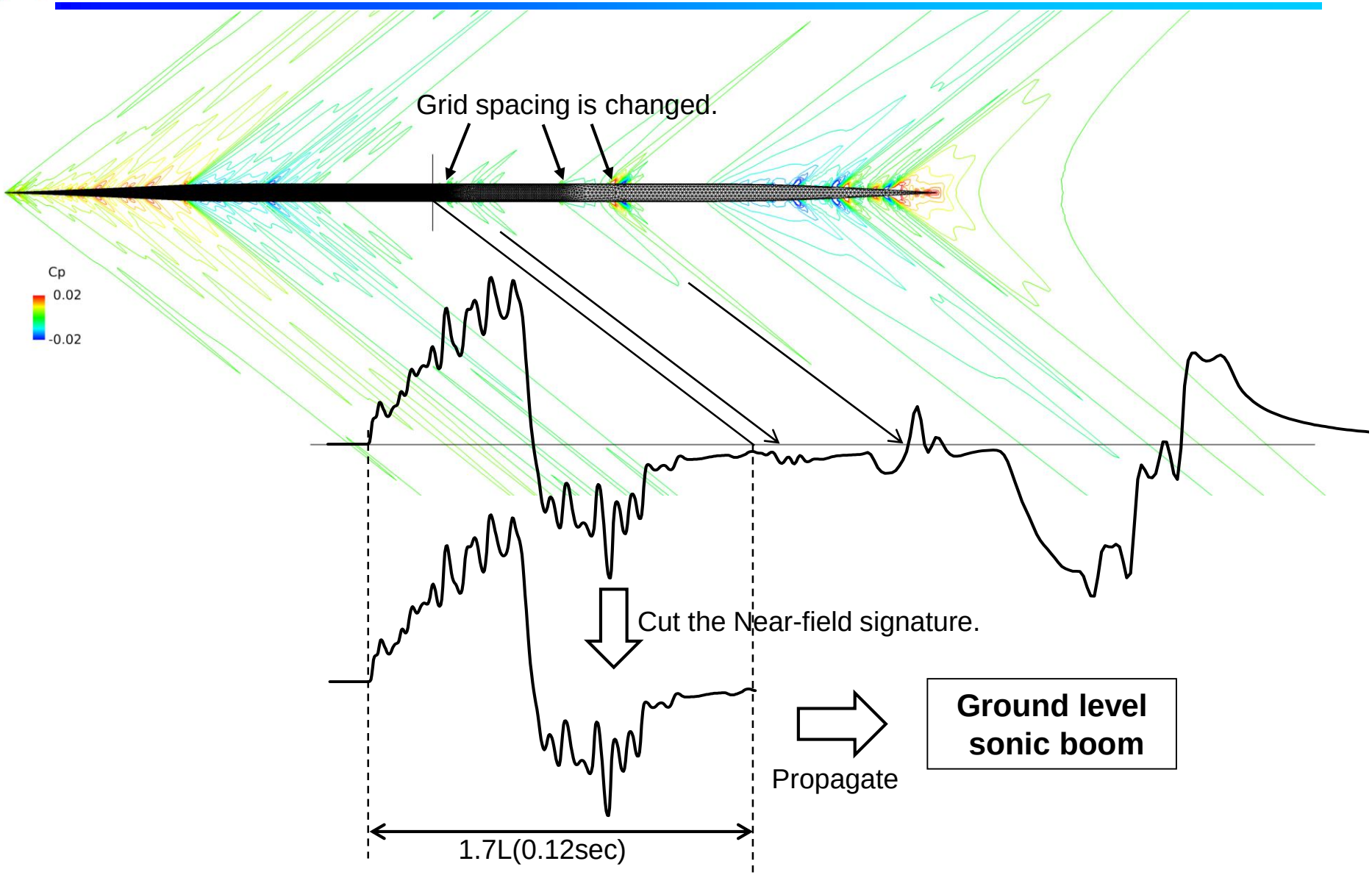






TAS code is sensitive for mesh quality.
C25D viscous and powered could not be solved using provided grid from SBPW2.

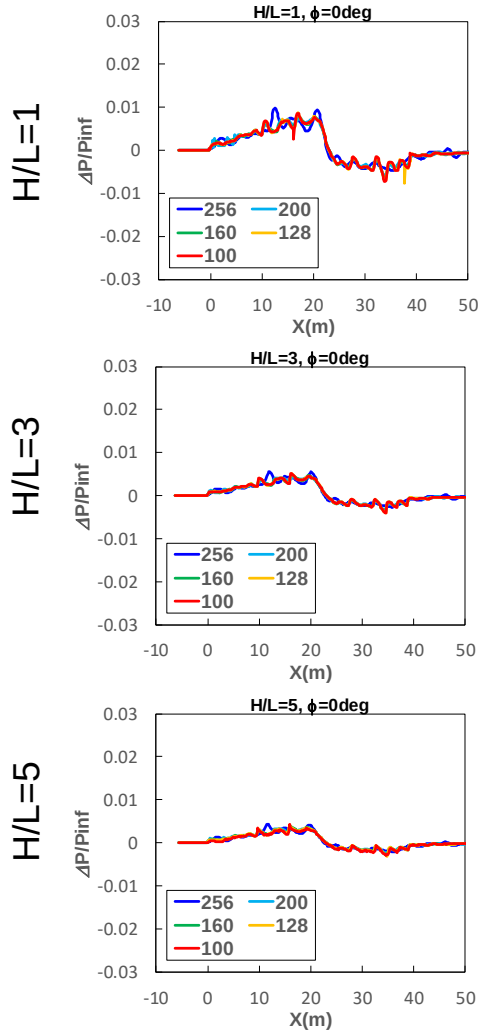
Near Field → Propagation



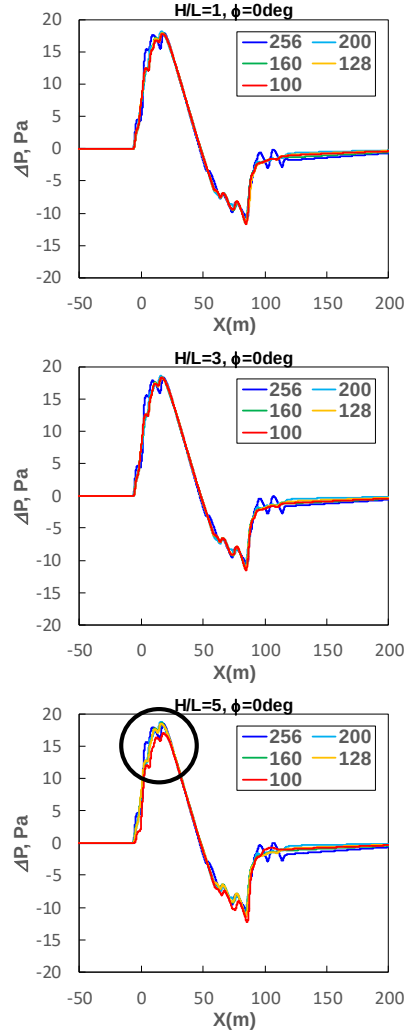
Near-field & Ground (ϕ=0deg)

Mixed

Near-field

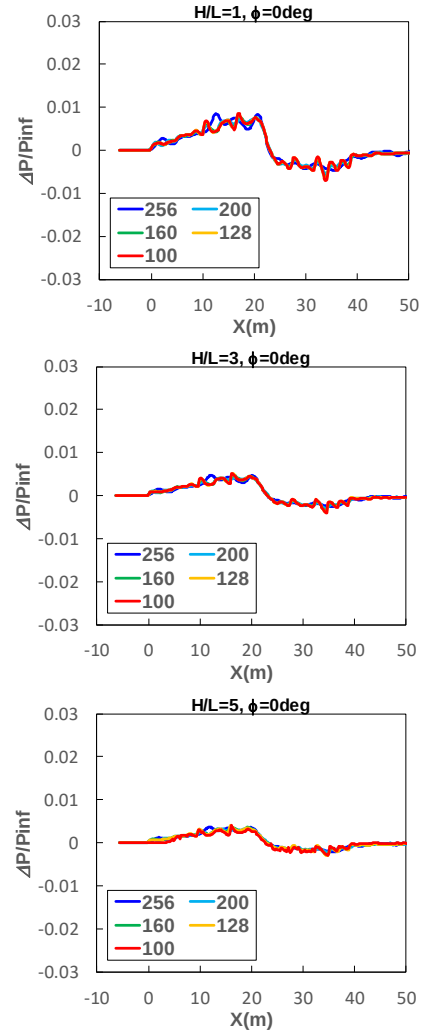


Ground

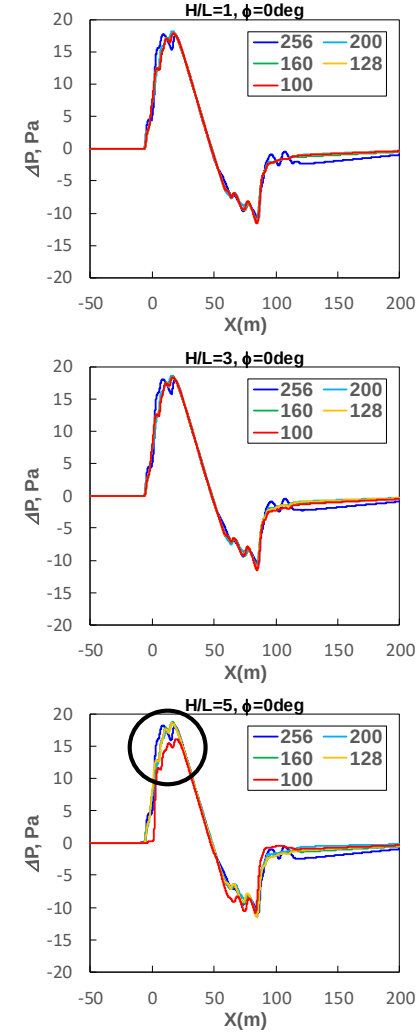


Tetra

Near-field

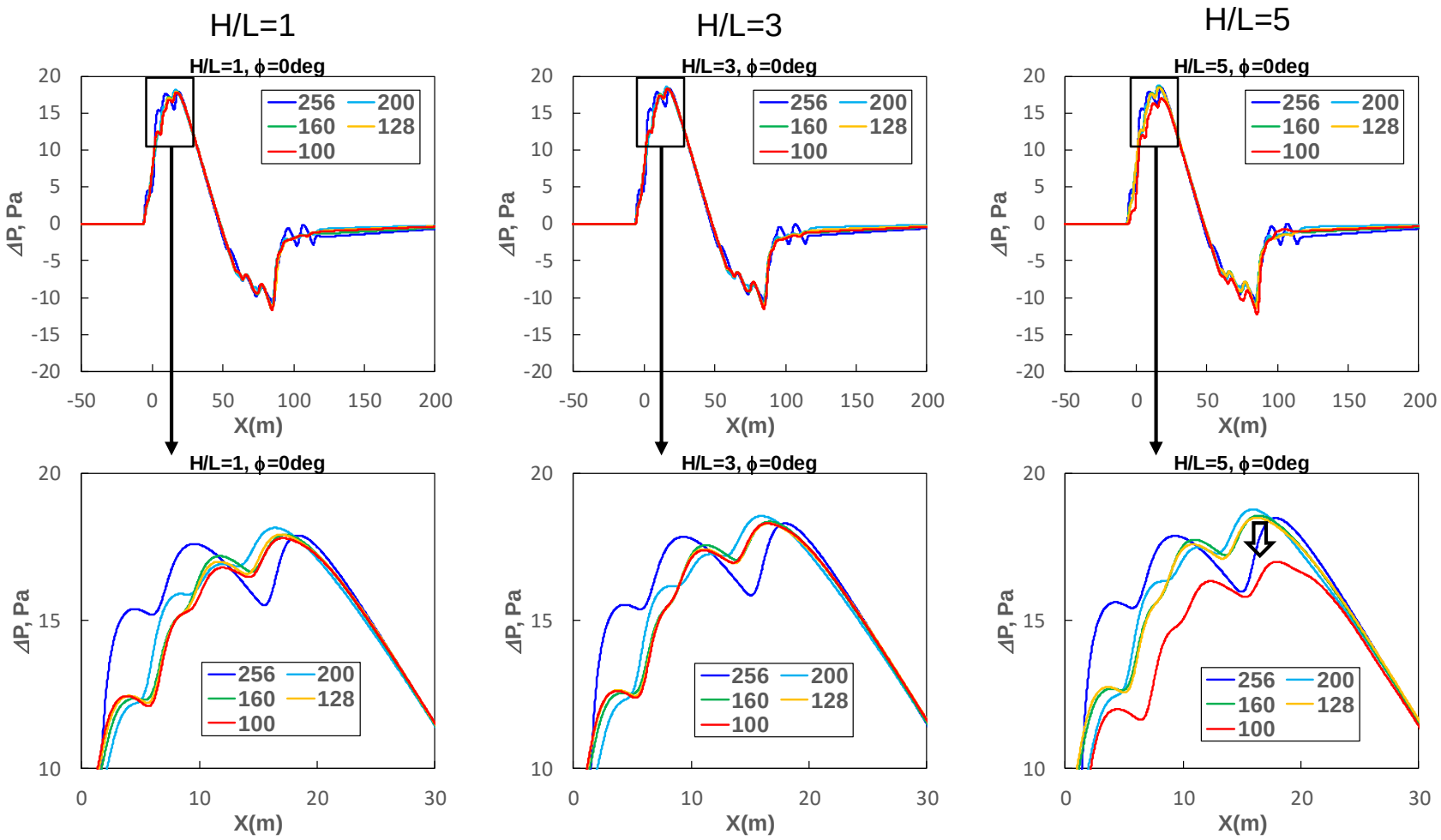


Ground



Mixed series have similar characteristics as Tetra series.

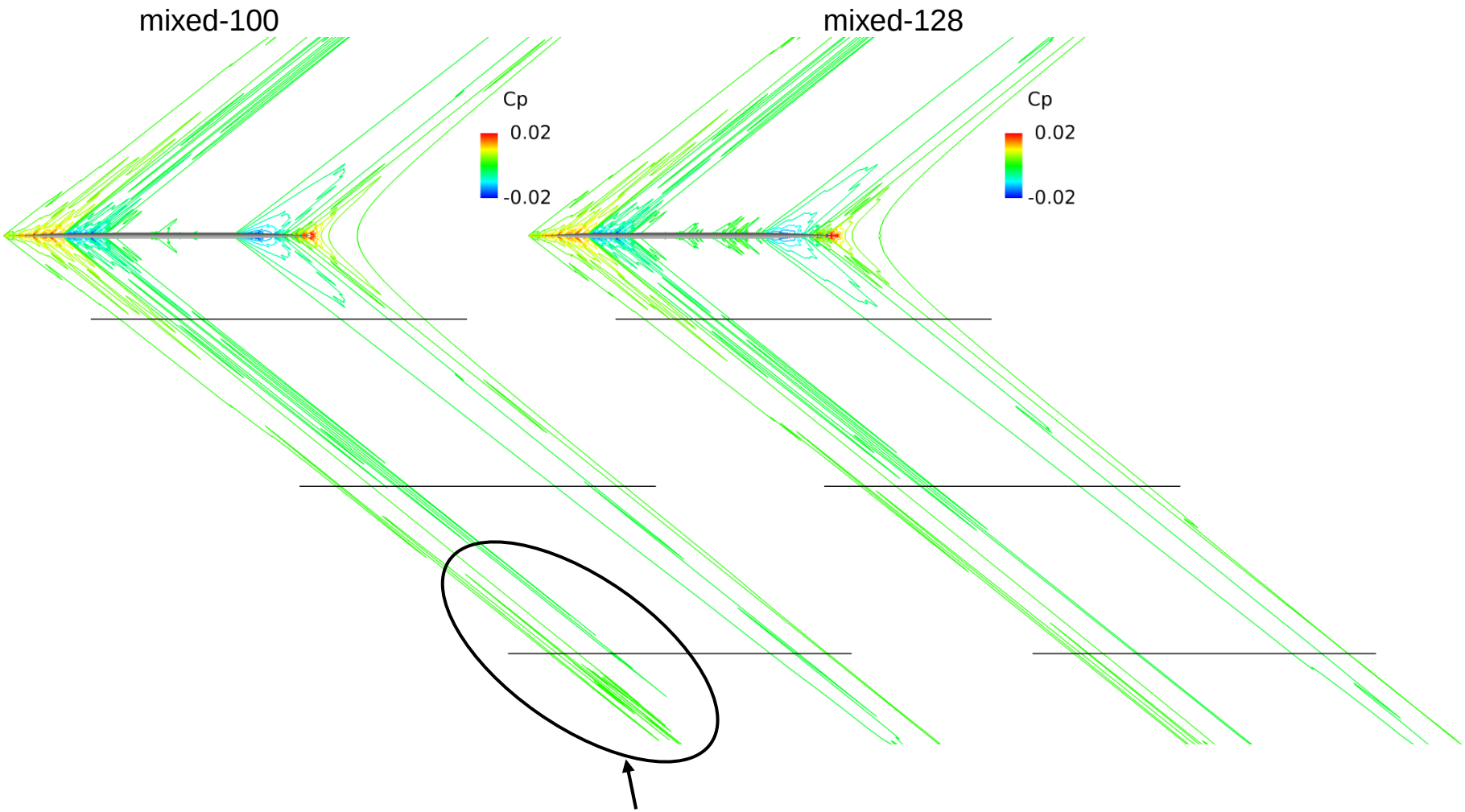
AXIE-mixed



100-160 are almost same. → converged

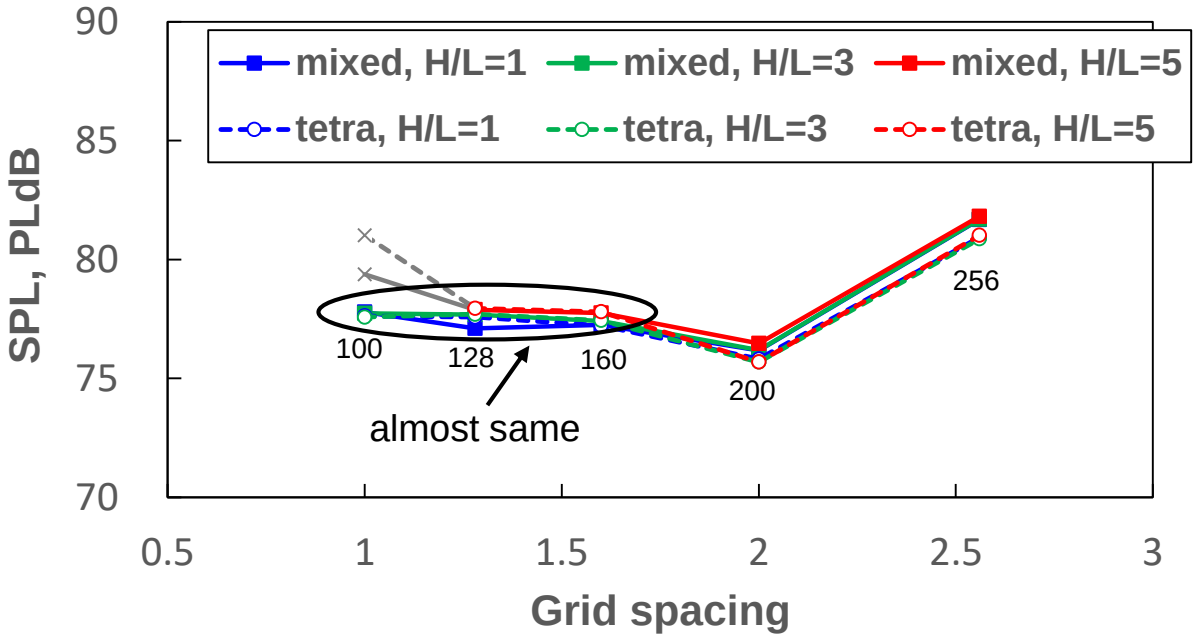
128-160 are almost same.
But 100 is different.

AXIE-mixed : 100 vs 128



Oscillations appear again even at K=0.001.

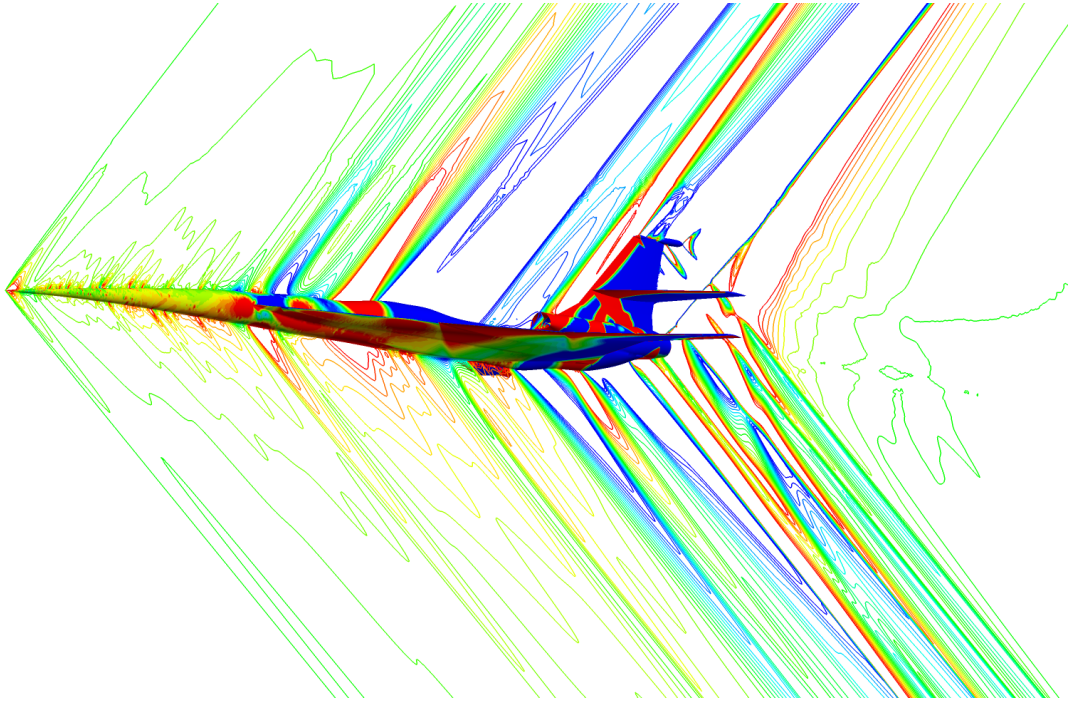
Loudness of AXIE



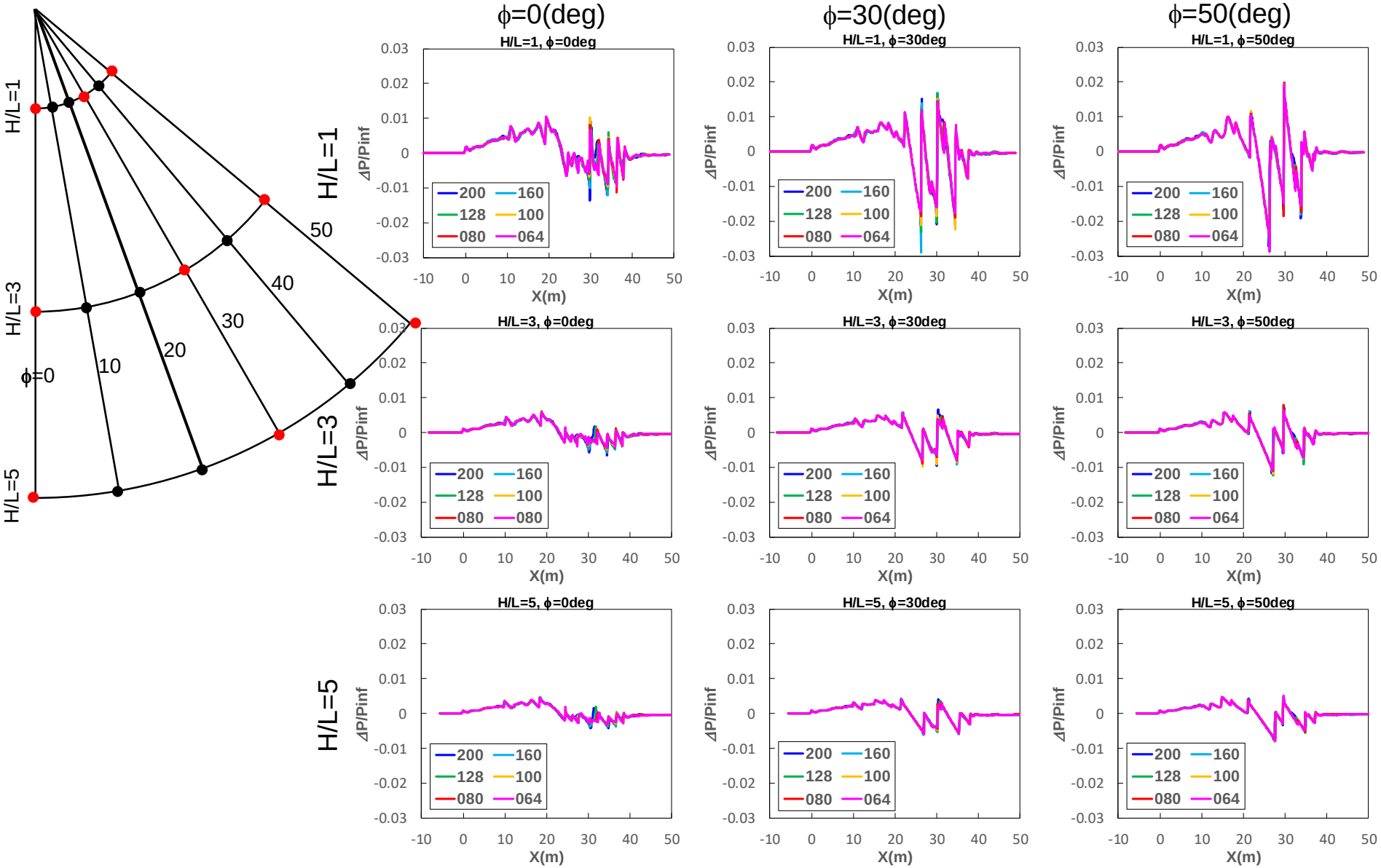
100-160 are almost same. → converged

C25D (Flow through)

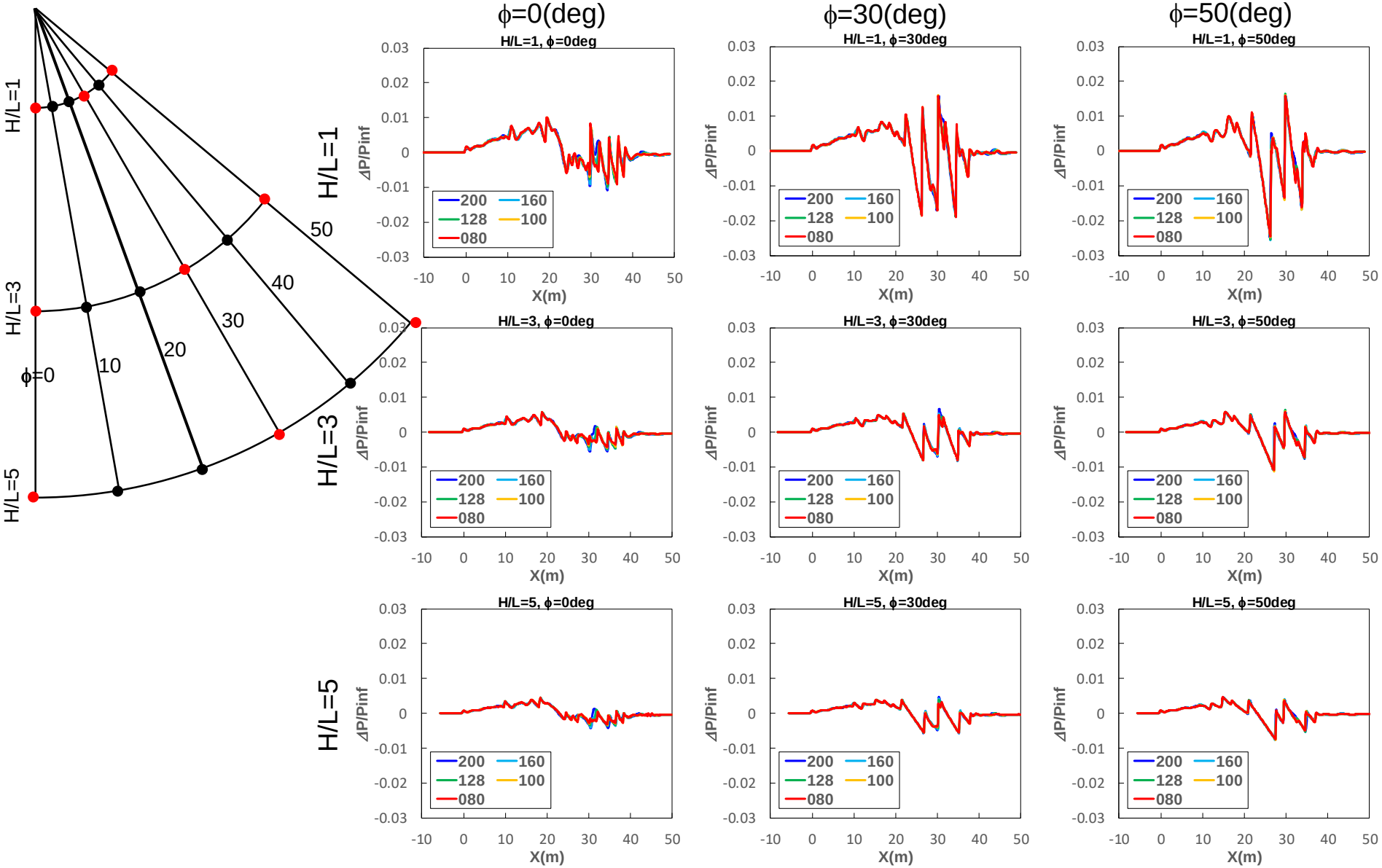
Model	Providor	viscousity	mesh	Grid Spacing(Resolution)					
c25d-flowthru	SBPW	inviscid	mixed	2	1.6	1.28	1	0.8	0.64
			tetrahedra	2	1.6	1.28	1	0.8	



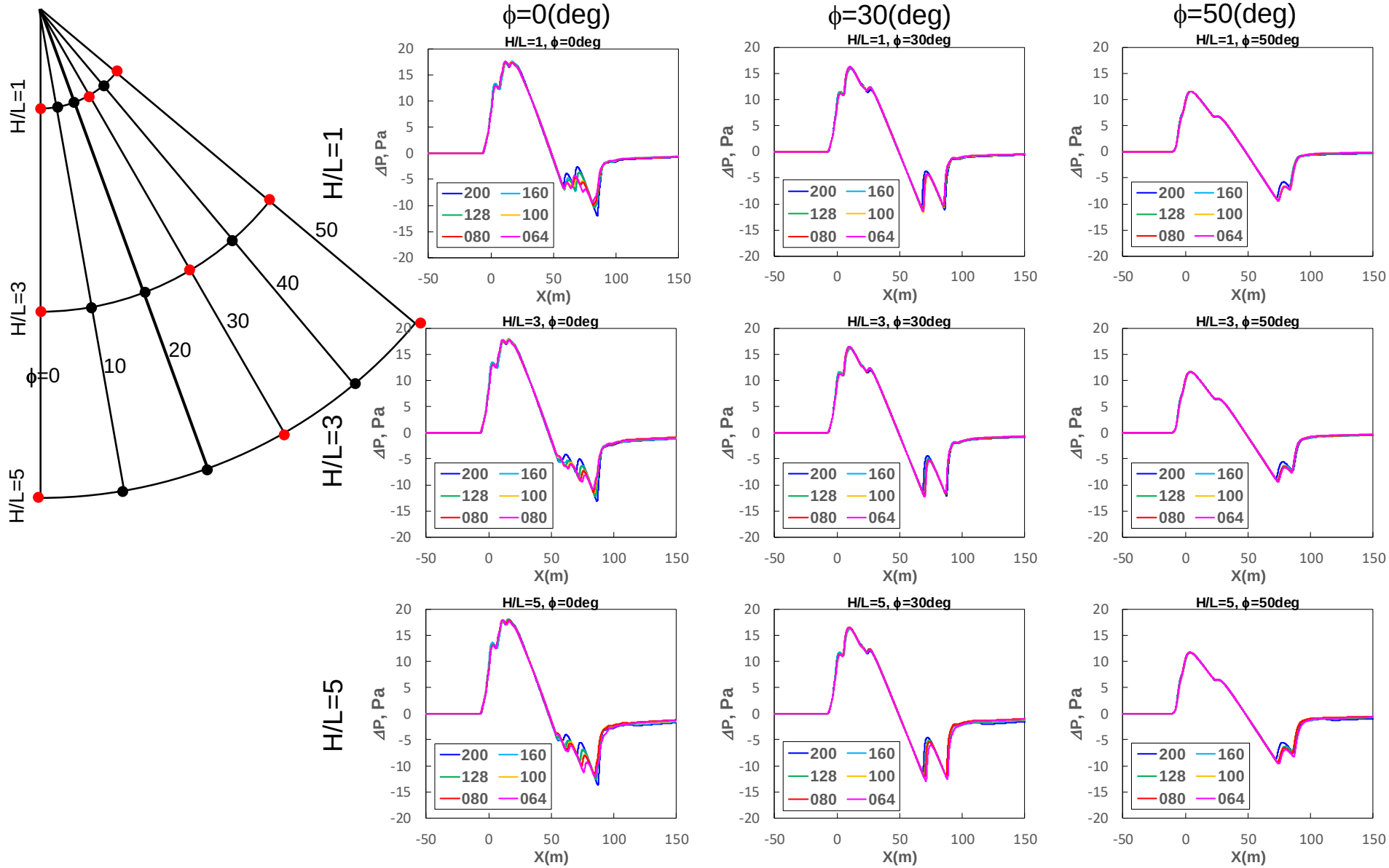
Near field: mixed



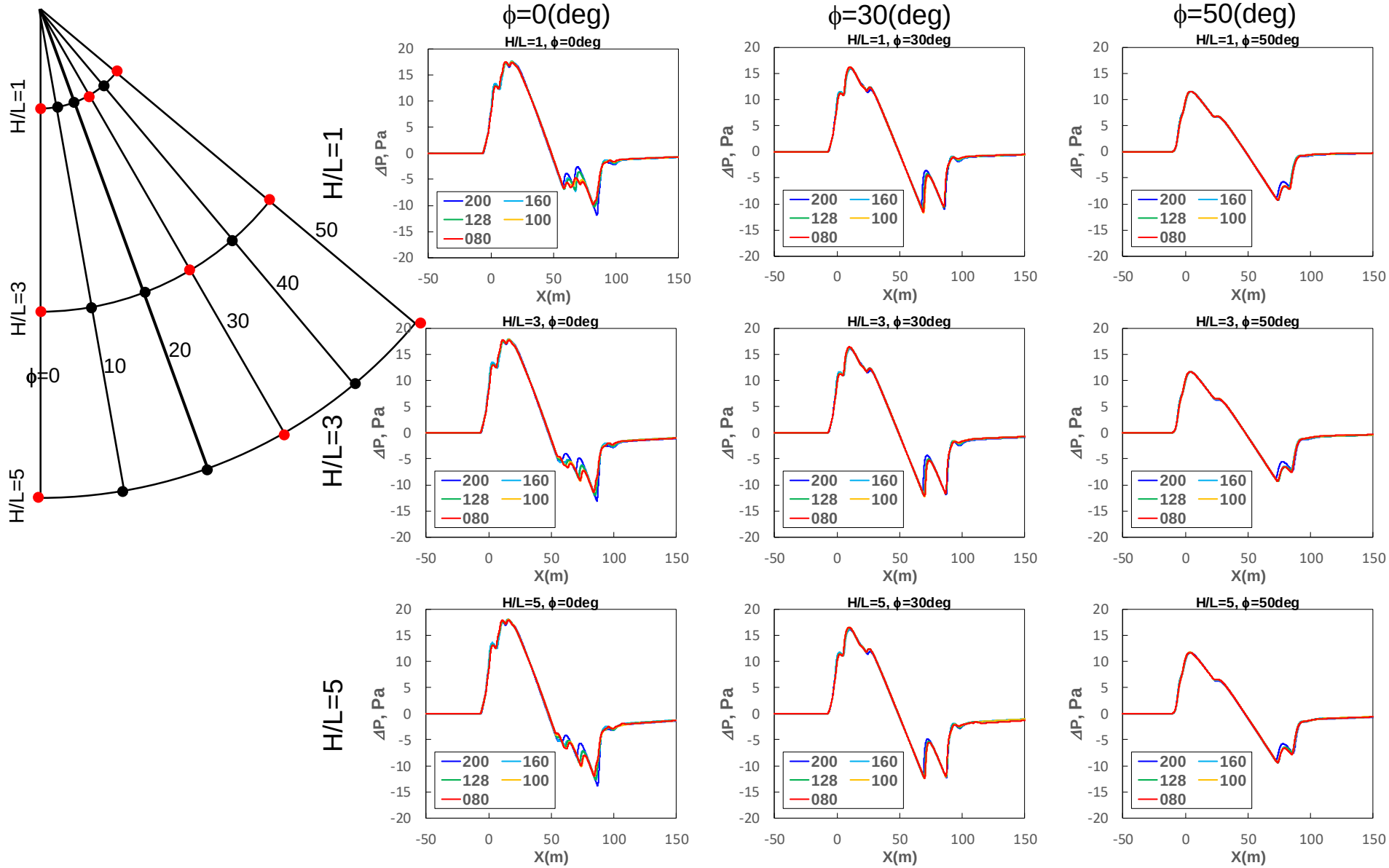
Near field: tetra



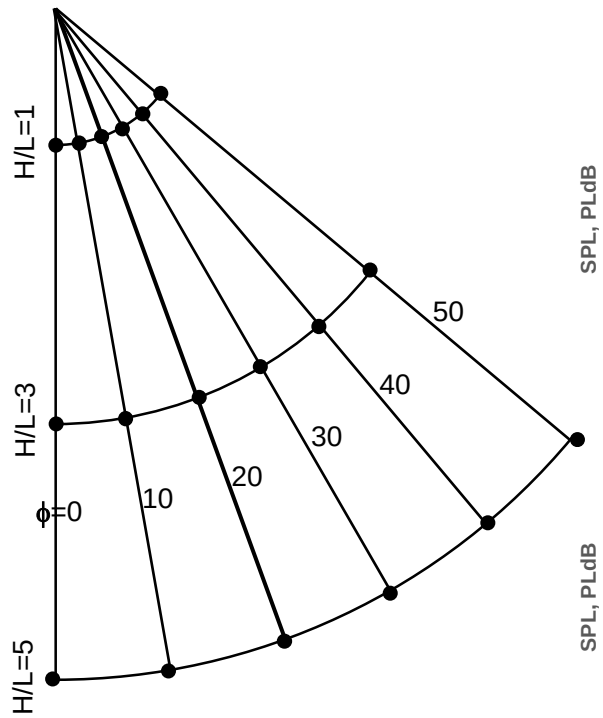
Ground: mixed



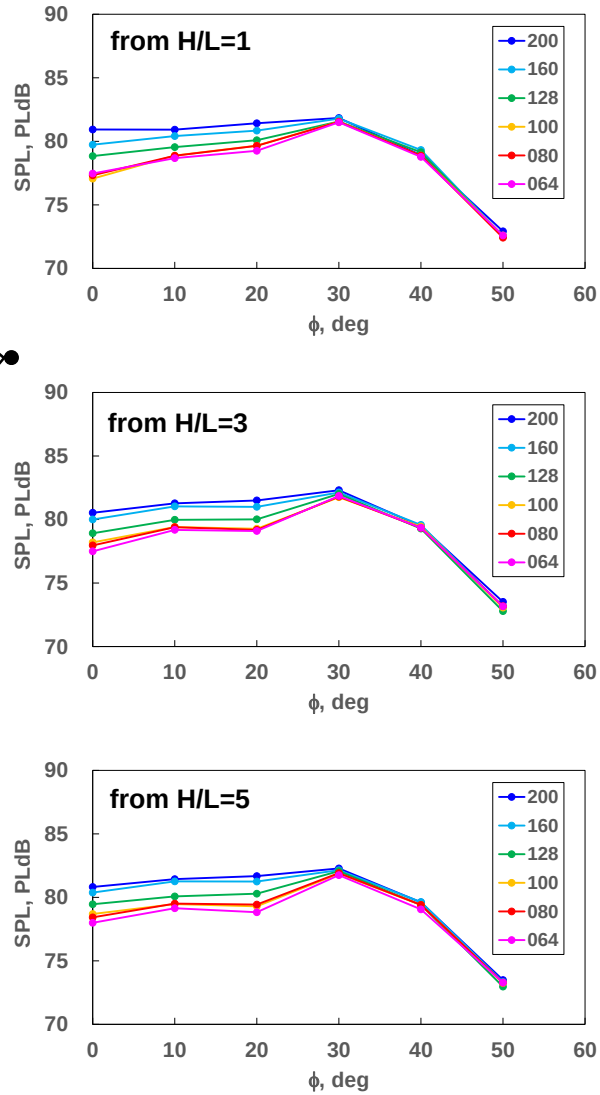
Ground: tetra



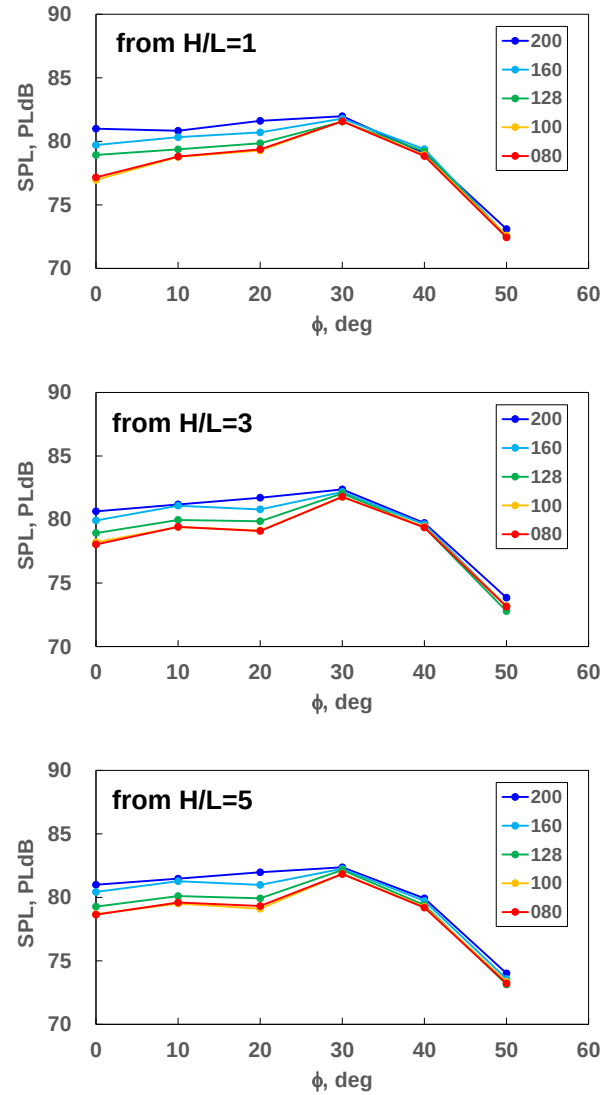
Loudness : Grid dependency



Mixed

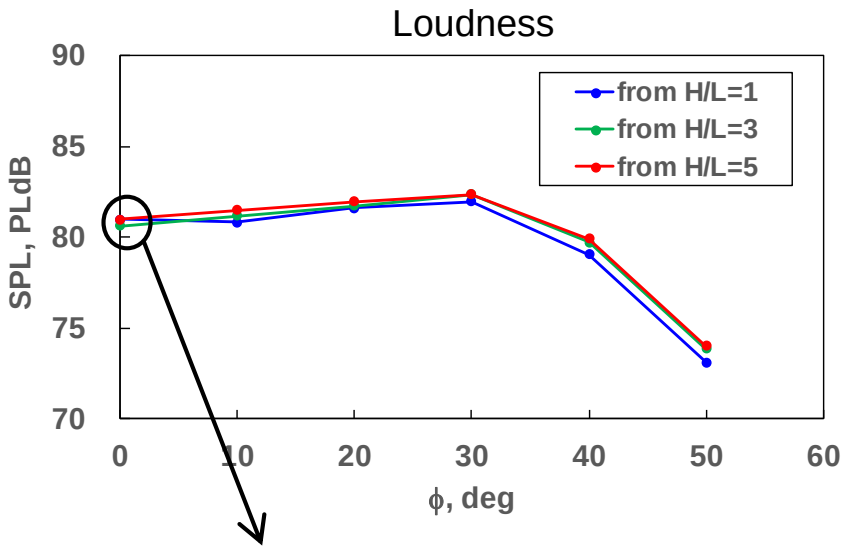


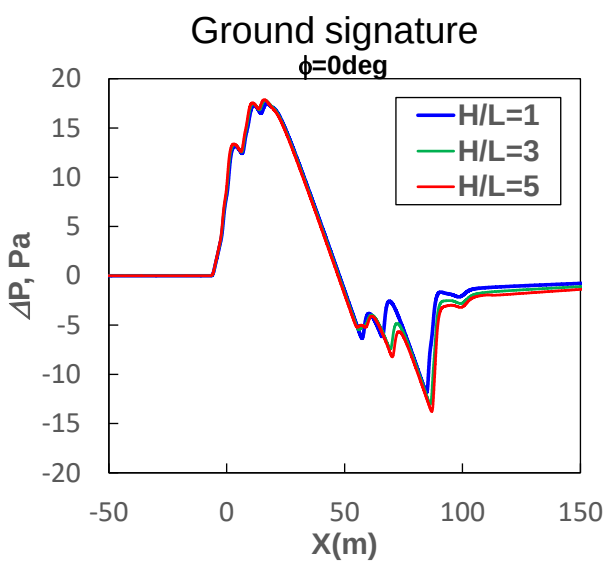
Tetra



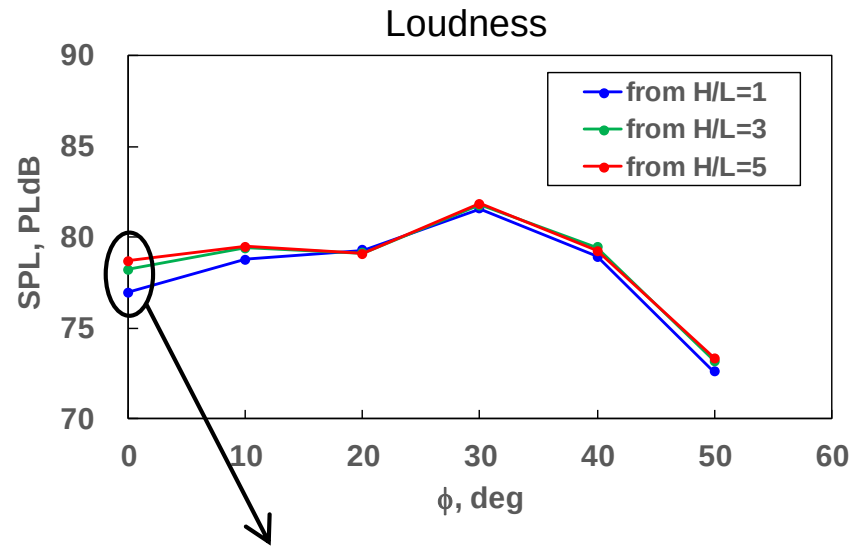
Loudness : Extracted position

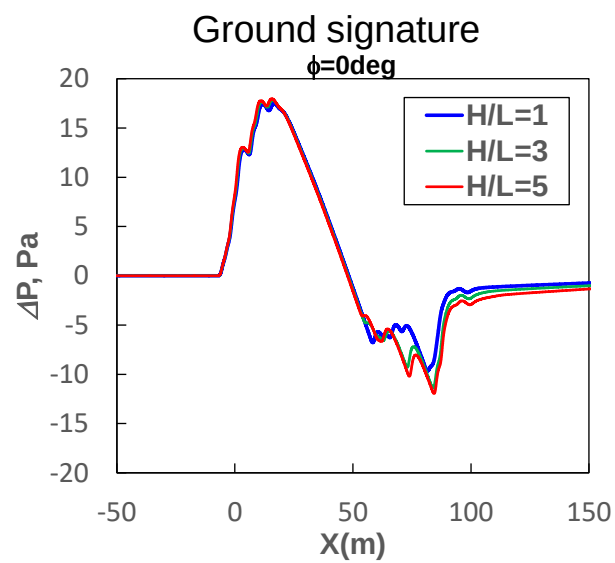
Coarse mesh (200)





Fine mesh (100)



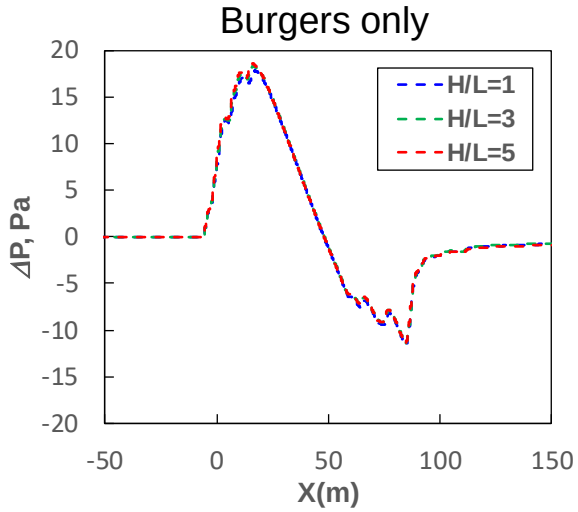


Multi-pole + Burgers

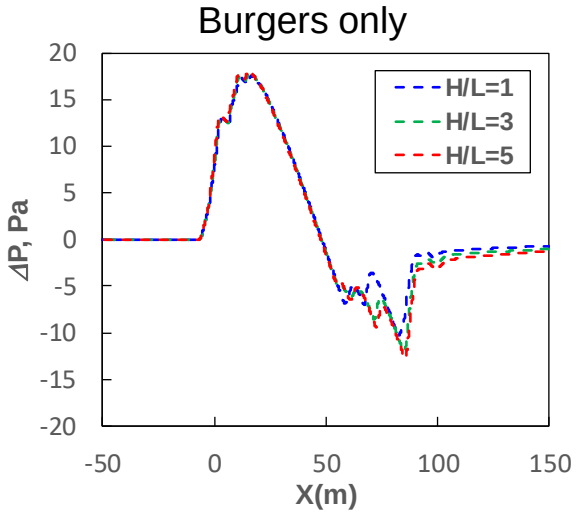
Model	Providor	viscousity	mesh	Grid Spacing(Resolution)					
axie	SBPW	inviscid	mixed	2.56	2	1.6	1.28	1	
			tetrahedra	2.56	2	1.6	1.28	1	
jwb	SBPW	inviscid	tetrahedra	1	0.83	0.7			
25d-flowthr	SBPW	inviscid	mixed	2	1.6	1.28	1	0.8	0.64
			tetrahedra	2	1.6	1.28	1	0.8	

Ground signature

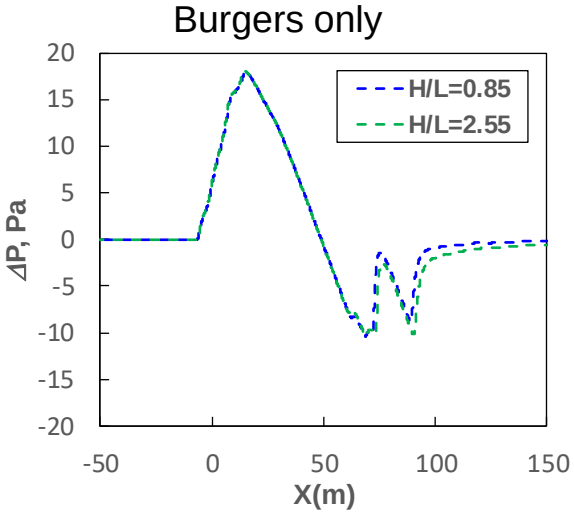
AXIE

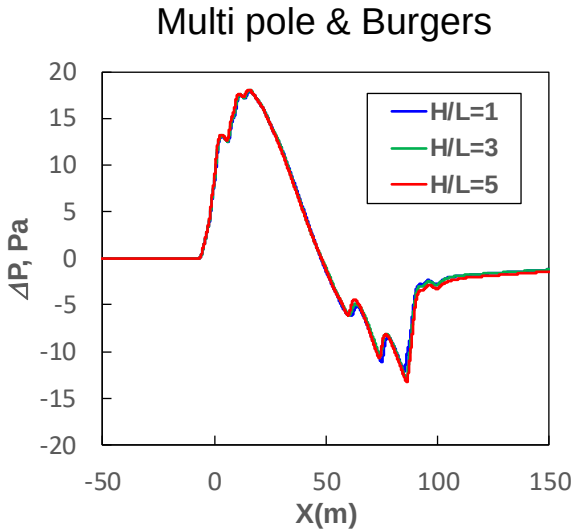


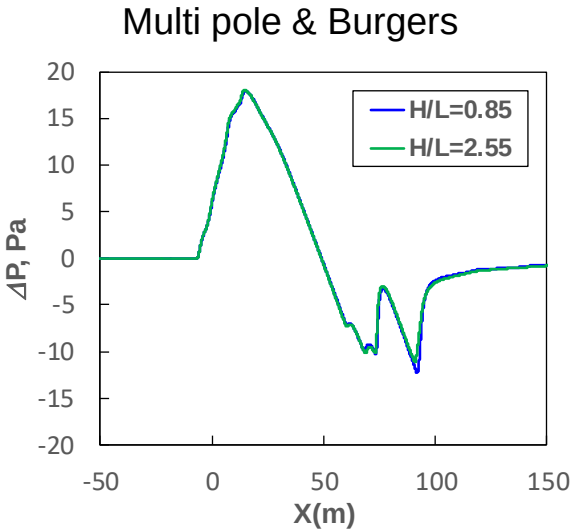
C25D



JWB

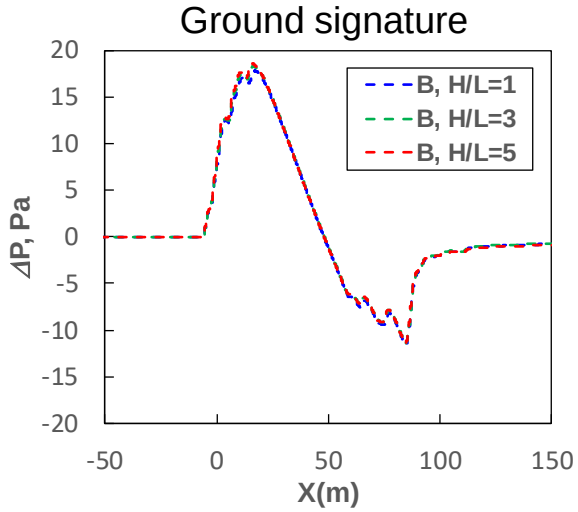


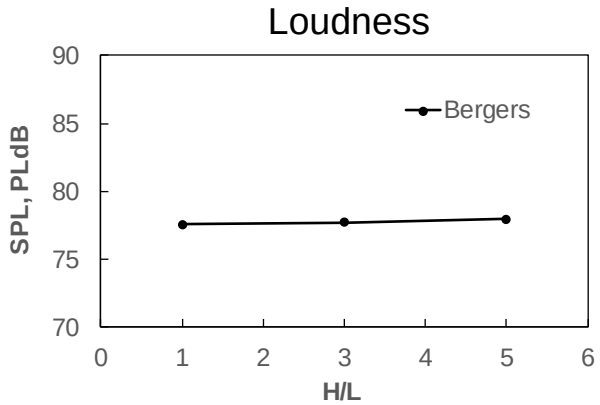




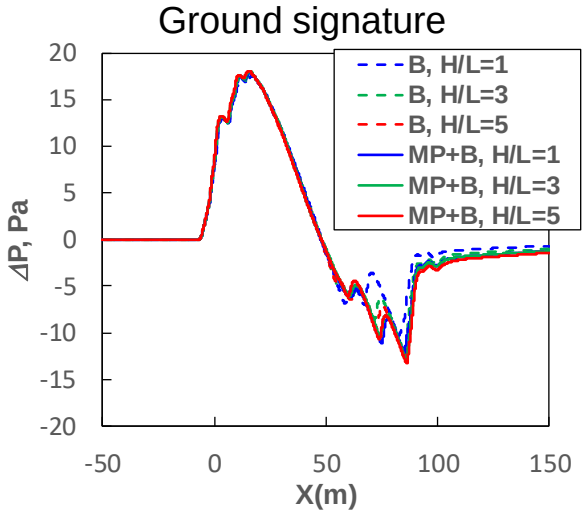
Multi-Pole & Burgers

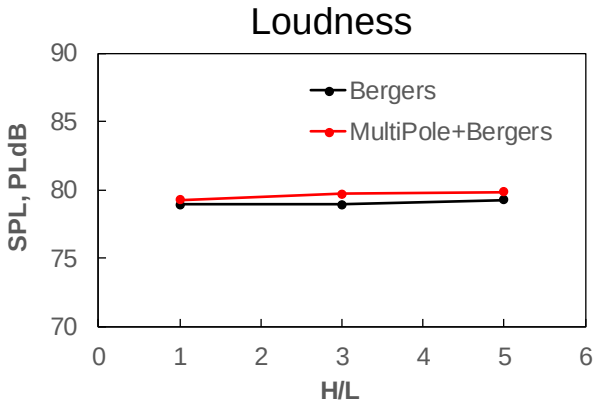
AXIE



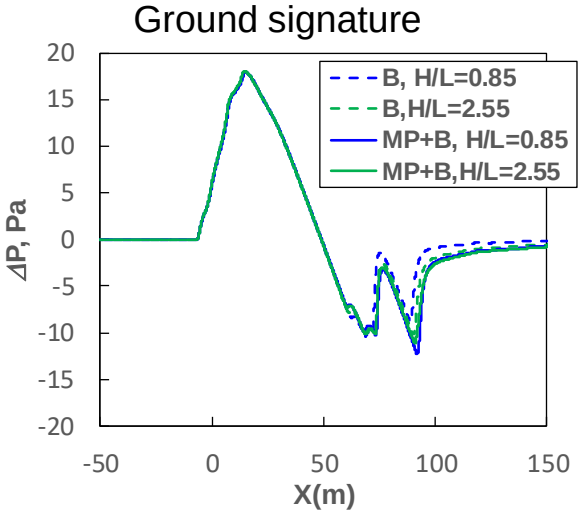


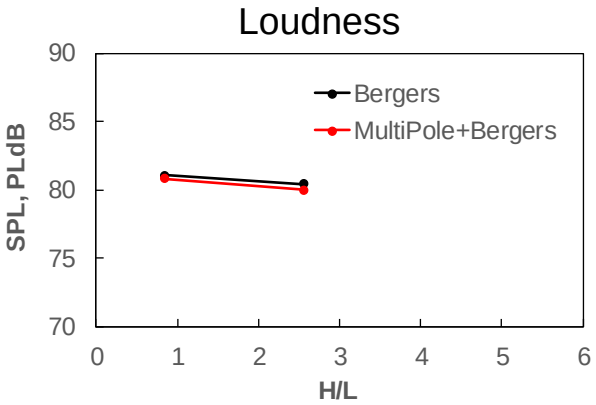
C25D





JWB



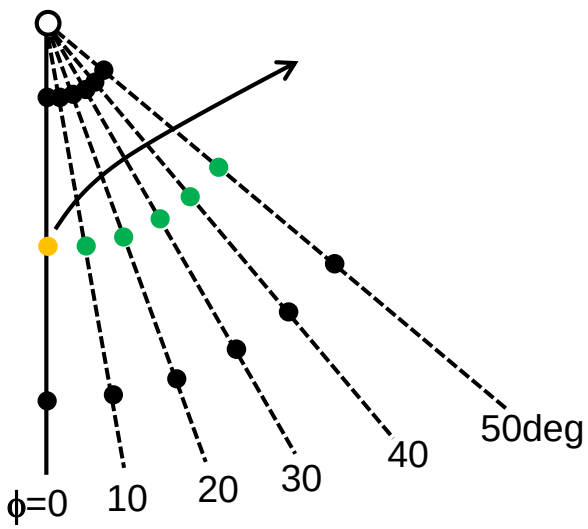


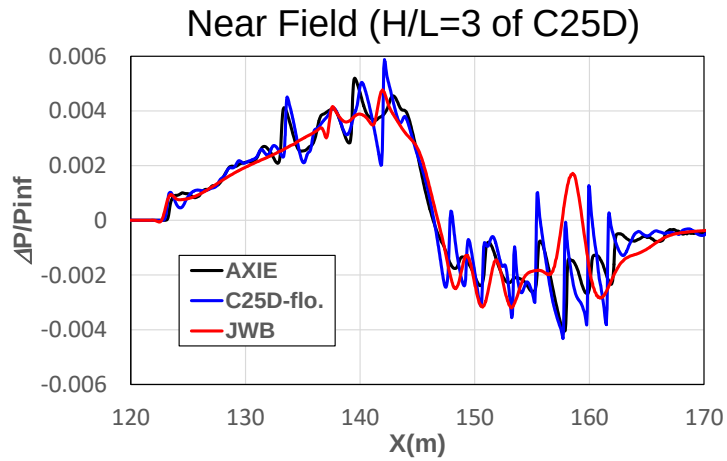
AXIE vs C25D vs JWB

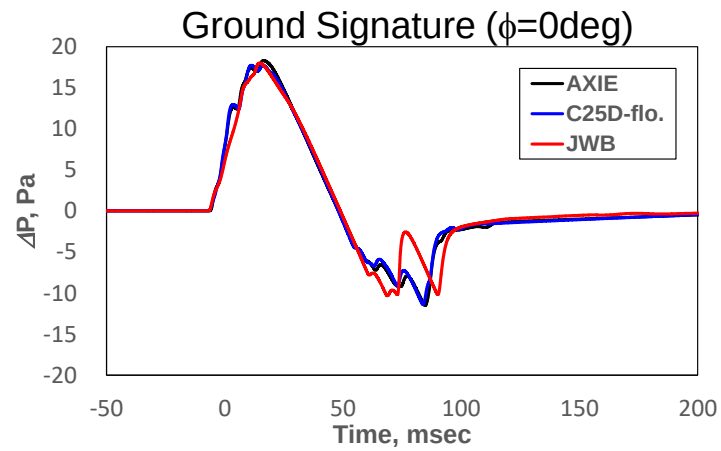
All Models

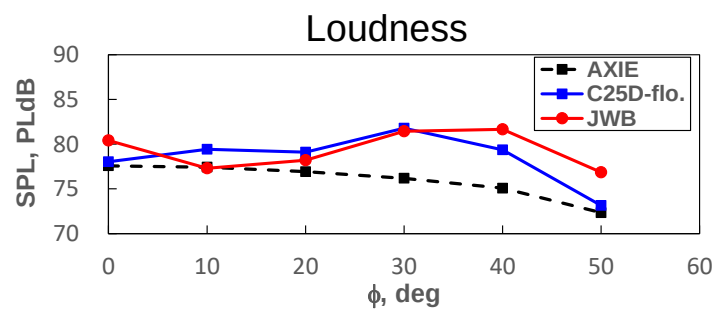
Viscosity : inviscid
Mesh : Tetra
Resolution
- AXIE : 100
- C25D : 080
- JWB : 070

Near field, Z= -99m
- AXIE : H/L=3
- C25D : H/L=3
- JWB : H/L=2.55









Conclusion

- **Analyzed cases**

  - AXIE, JWB, C25D(flow-thorough)

- **Limiter function**

  Limiter function is related to sharpness of near field pressure signature.

  Venkatakrishunan limiter : limiter factor；K=1.0, 0.1, 0.01, 0.001

  K=0.01 – 1 are almost same results.

  Limiter factor(K) is changed if unexpected oscillation is observed.

- **Mesh type**

  Mixed and Tetra has similar characteristics.

- **Mesh resolution**

  AXIE: 100-160 are almost same.

  JWB : 070-100 are almost sane.

  C25D : 064-100 are almost same.

- **3 models**

  It is found that JWB has similar to the low-boom effect of the C25D.