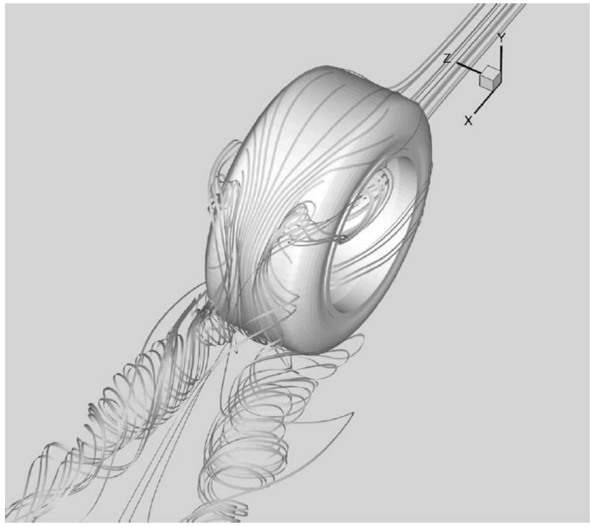


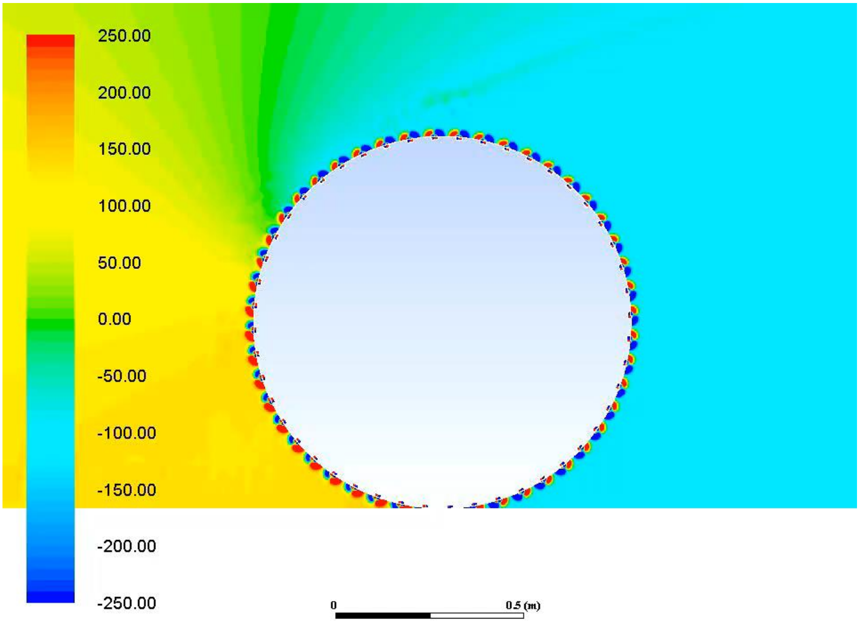
Aero-acoustics Noise Prediction of Treaded Tire

Bhanu Gupta

Sushil Kumar Sonar

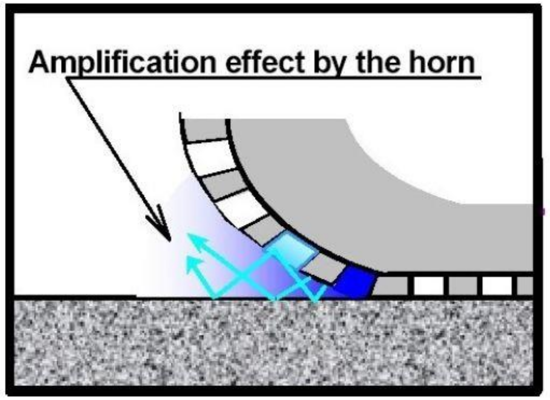
Content

- Introduction
- Problem Statement & Simulation Approach
- Pre-Processing : Computational Domain & Meshing
- Physics & Numerical Setup
- Results & Discussion
- Conclusion

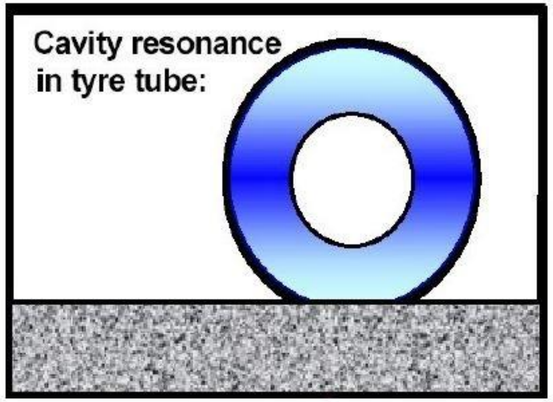


Introduction

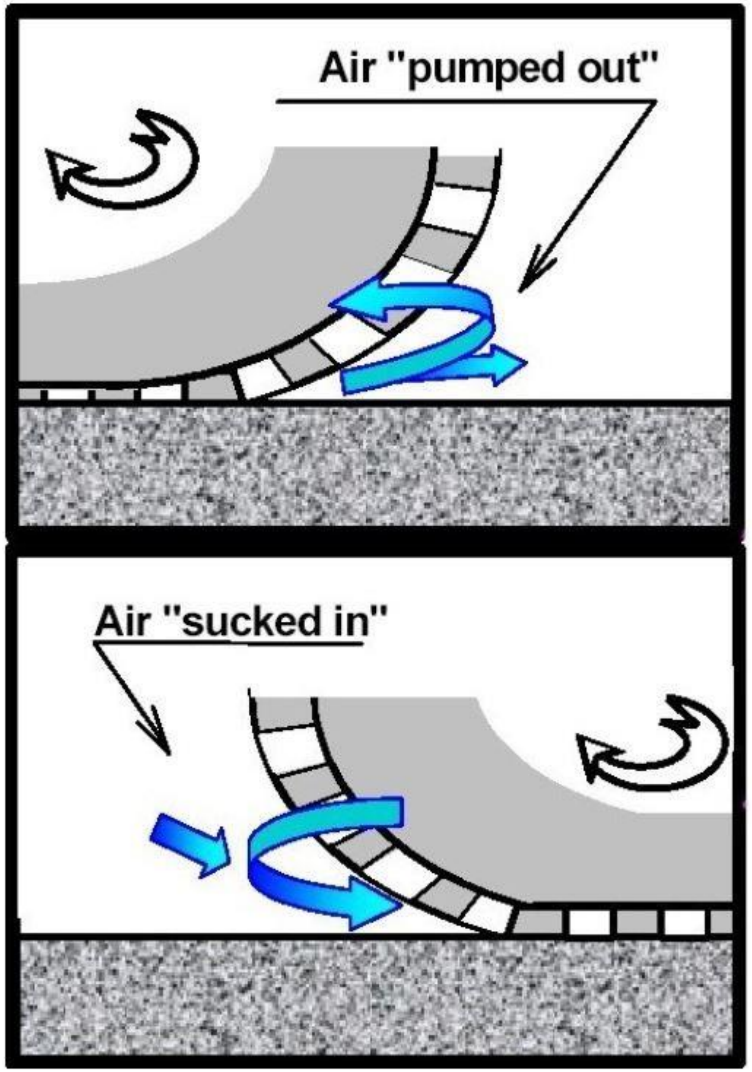
- **Motivation : New tire noise norms being introduced for tire industry demands**
- **Tire Noise Generation Mechanism**
  - **Aero-acoustic noise source modeling for rotating tire**
    - **Physics: Air Pumping at entrance and exit in grooves at tire and road contact**
      - **Air compression and air pumping causes aerodynamic noise**
      - **High and medium frequency range noise (Above 1 Khz)**



The horn effect created by the tire and pavement



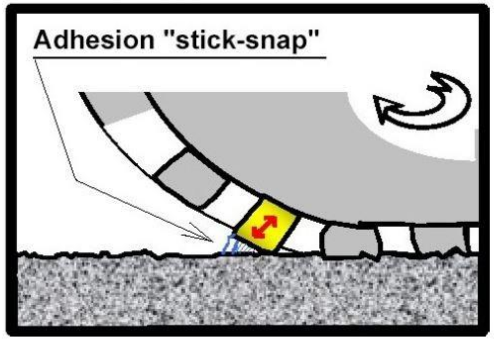
Acoustic resonance in the air space inside the tire



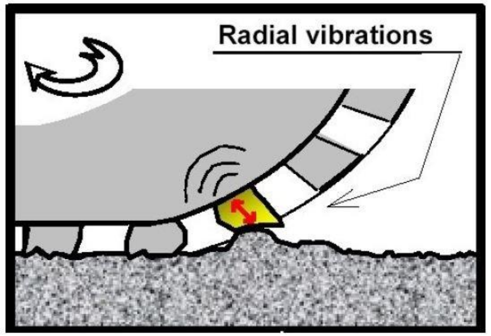
Air pumping at the entrance and exit of the contact patch

Introduction

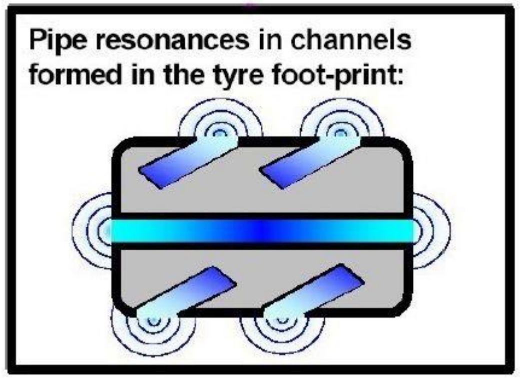
pavement

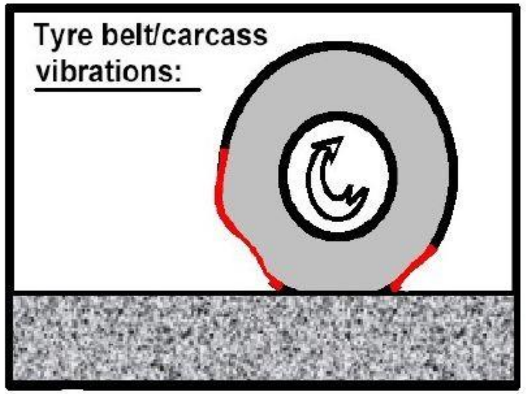


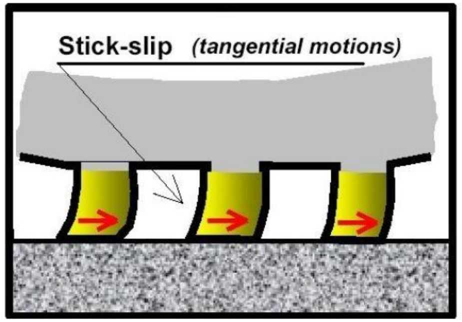
Adhesion between the tread block and pavement at the exit of the contact patch



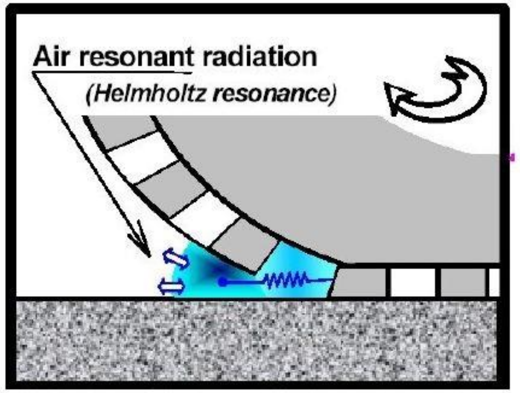
Vibration caused by tread block/pavement impact



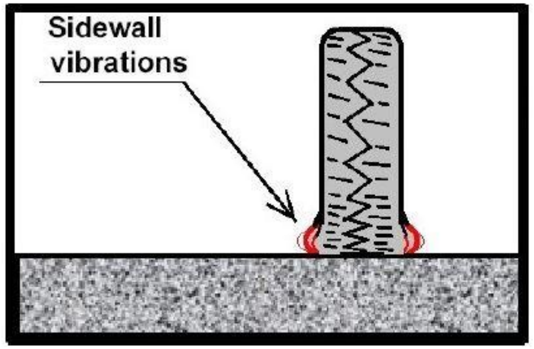




Slip-stick motion of the tread block on pavement



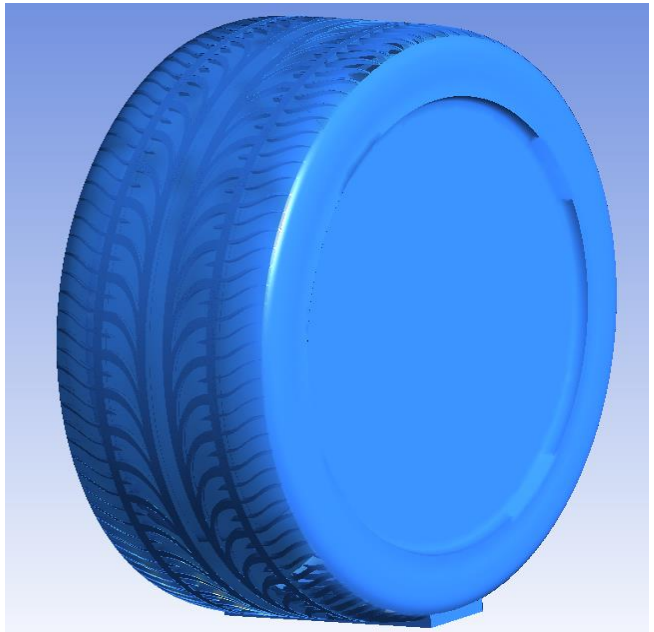
Sound amplification caused by organ pipe and Helmholtz resonator geometries within the contact path

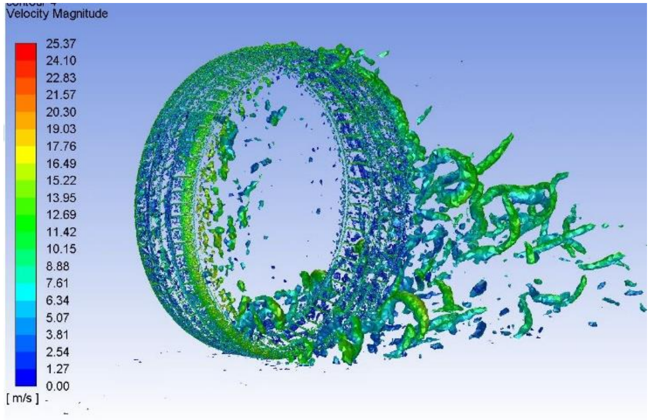


Vibration of the tire carcass around the tread band and at the sidewall of the contact patch

Problem Statement

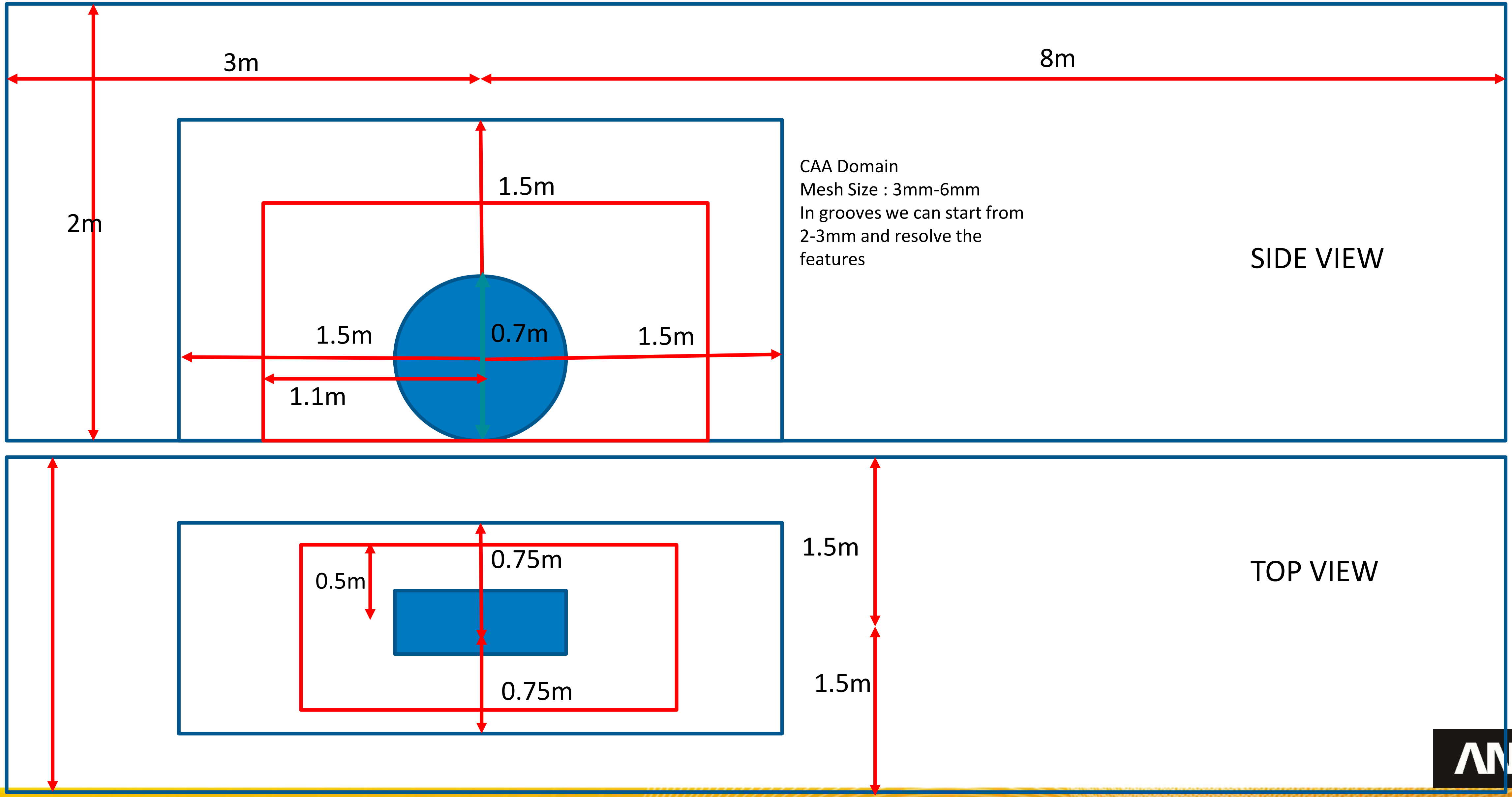
- Predict Aero-acoustics noise in frequency range 10Hz-4KHz due to rotation of tire interaction with ground and atmosphere at given speed
  - Usually for tire aerodynamic noise the frequency of interest is 1Khz-4khz range. For this sample frequency range taken was 1-Hz-4Khz
- Simulation Approach
  - Computational Aero Acoustics(CAA) approach used which compliments Experimental approach
  - Sliding mesh approach used to rotate the tire
  - Tire road contact path restriction modeled using either porous media or no cell zone present at that location
- Approximation : No deformation of tire included while tire interacts with road



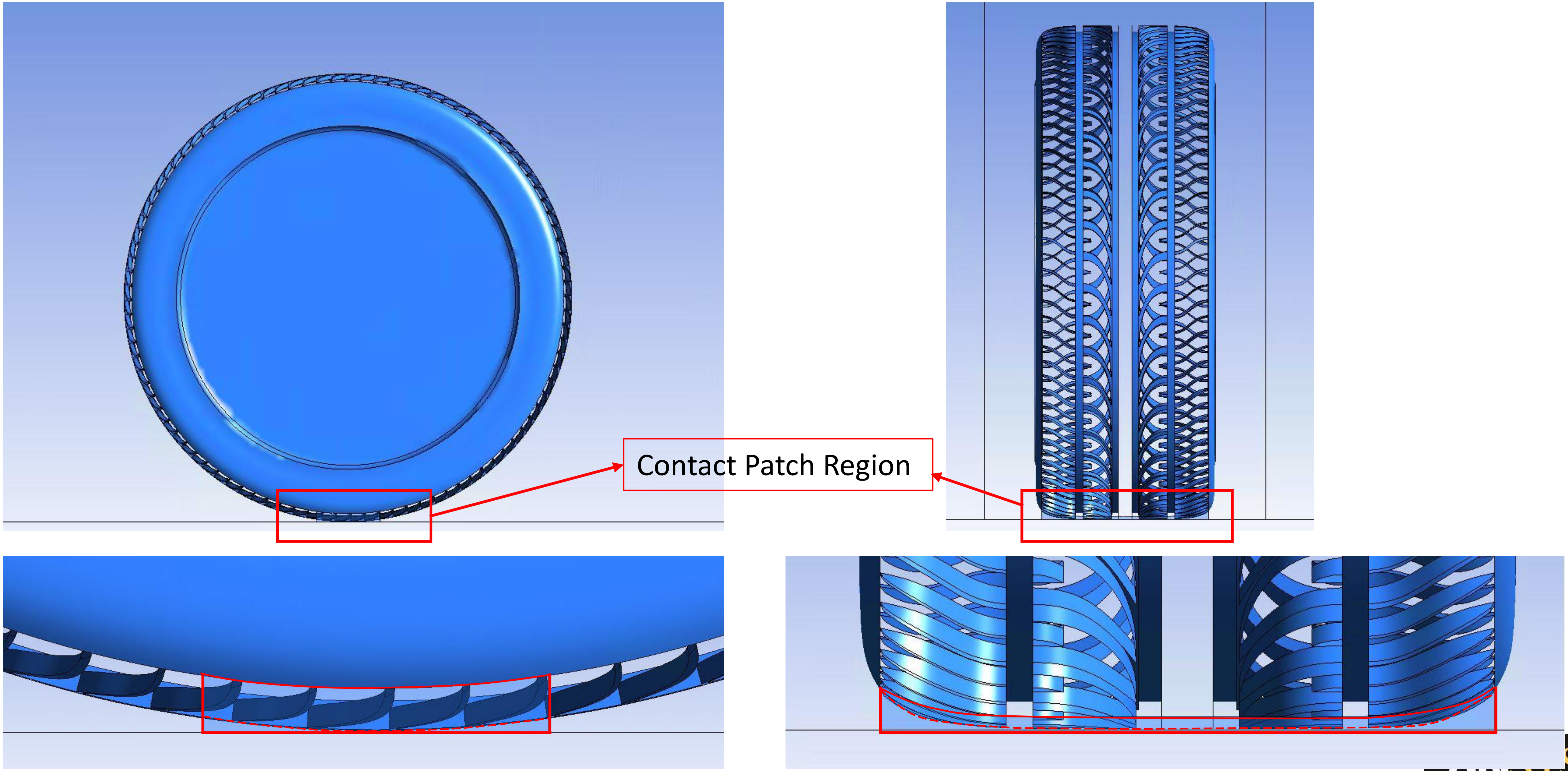


Velocity Contours on Iso-surfaces (Q criterion)

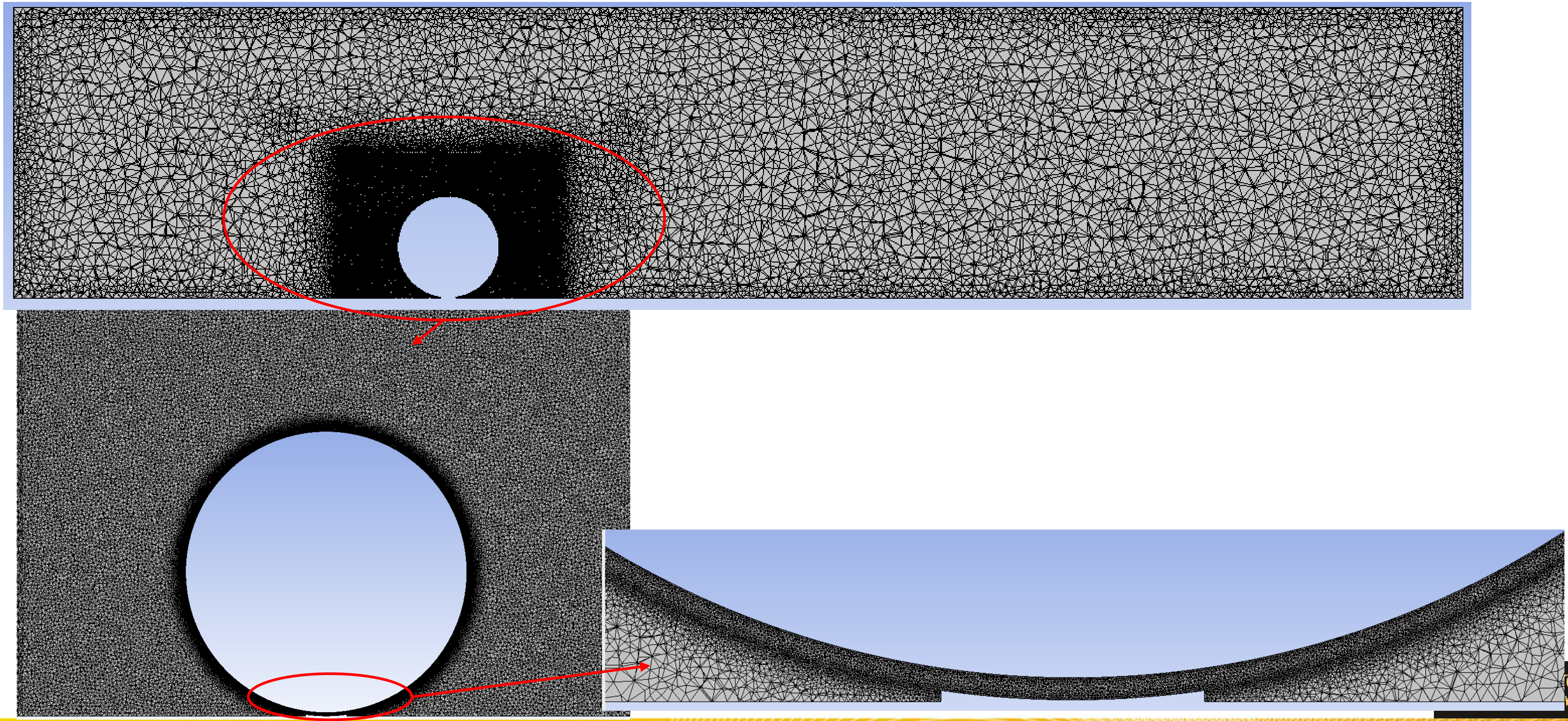
Pre-processing : Computational Domain



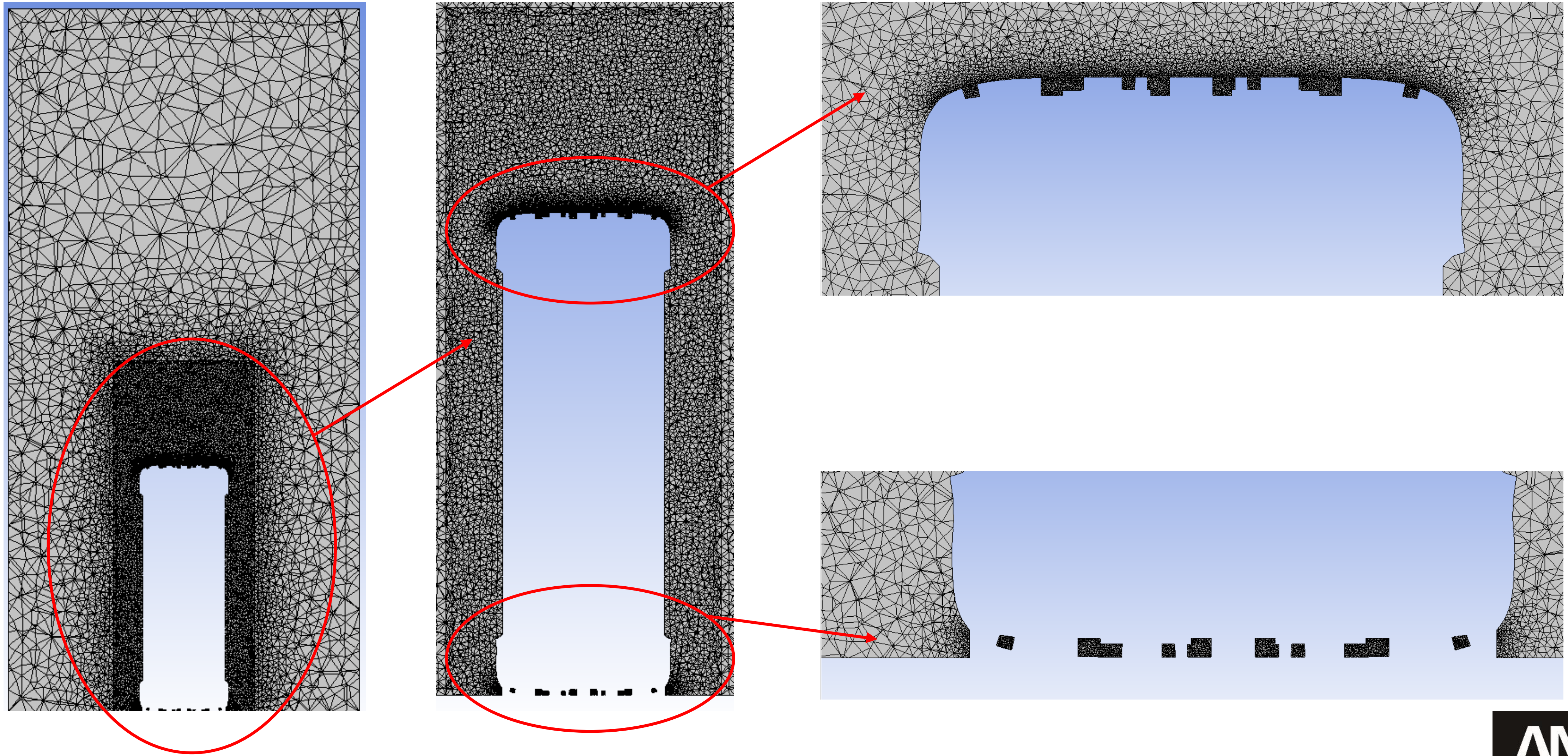
Pre-processing : Computational Domain



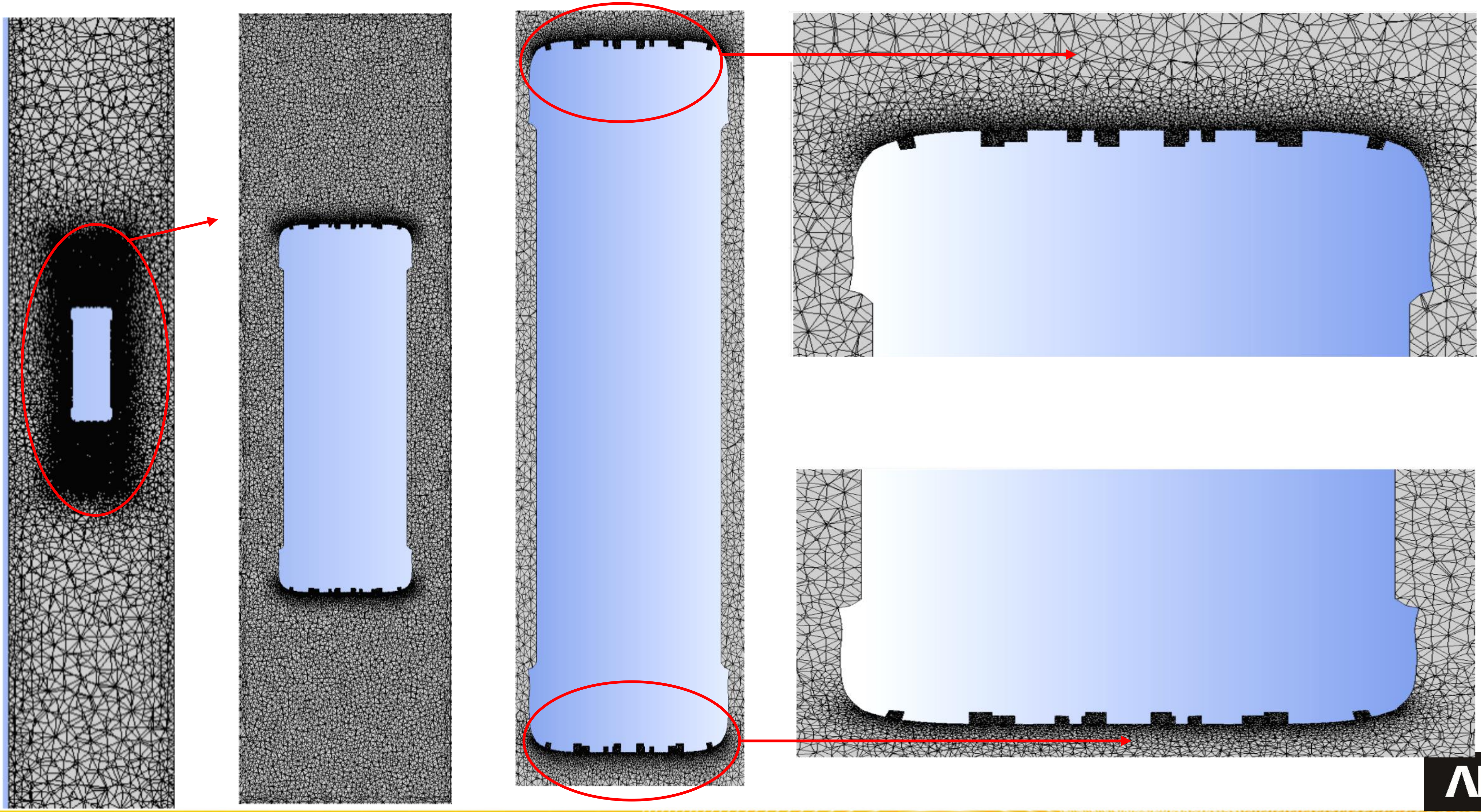
Pre-Processing : Meshing



Pre-Processing : Meshing

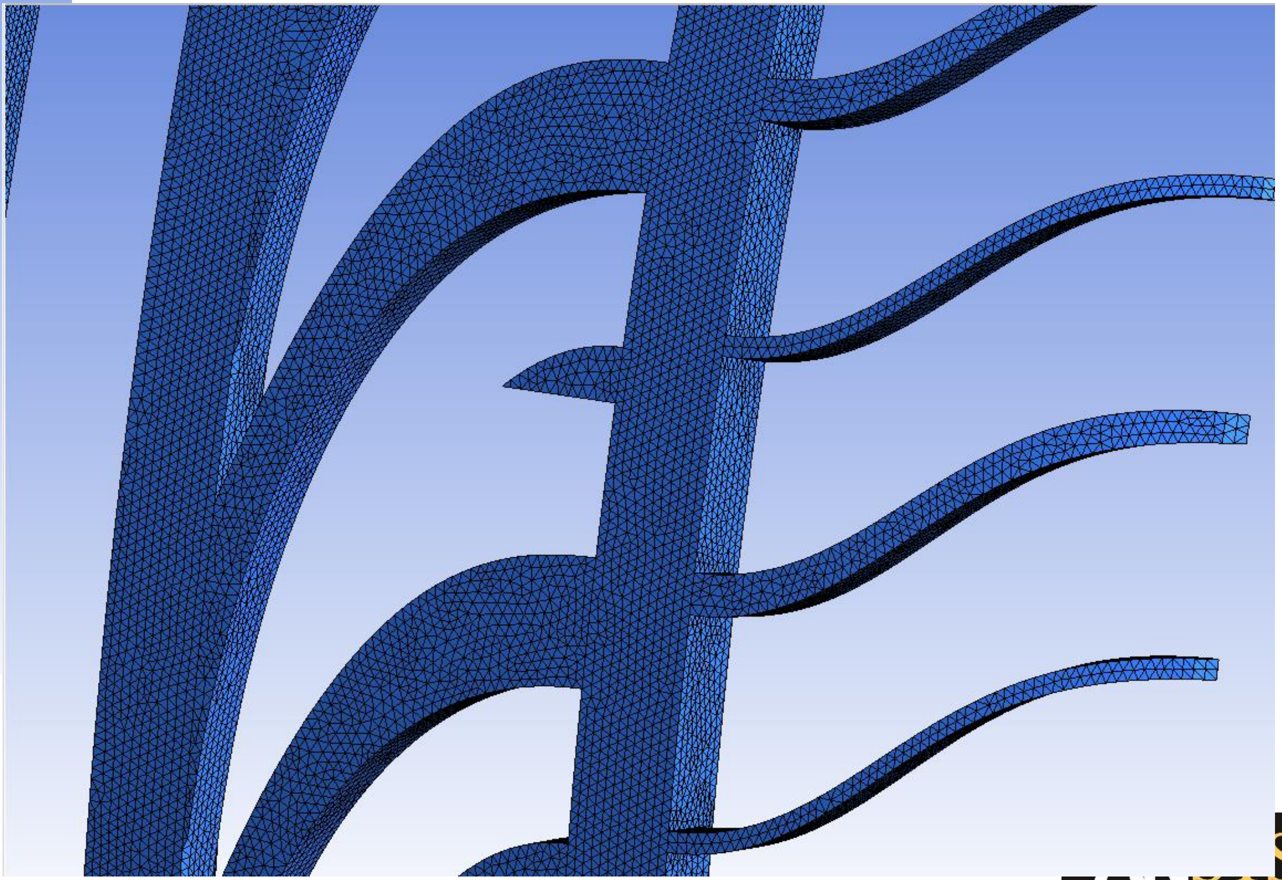


Pre-Processing : Meshing



Pre-Processing : Meshing

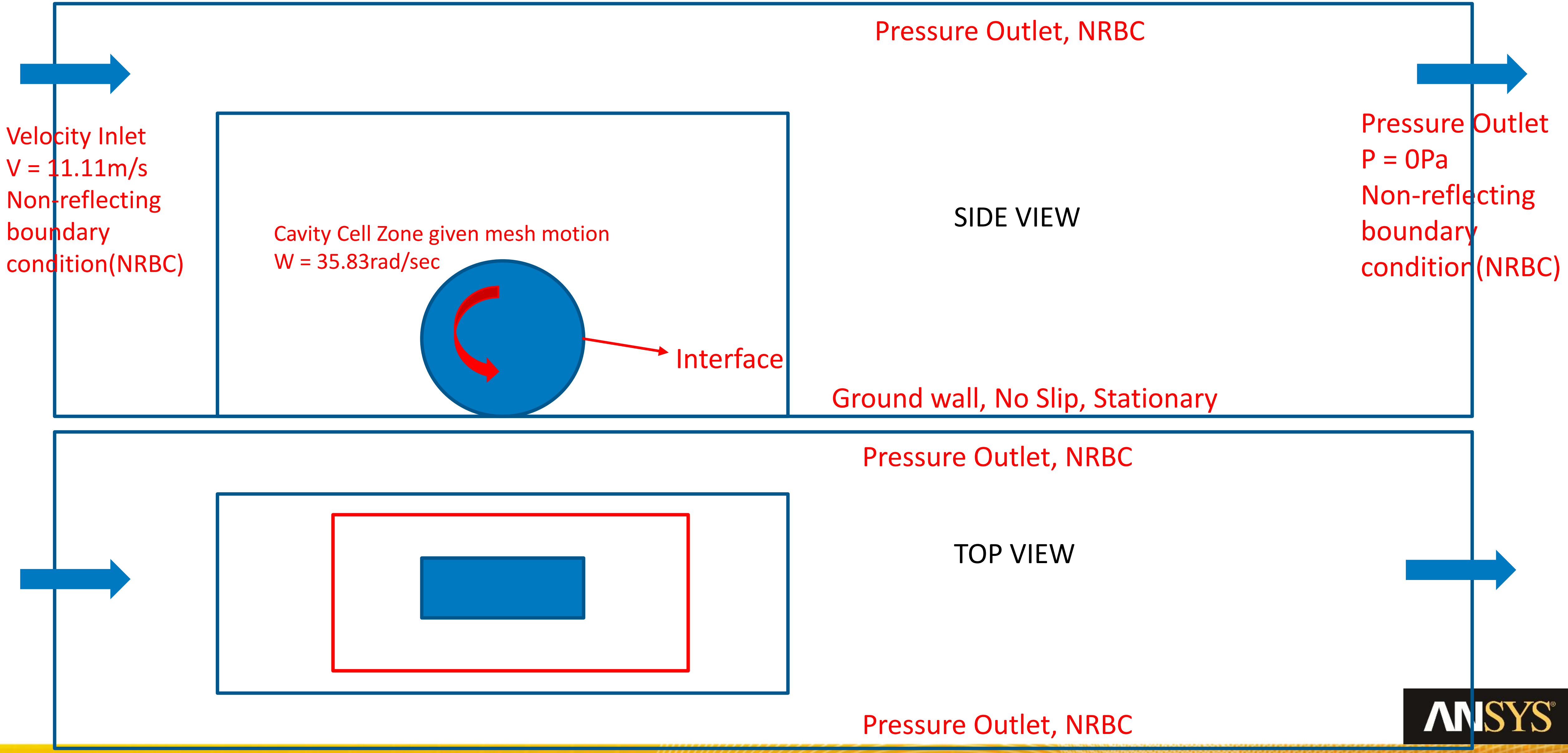
Mesh Elements : Tetrahedron
Mesh Count: 28.74million
Maximum Equivolume Skewness = 0.93
Maximum Aspect Ratio = 39.0



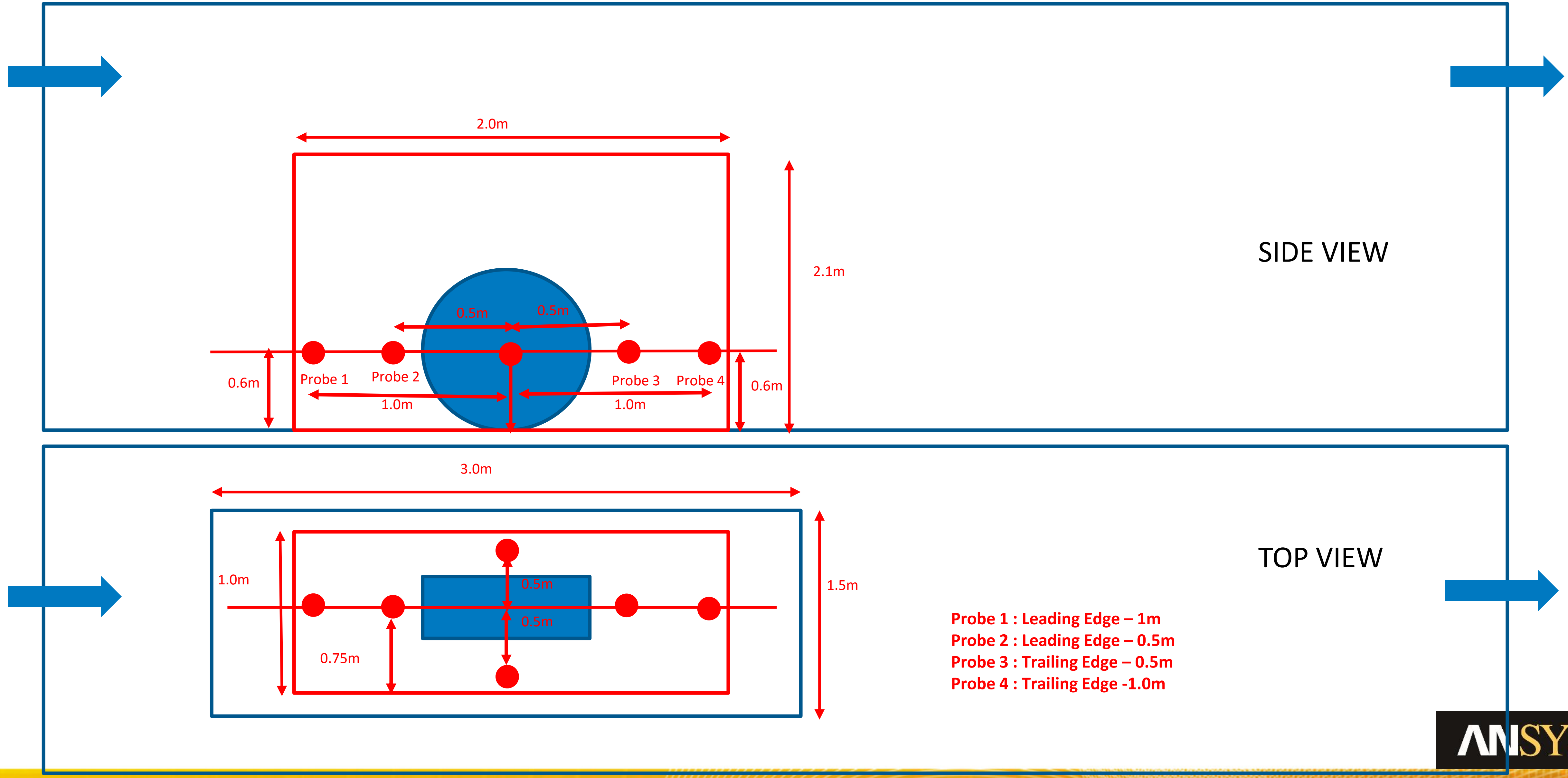
Physics & Numerical Setup

- Transient Modeling
- Turbulence models : sst-kw and DDES
- Material
  - Air : Ideal Gas
- MRF and Sliding Mesh Modeling

Physics & Numerical Setup : Boundary Conditions



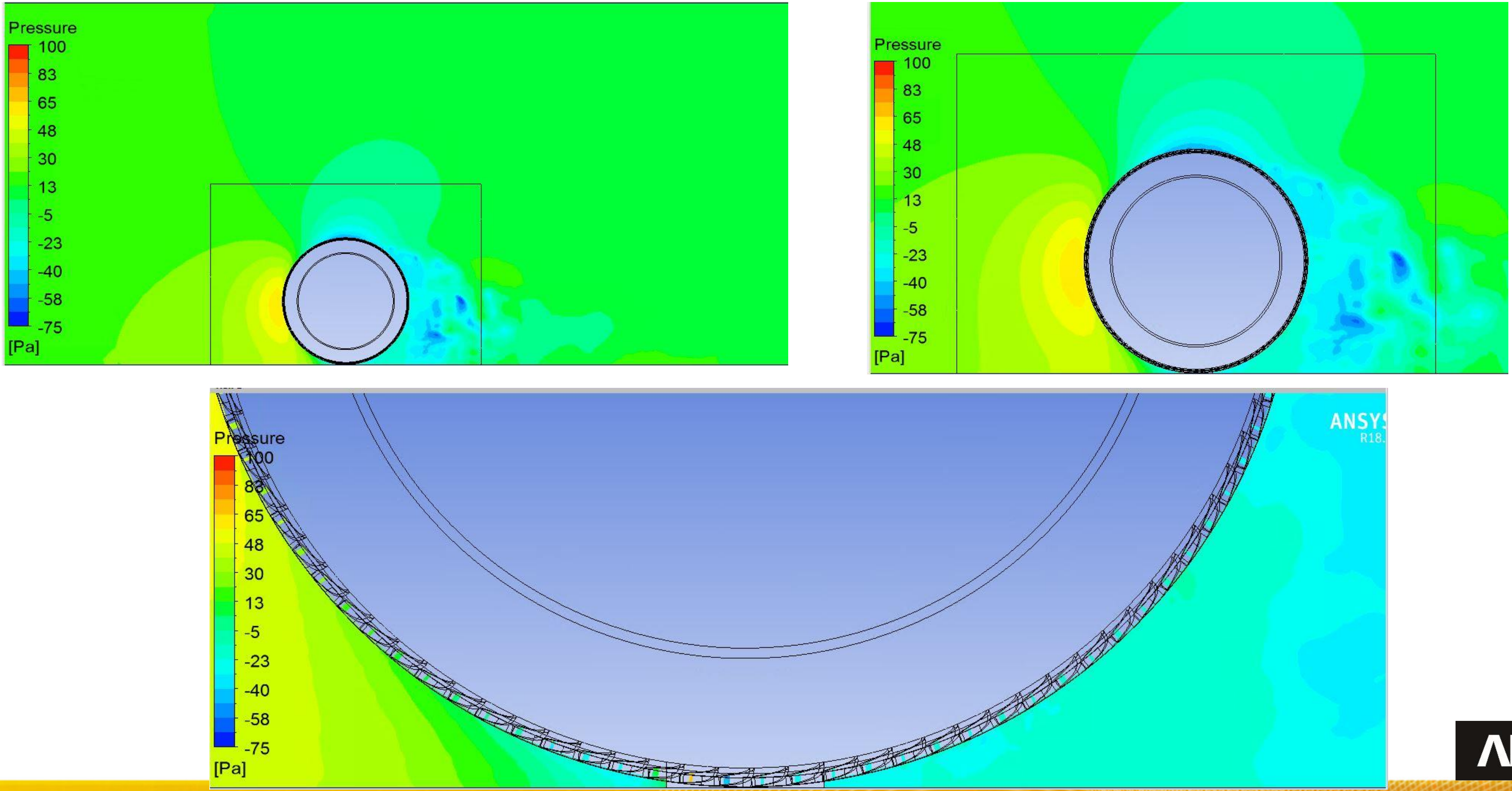
Pre-processing : Pressure Probes for CAA Modeling



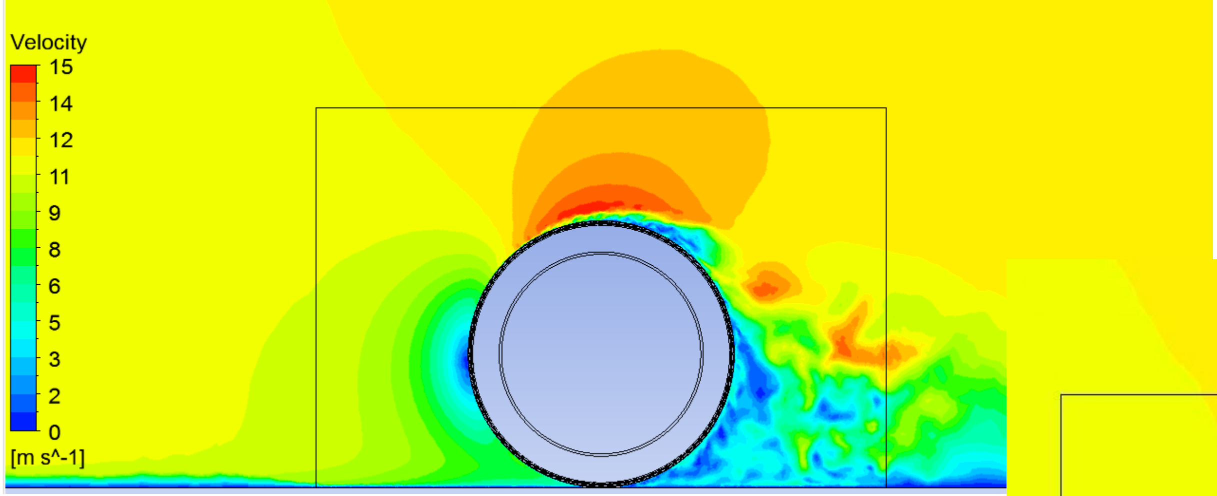
Probe 1 : Leading Edge – 1m
Probe 2 : Leading Edge – 0.5m
Probe 3 : Trailing Edge – 0.5m
Probe 4 : Trailing Edge -1.0m

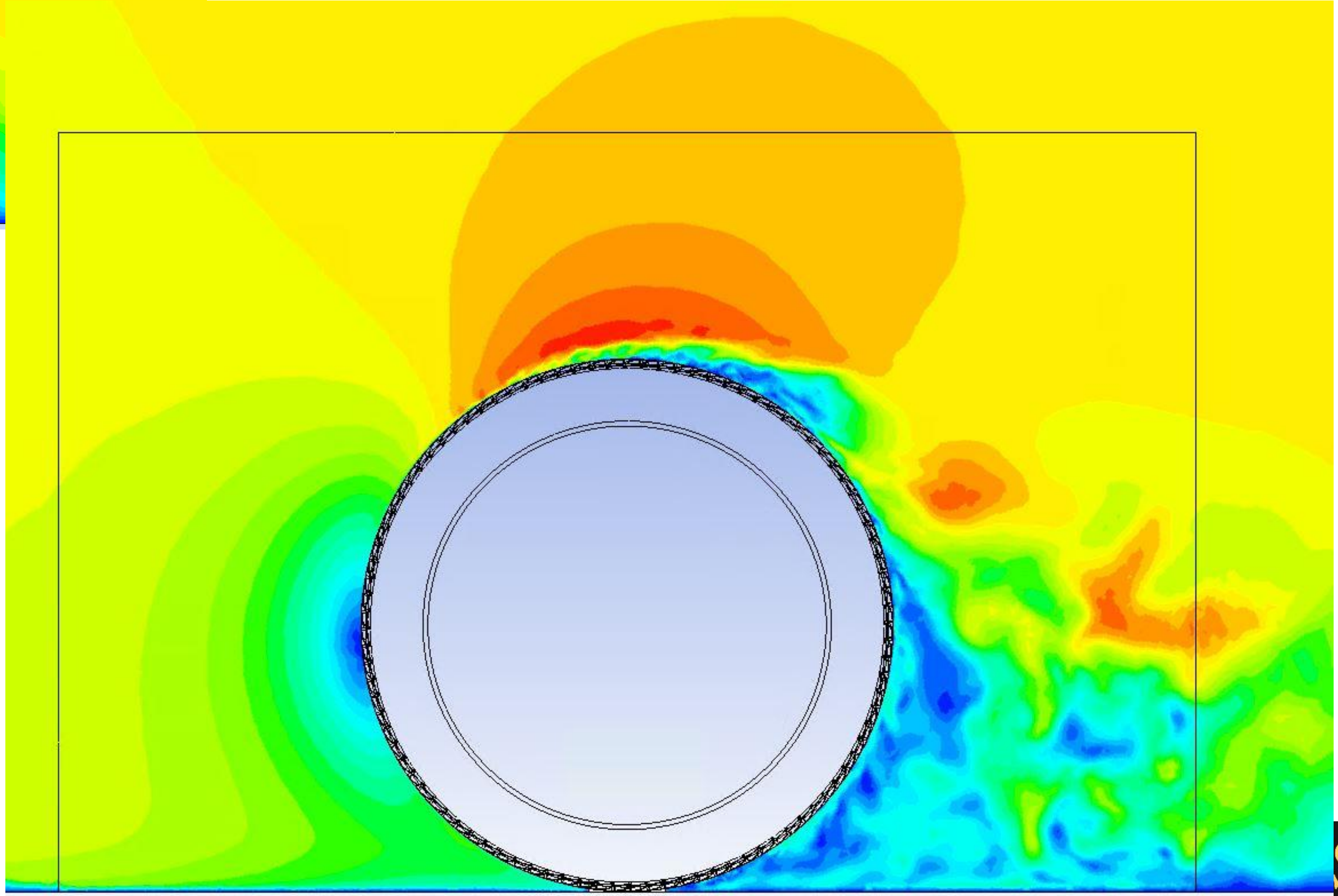
Results and Discussion

Pressure Variation at Vertical Plane Along the Flow Direction

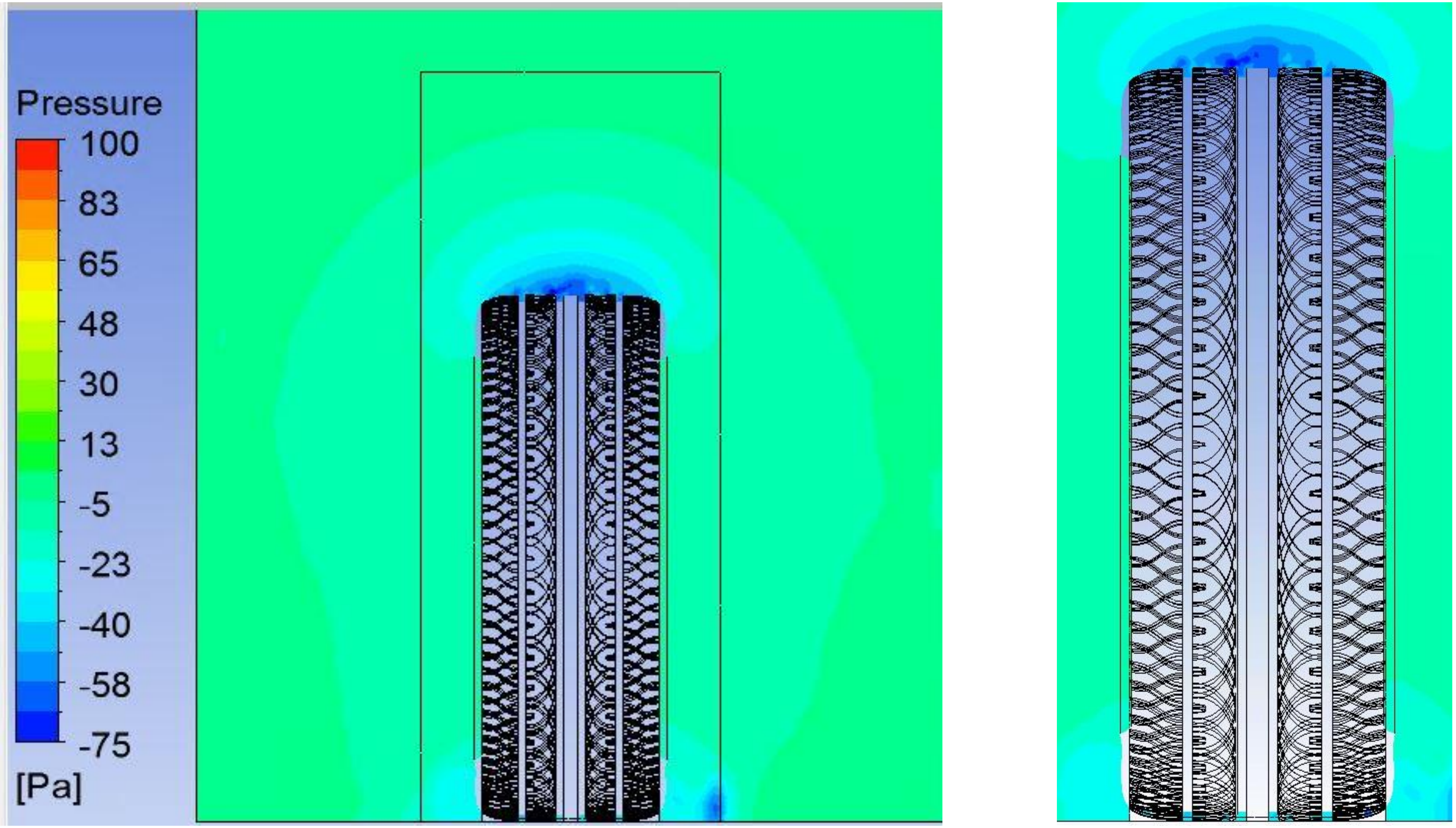


Velocity Variation at Vertical Plane Along the Flow Direction

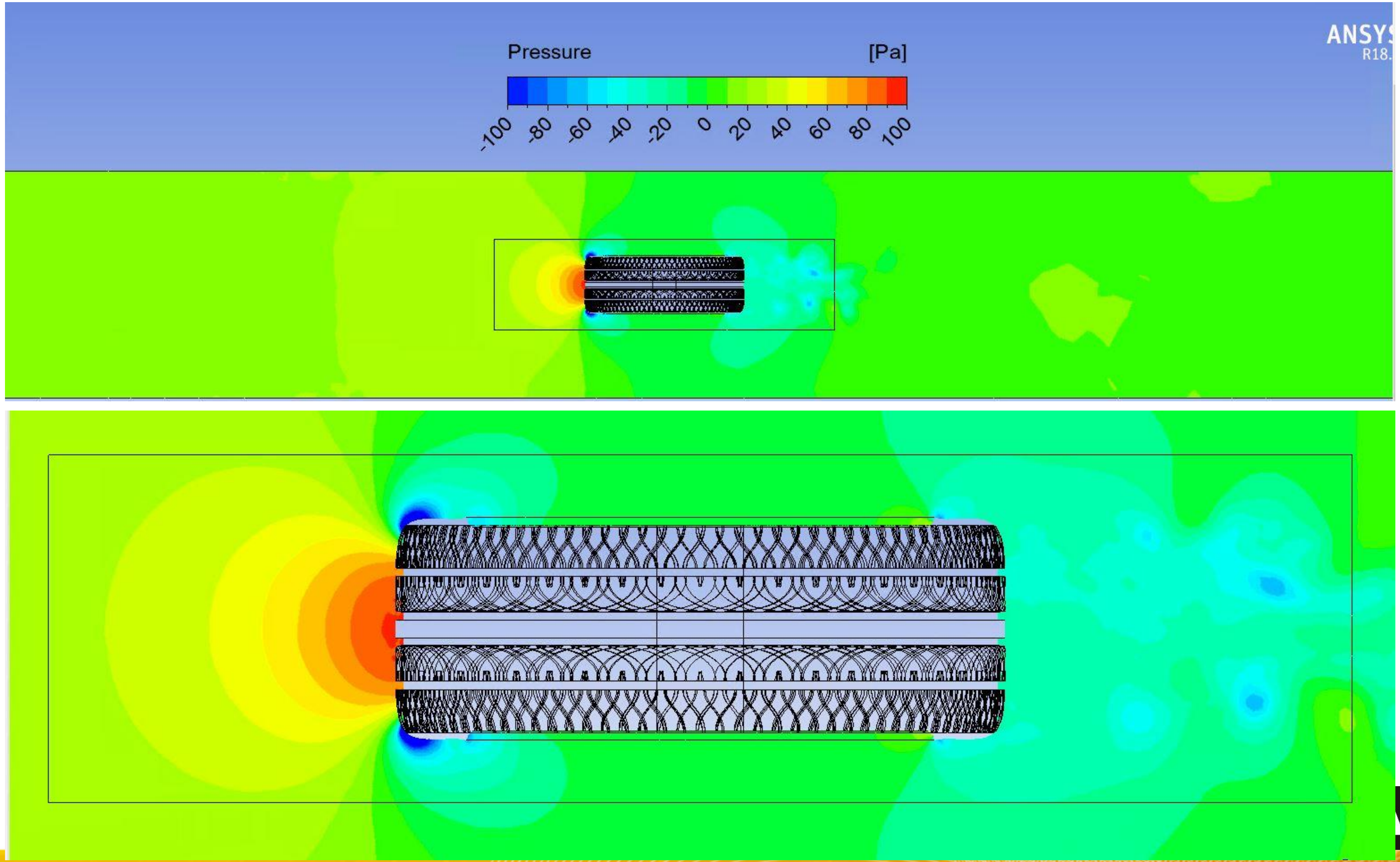




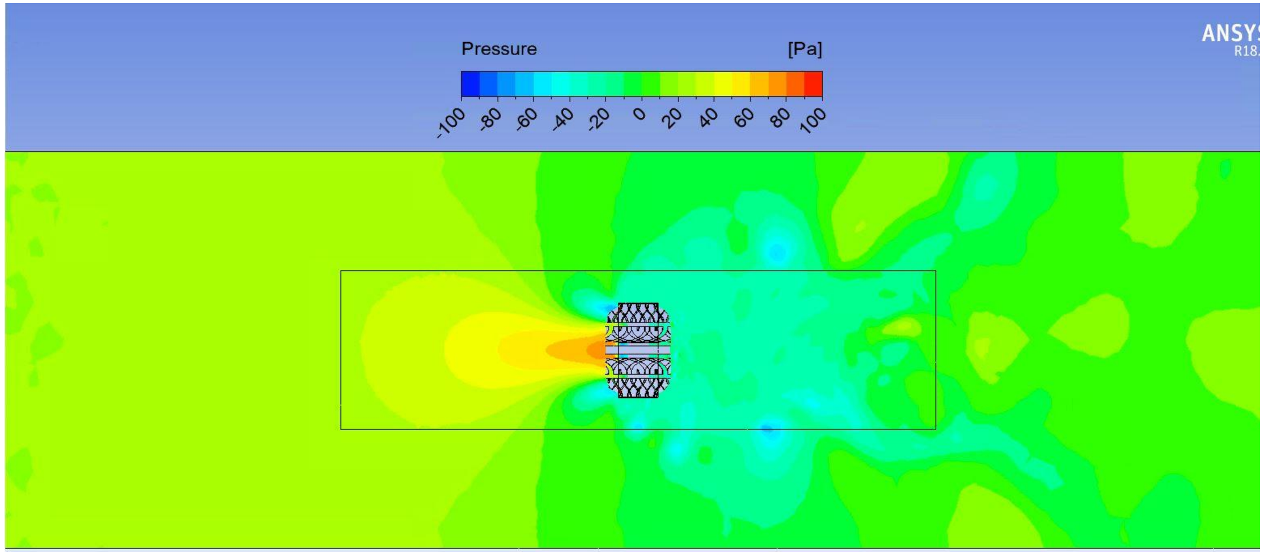
Pressure Variation on Vertical Plane

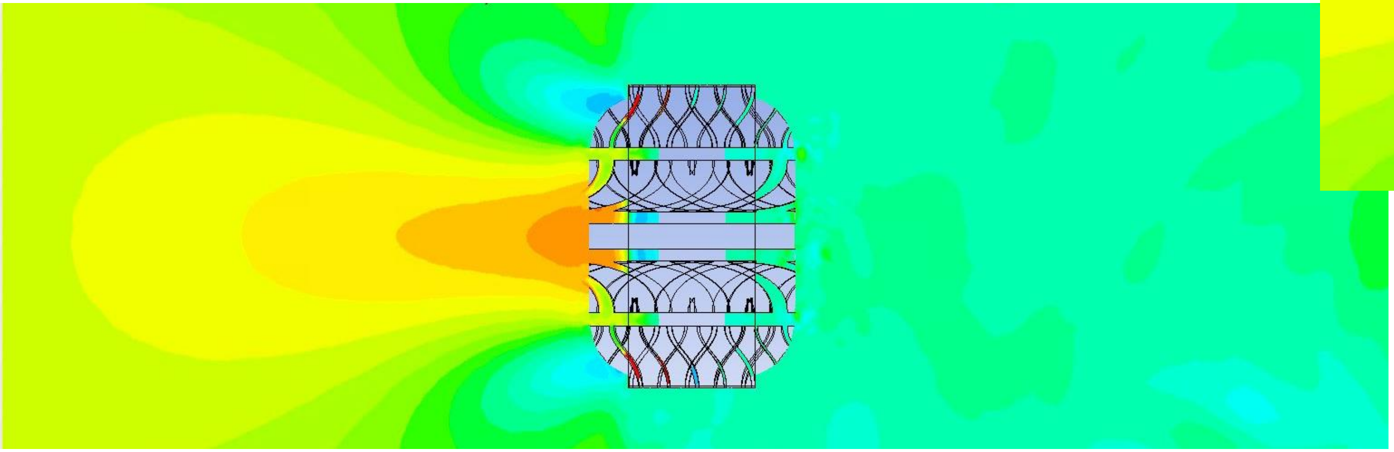


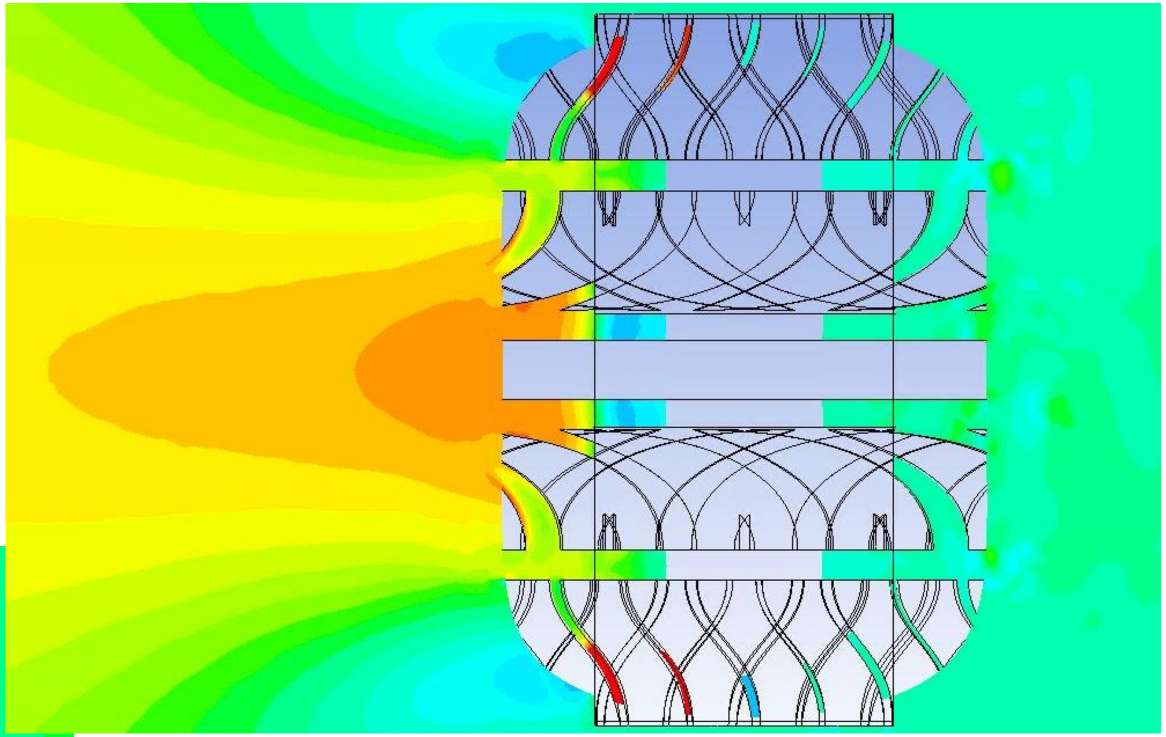
Pressure Variation on Horizontal Plane at Tire Mid Height



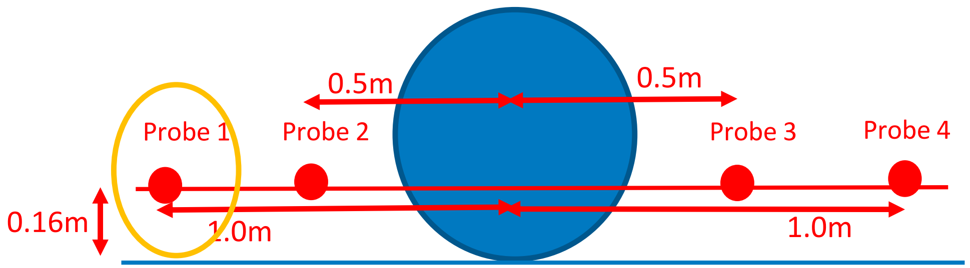
Pressure Variation on Horizontal Plane Near Ground



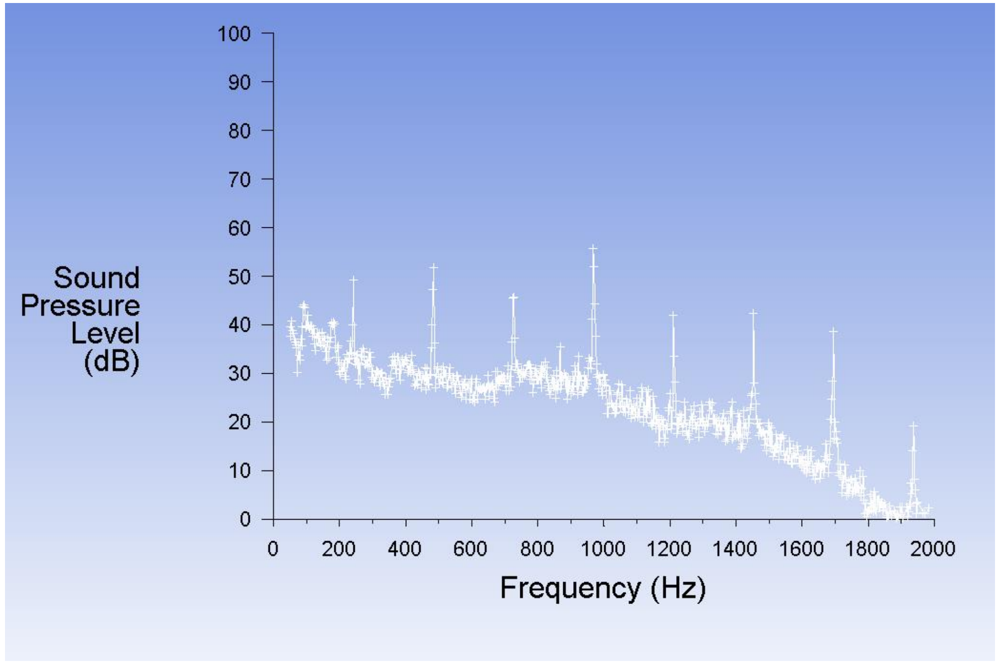




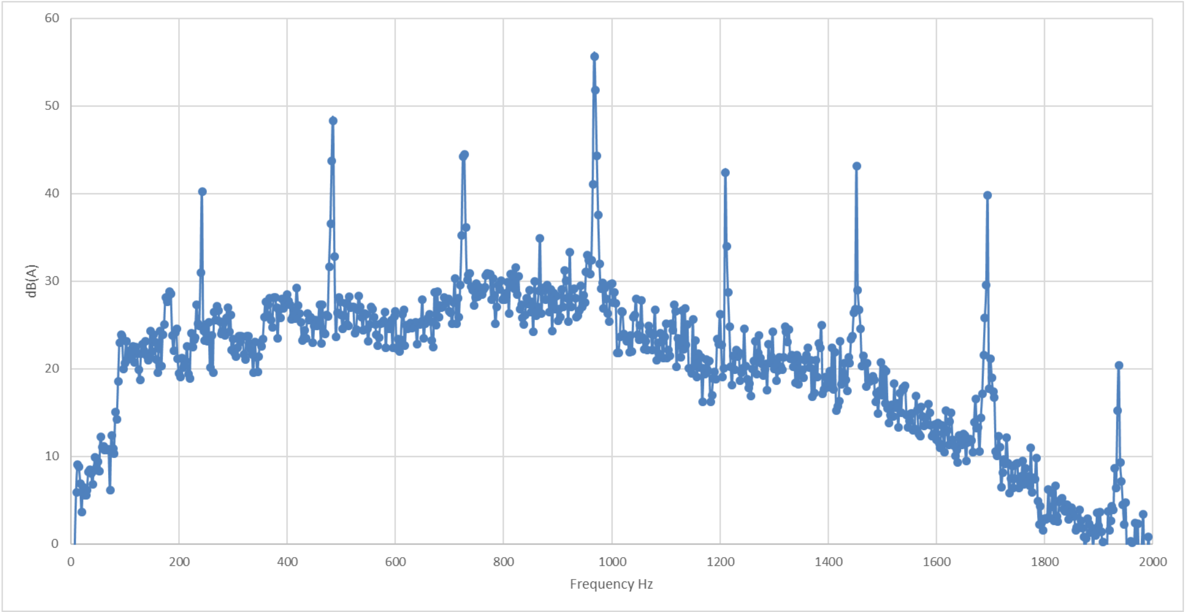
Probe 1



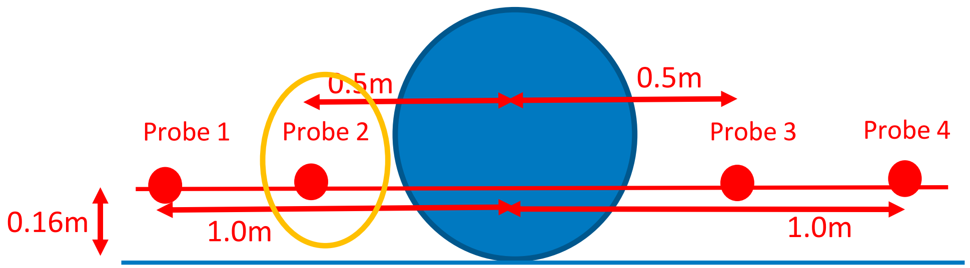
- Tonal Noise observed for given thread design upstream
- No broadband noise observed



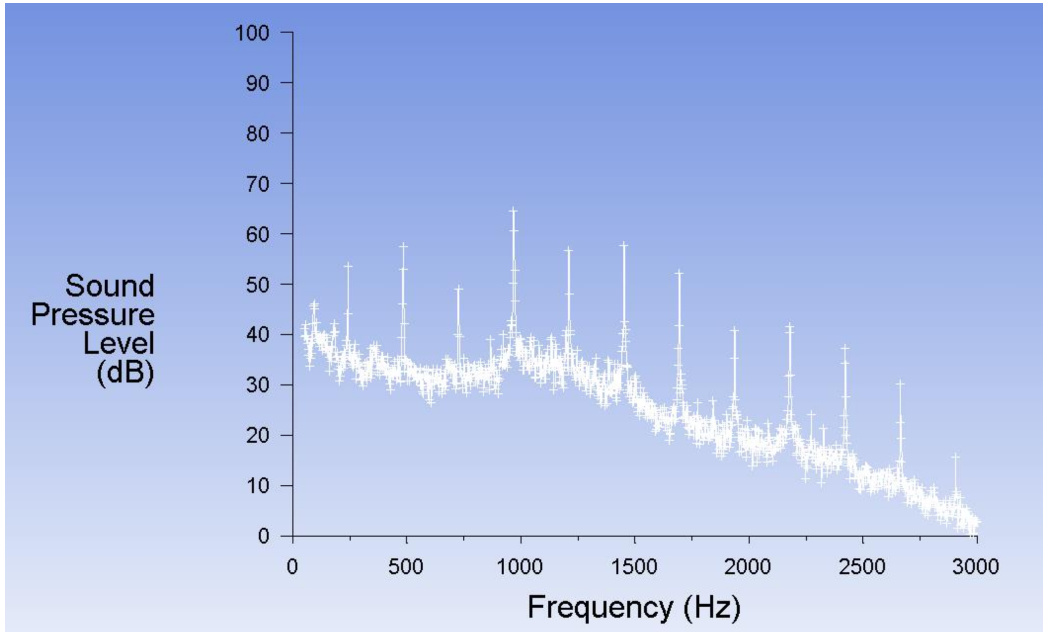
Frequency Vs dB(A): Leading Edge 1.0m

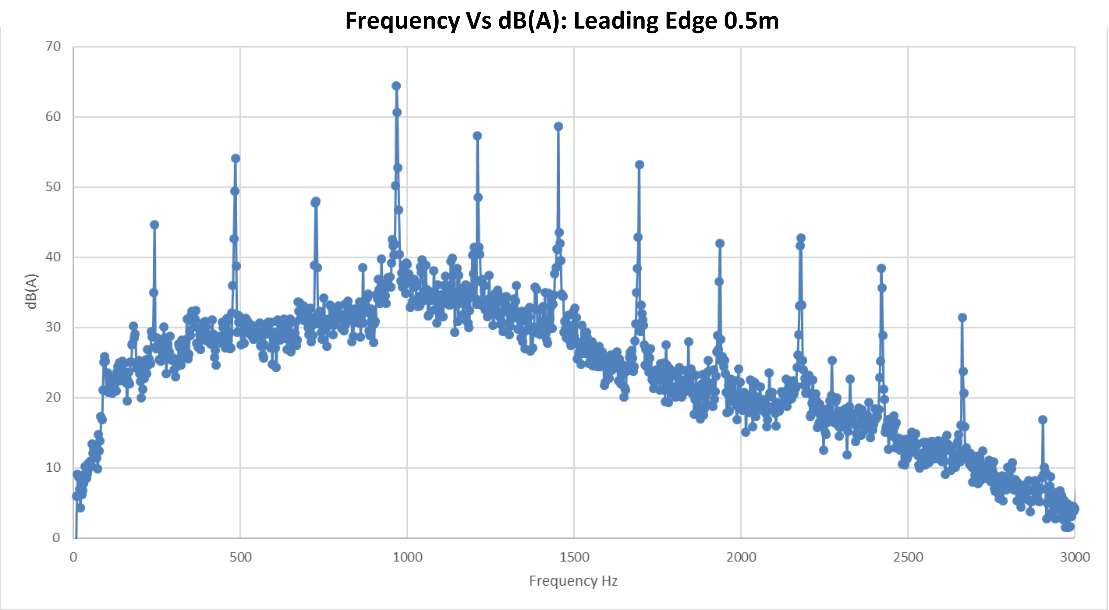


Probe 2

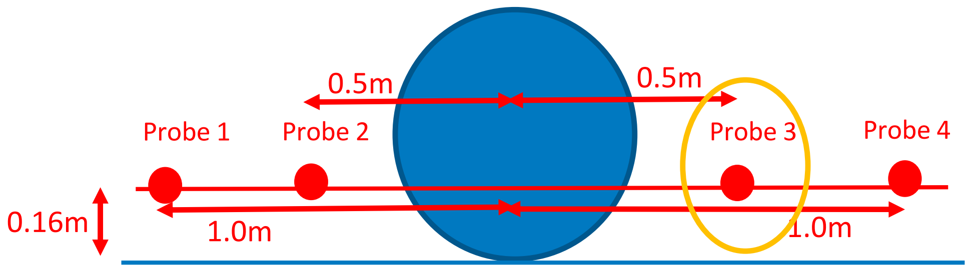


- **Tonal Noise observed for given thread design**

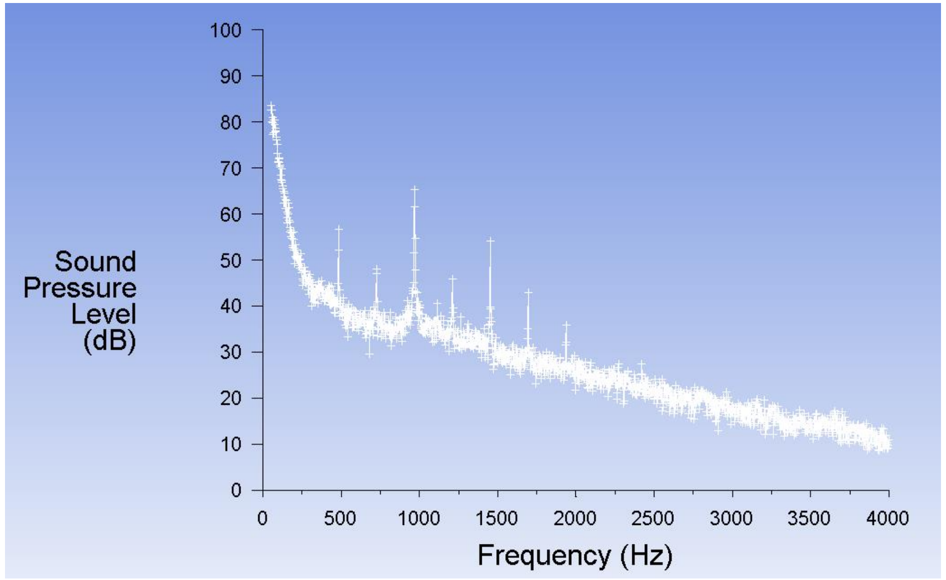




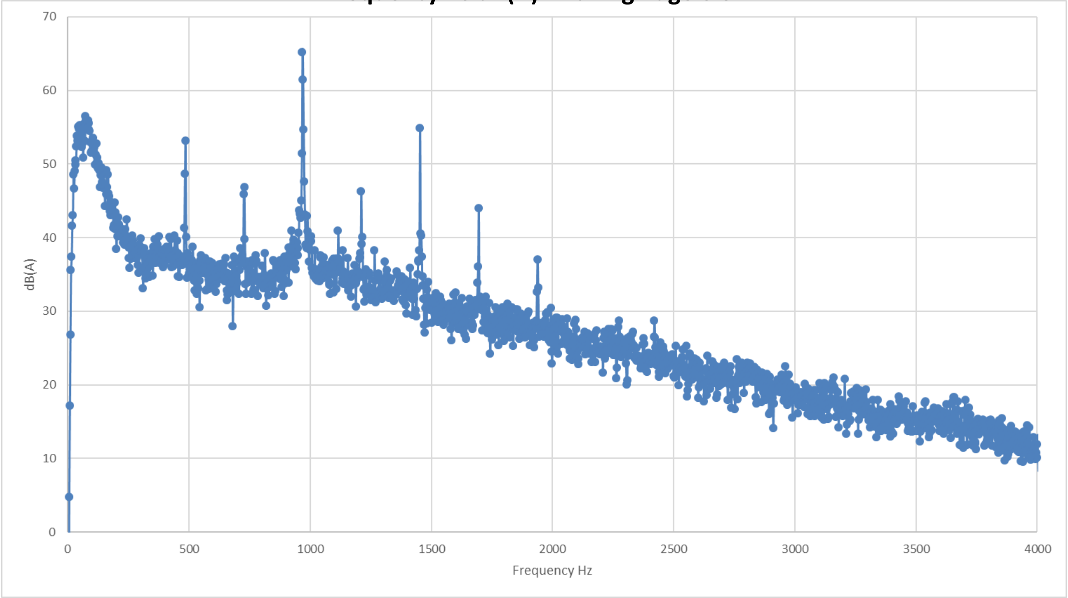
Probe 3



- Tonal noise reduced downstream
- Broadband noise more dominant which is expected to due flow through thread



Frequency Vs dB(A): Trailing Edge 0.5m



Summary

- **High frequency(1KHz-4KHz) pipe resonance and broad band noise captured**
  - Validated with experimental data
- **No tonal noise observed as expected for given tire design**
- **No deformation of tire included while tire interacts with road**
  - Lead to ignoring the air compressibility and flow acceleration in grooves due to deformation of grooves during grooves and road interaction
  - Modeling deformation may lead to expensive computational solution but not much effect on the final accuracy
- **Future scope of work**
  - Capture low frequency(500Hz-1KHz) noise due to tire impact and stick-slip mechanism phenomenon by Aero-vibro Modeling approach
  - Study noise due to interaction of various road condition with different tire pattern

