ENGINEERING TOMORROW

CFD-Based Optimization of Acoustic Noise in the Diffuser Section of an Expansion Valve

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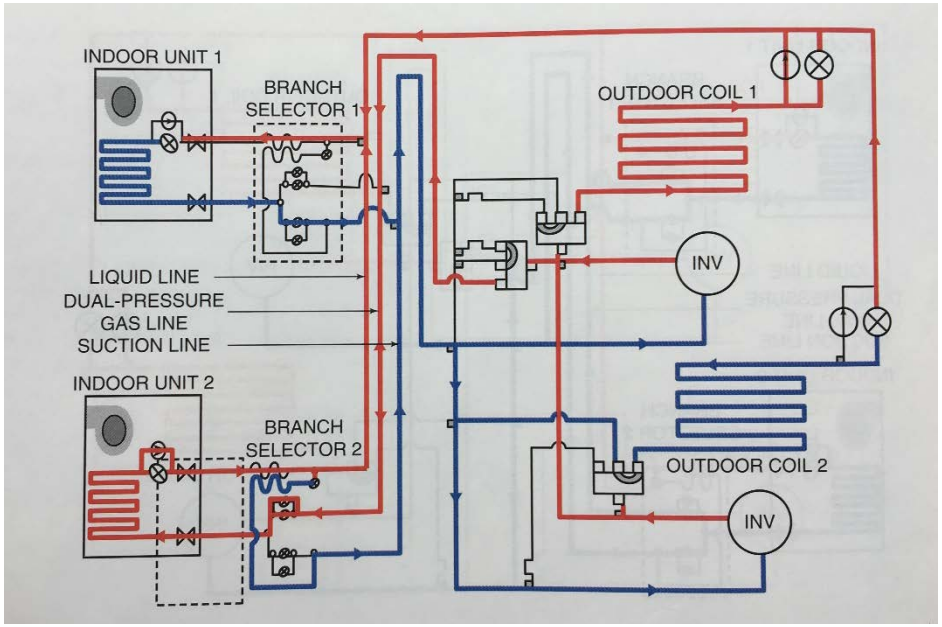
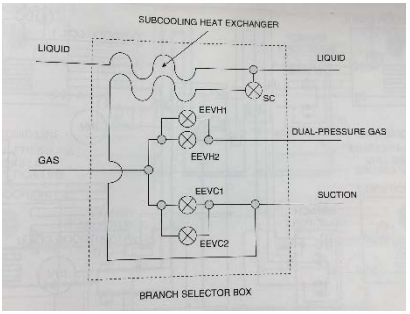
Introduction

- Flow noise in valves is becoming more important:
  - Electronic expansion valves (EEVs) are used as components in many applications, e.g. for variable refrigerant flow (VRF) systems

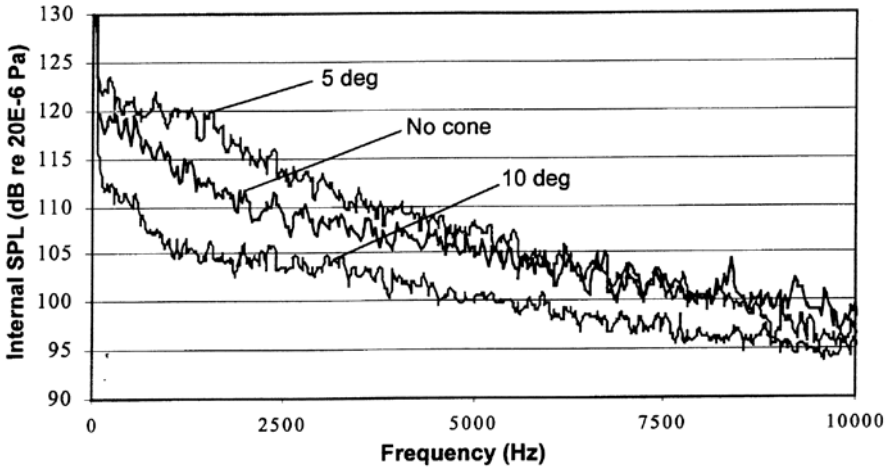


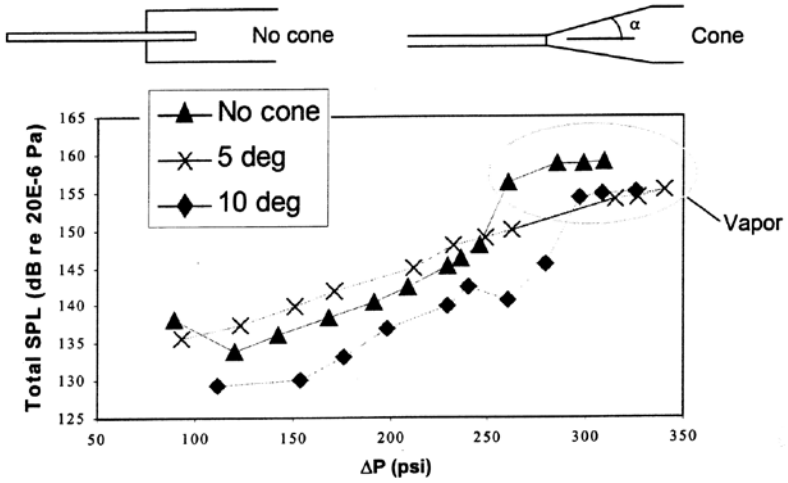


Pictures from: Tomczyk J., Silberstein E., Whitman B. and Johnson B. (2002), Refrigeration and Air Conditioning Technology, 8th Ed., Cengage Learning

Measurements
Pressure inside the flow

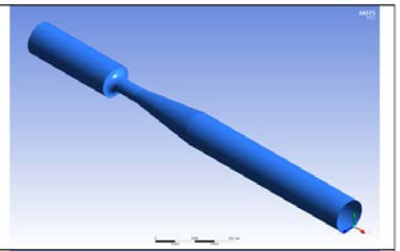
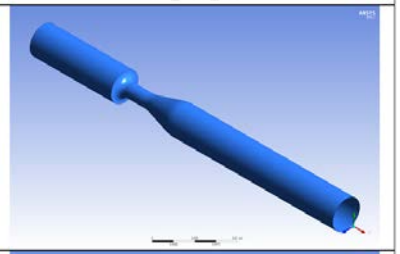
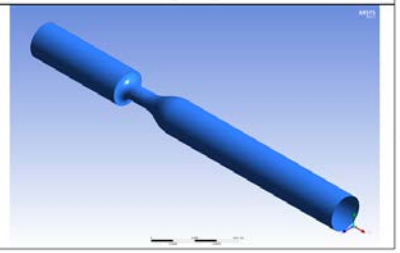
- Singh G.M., Rodarte E., Miller N.R. and Hrnjak P.S. (1999), Noise Generation from Expansion Devices in Refrigerant, ACRC Report TR-152:
  - Pressure measured >15 diameters downstream
  - Larger angle→lower noise:
    - ”Surprisingly”

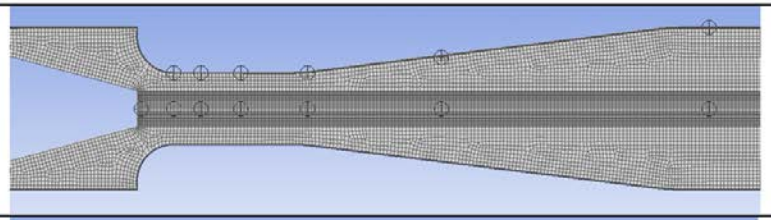
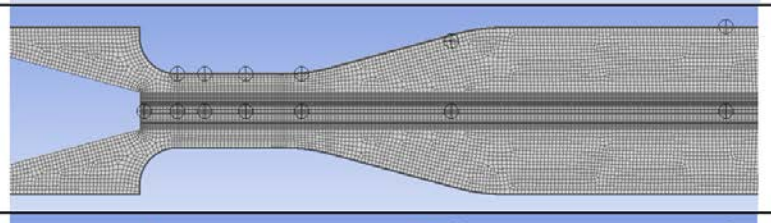
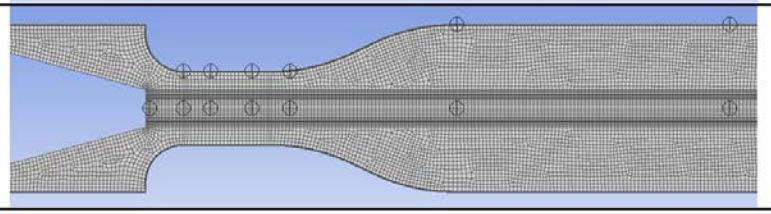




CFD geometries

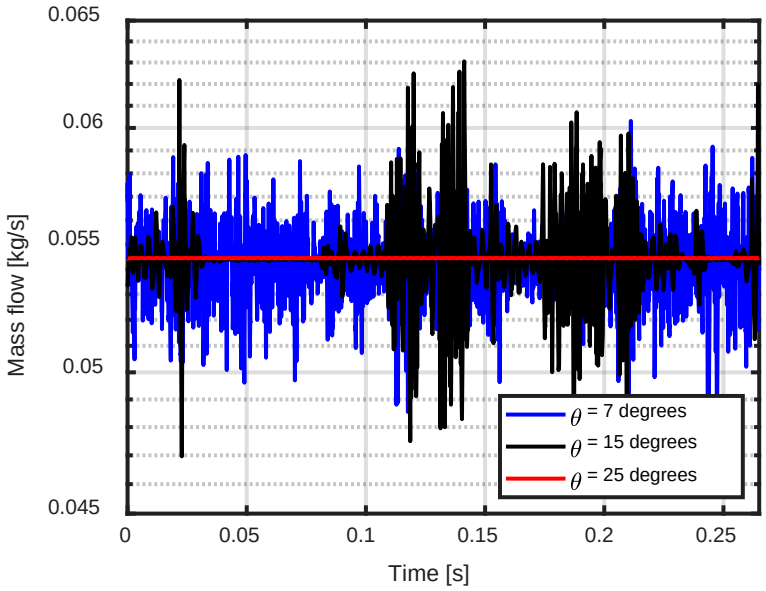
- Flow from left to right
- Cone before choke
- Diffuser section after choke:
  - Diffuser half-angle θ is varied

Geometry a: θ = 7 degrees	
Geometry b: θ = 15 degrees	
Geometry c: θ = 25 degrees	

Geometry a: θ = 7 degrees	
Geometry b: θ = 15 degrees	
Geometry c: θ = 25 degrees	

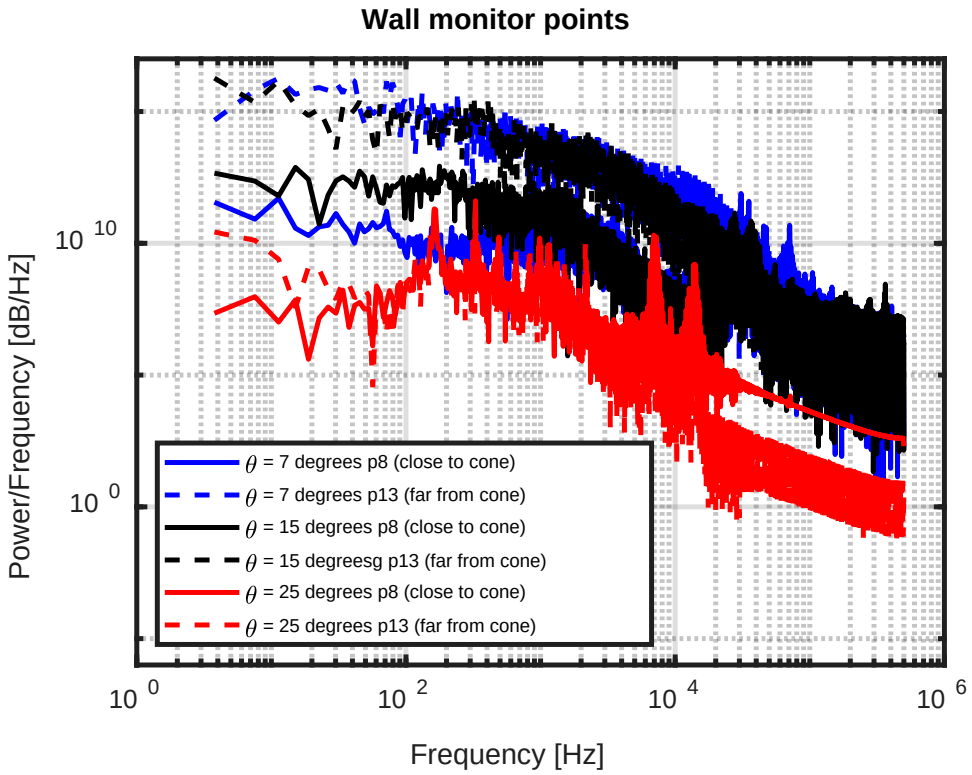
CFD results
Mass flow and stability

- CFD:
  - Pressure-based transient
  - Compressible single-phase fluid (virtual refrigerant)
  - Turbulence: Scale-adaptive simulation (SAS) method
- Mass flow:
  - 7 degrees: Continuous fluctuations
  - 15 degrees: Intermittent bursts
  - 25 degrees: Steady



CFD results
Power spectral density

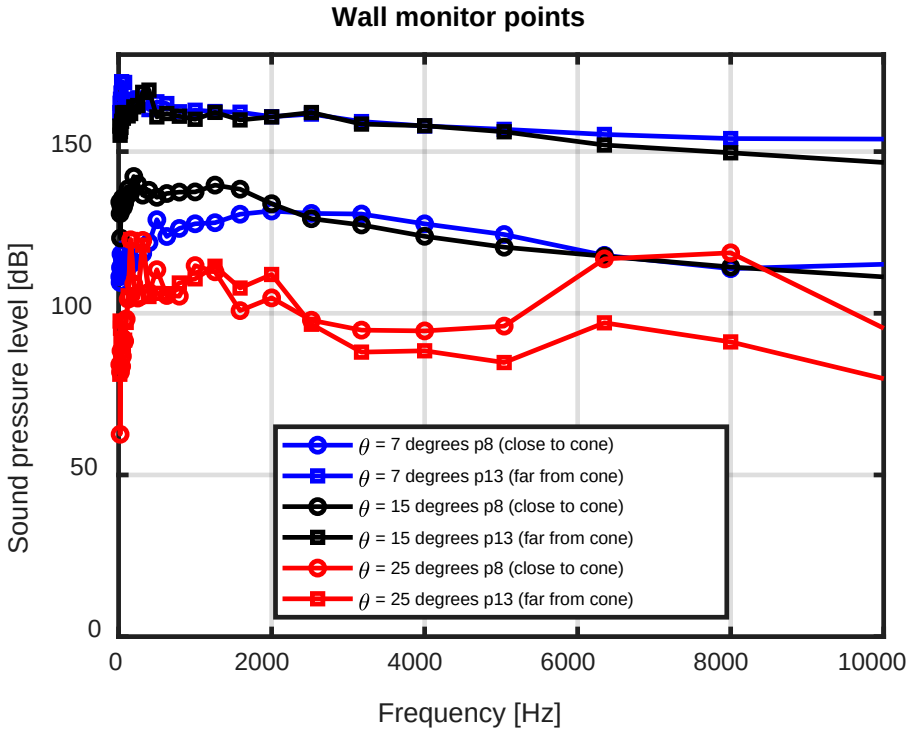
- Overall noise level lower for 25 degrees compared to 7&15 degrees
- Pronounced frequency peaks (7&14 kHz) in the 25 degree spectra

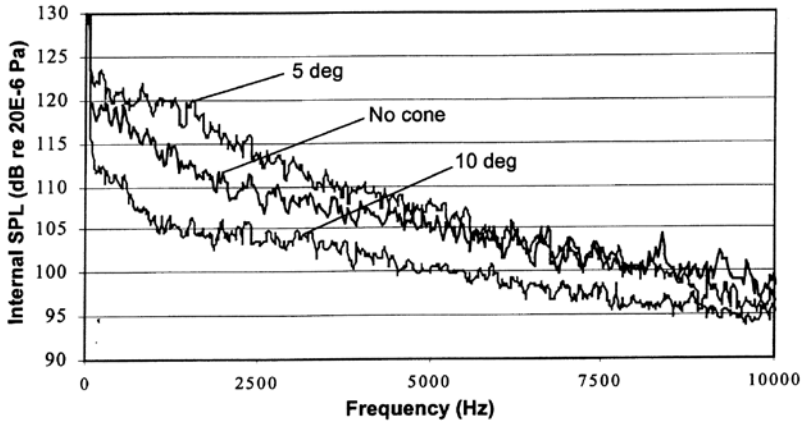


CFD results
Sound pressure level

- CFD (left) compared to measurements (right):
  - Higher amplitude
  - High frequency peak for 25 degrees

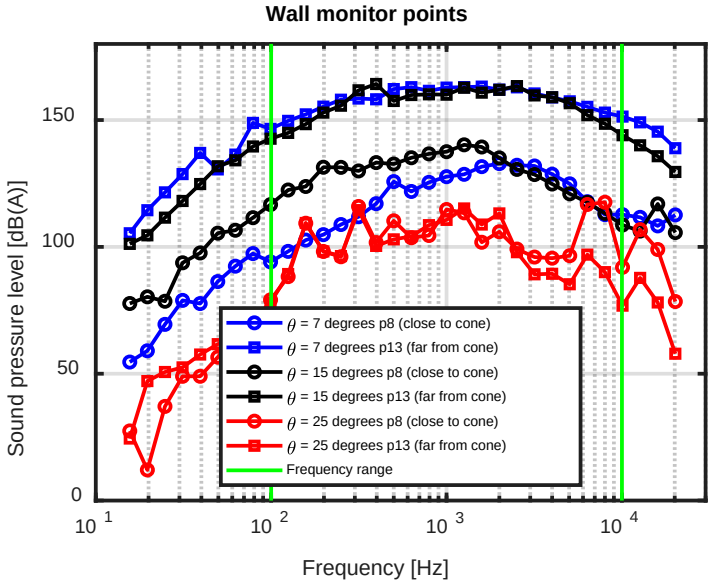
→Both may be because simulation points are close to the choke

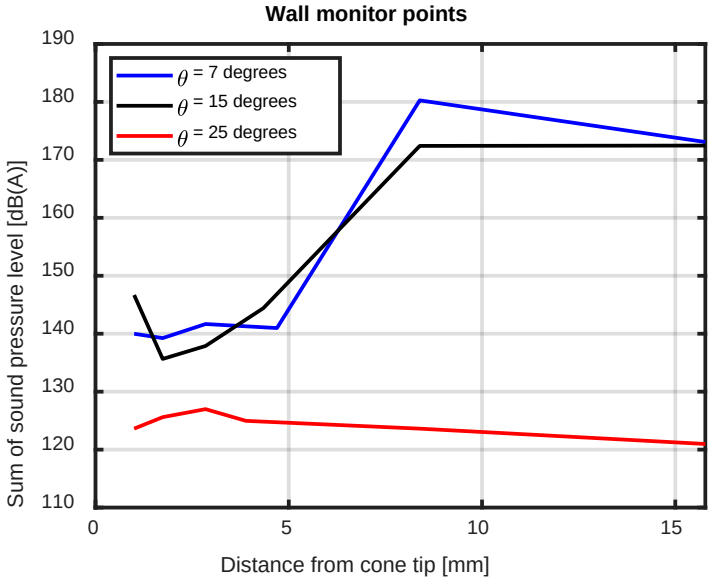




CFD results
One-third octave bands

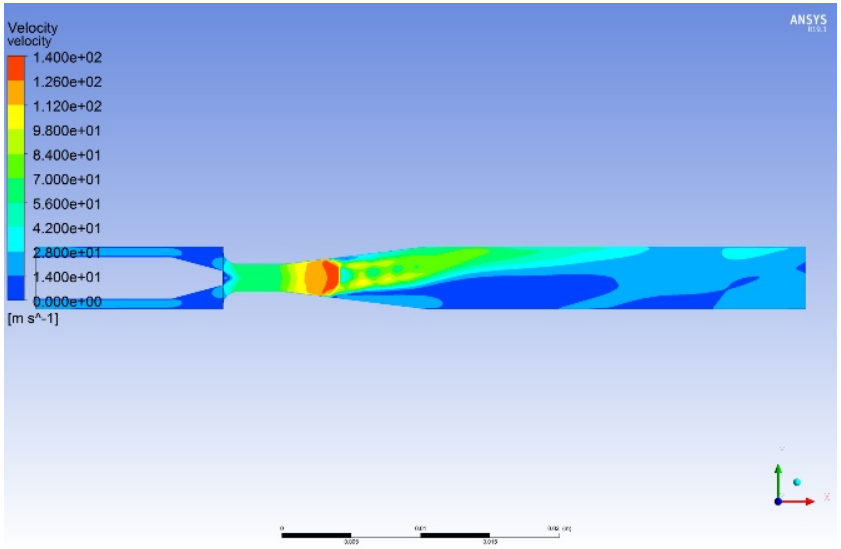
- Left: A-weighted sound pressure level (SPL)
- Right: Sum of A-weighted SPL from 100 Hz to 10 kHz:
  - In choke:
    - 25 degrees is 10 dB lower than the two other geometries
  - In diffuser section:
    - 25 degrees up to 50 dB lower than the two other geometries

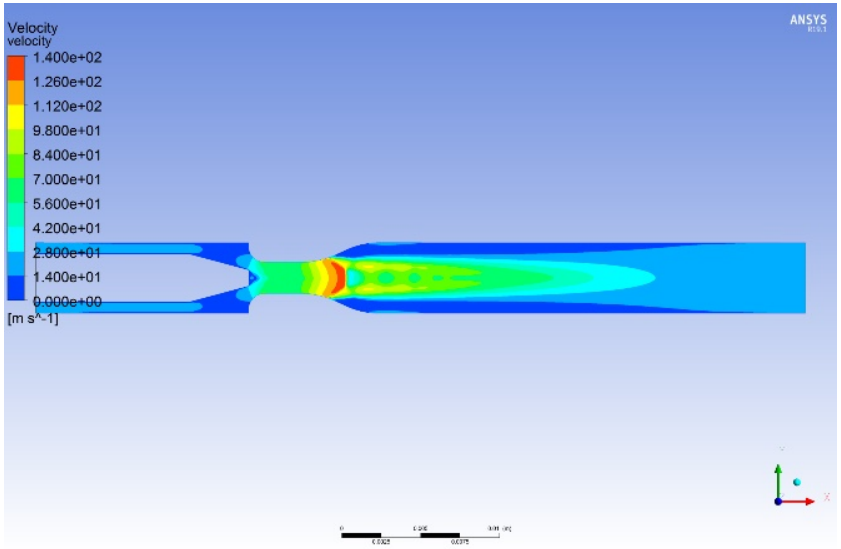




CFD results
Velocity magnitude

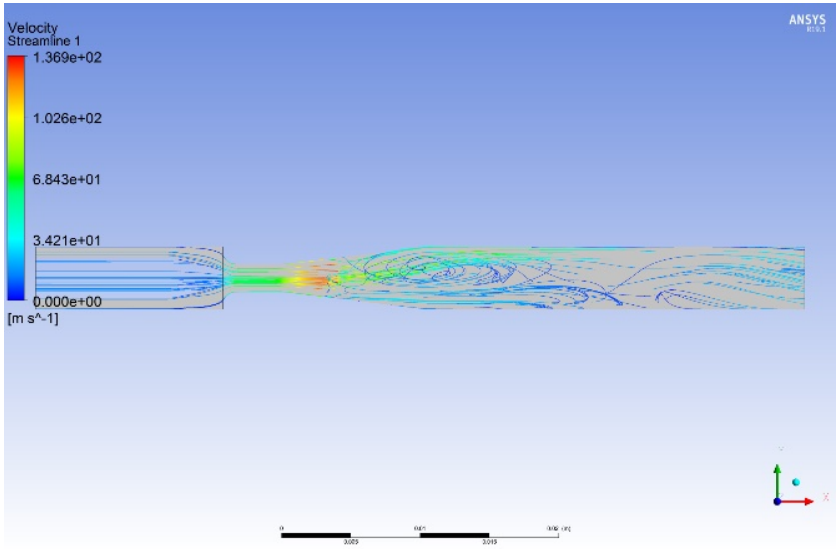
- Left: 7 degree diffuser:
  - Jet attaches to the wall
- Right: 25 degree diffuser:
  - Jet symmetric through diffuser

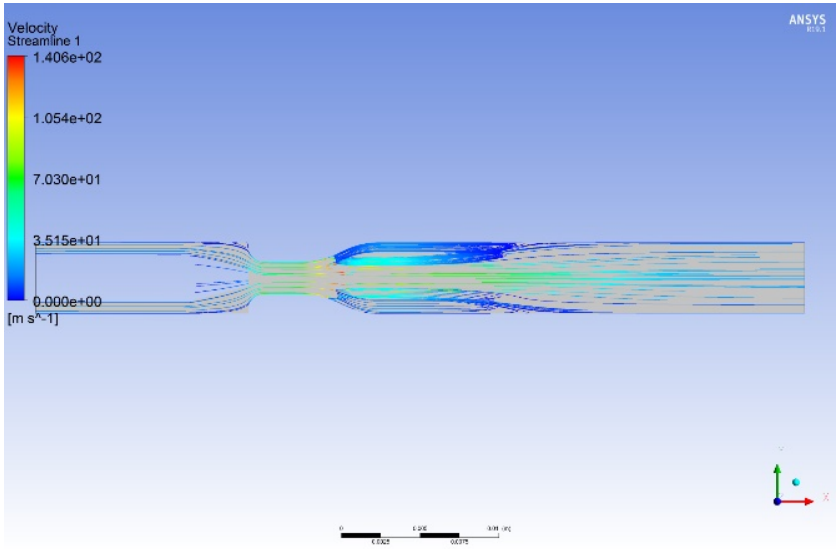




CFD results
Velocity streamlines (side-view)

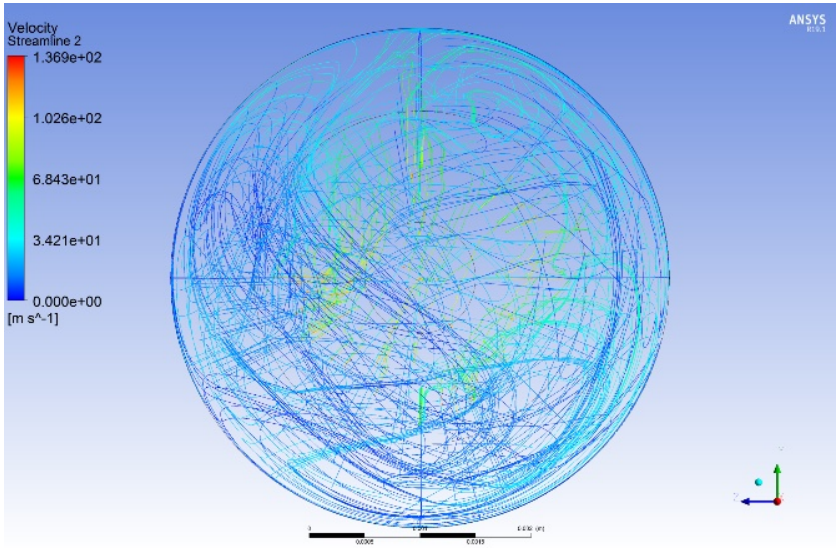
- Left: 7 degree diffuser:
  - Chaotic flow in diffuser
- Right: 25 degree diffuser:
  - Clear flow separation in diffuser→Recirculation zone

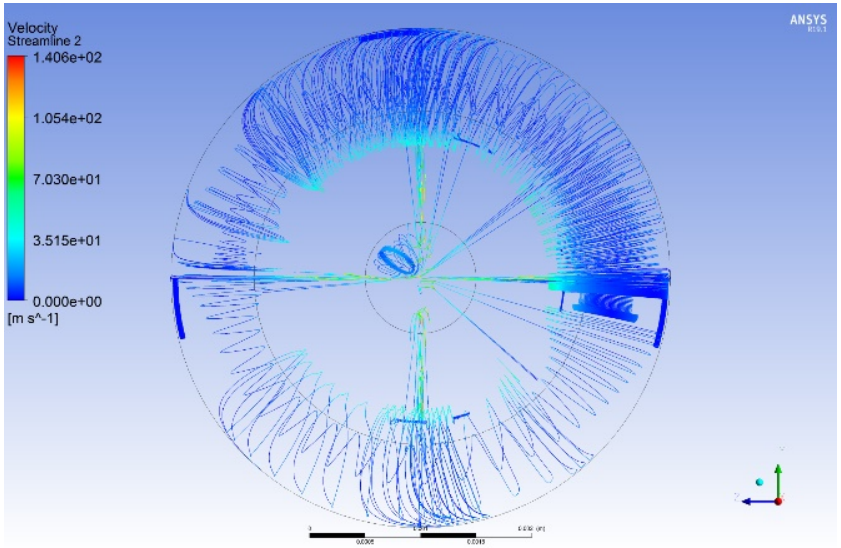




CFD results
Velocity streamlines (end-view)

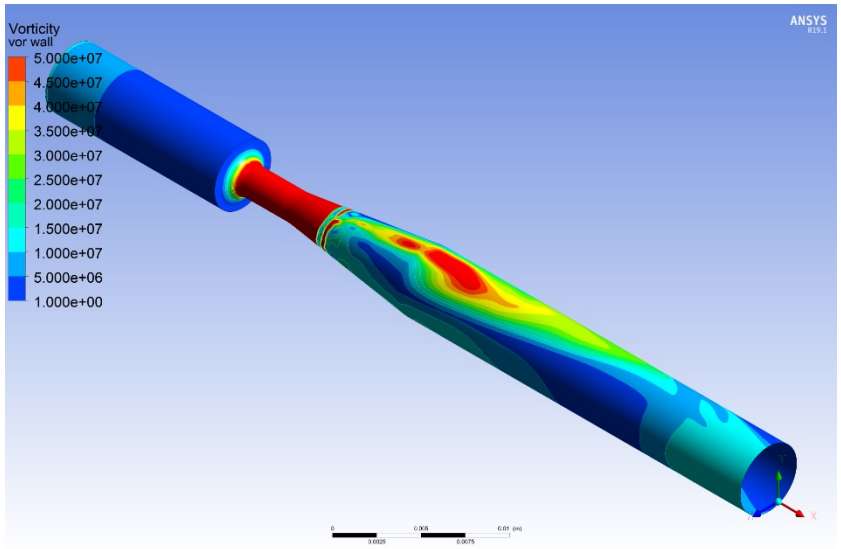
- Left: 7 degree diffuser:
  - Chaotic flow
- Right: 25 degree diffuser:
  - Vortex ring signature

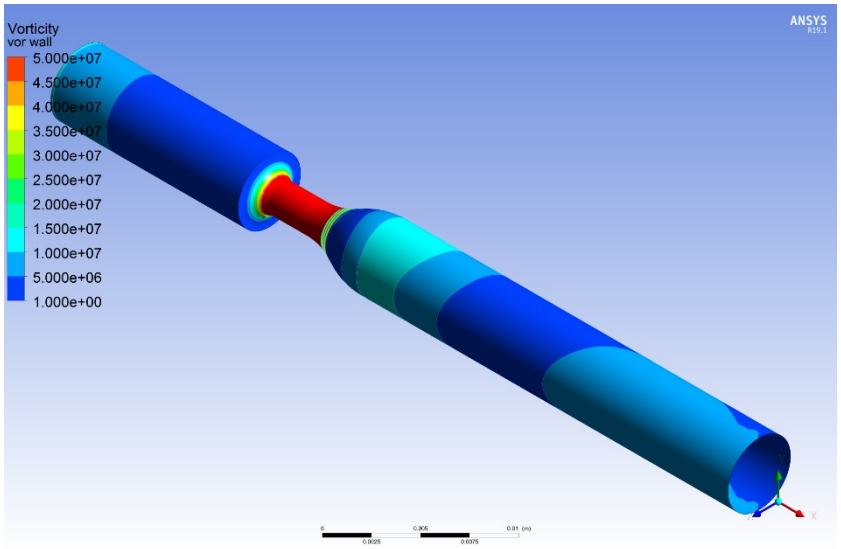




CFD results
Vorticity magnitude

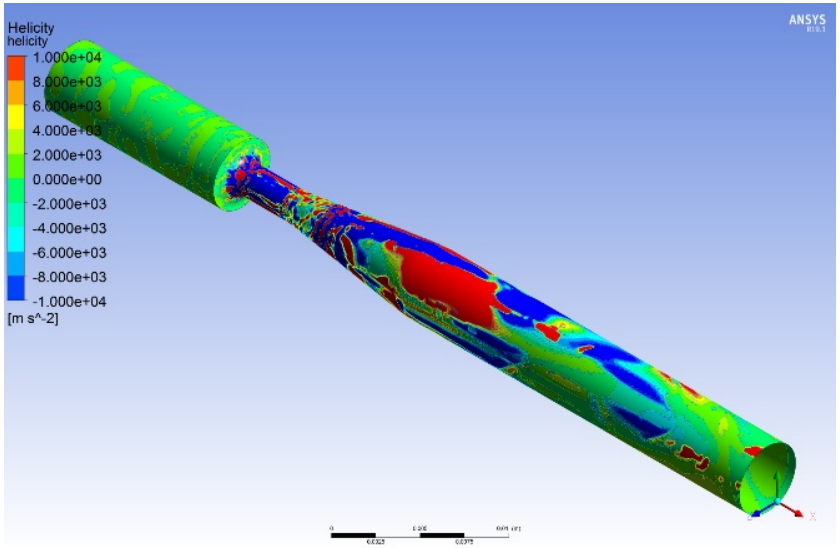
- Left: 7 degree diffuser:
  - Large vorticity in some areas of the diffuser
- Right: 25 degree diffuser:
  - Smaller vorticity in the diffuser

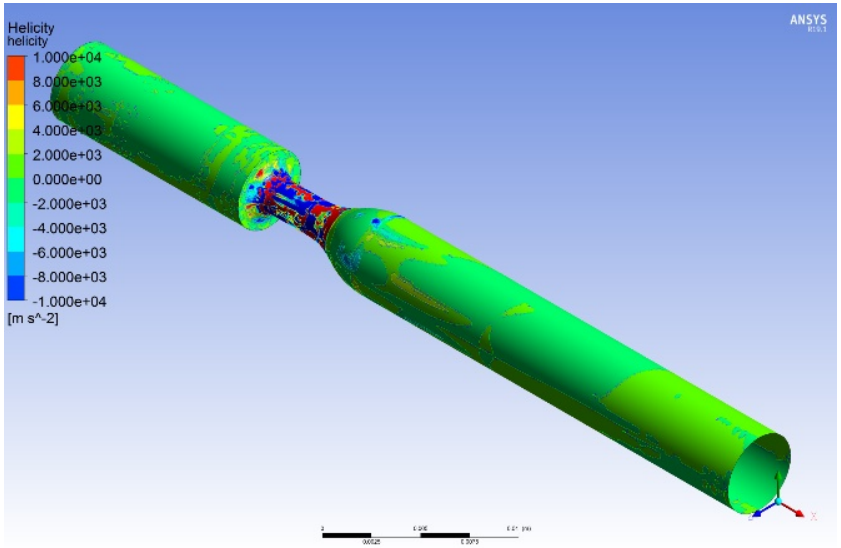




CFD results
Helicity density

- Left: 7 degree diffuser:
  - Large helicity density magnitude in some areas of the diffuser
- Right: 25 degree diffuser:
  - Small helicity density magnitude in the diffuser





Conclusions

- We have performed CFD simulations to study the acoustic performance of different diffusers:
  - The diffuser with largest angle displays the lowest noise level:
    - This is in agreement with previous measurements
  - The reason for the low noise level for the large-angle diffuser appears to be the existence of a vortex ring which acts to shield the wall from noise generated farther inside the flow:
    - Thus, an abrupt expansion may also perform well:
      - However, it has to be kept in mind that many valves are bidirectional
- Next: Find faster/better methods to quantify noise at the wall:
  - Example: Sum of helicity density magnitude on the wall:
    - Large sum→High noise level
    - Small sum→Low noise level