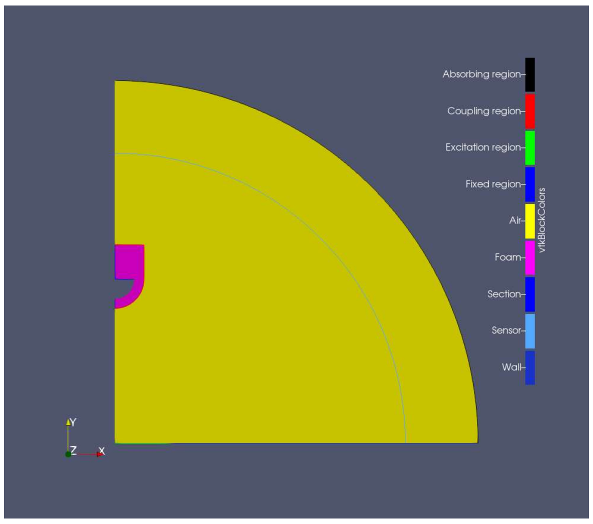
Homework0_e12329556_Yash_Waware

Exercise | Acoustic scattering by a flexible object

Assignment

1. Create a suitable mesh for the problem

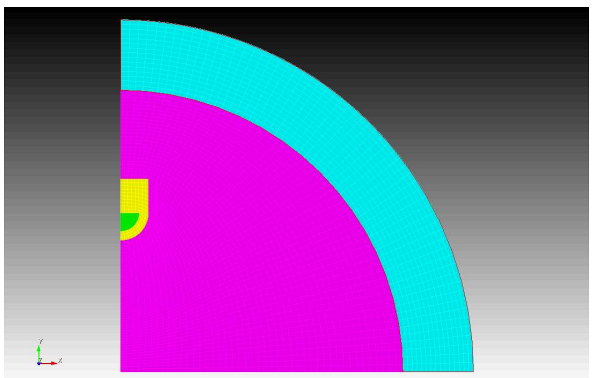
- Define the necessary regions and assign meaningful names.



- Estimate the necessary spatial discretization. **(1 Point)**

QUAD8 elements is chosen becasue it provides higher-order interpolation compared to lower-order elements (e.g., QUAD4). This results in a more accurate representation of the solution, especially if there are variations in the acoustic field within an element.

- Create an image of your mesh and describe how you choose the discretization. **(1 Point)**



Since the geometry is symmetric, we can cut the geometry into half and take advantage of this symmetry to reduce the size of the computational domain. The interested frequency range of the study is 100 to 1000 Hz, we are analyzing the system at specific frequencies like 100, 400, 700 and 1000 Hz for harmonic analysis. We have also defined the density and compression modulus of air 1.225 kg/m3 and 1.4271 · 105 Pa and the flexible body is constructed from foam with density, Young modulus and Poisson number of 320 kg/m3, 35.3 · 106 Pa and 0.383, respectively.

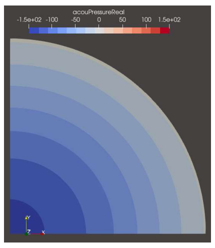
2. Setup harmonic analysis

Perform harmonic simulation

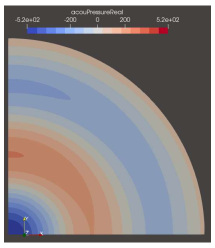
1. Without the solid scatterer, i.e., radiation into the free field
2. With rigid scatterer

and compare the results by answering the following questions.

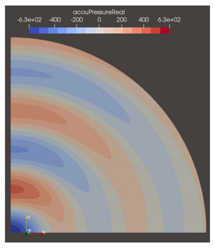
- Plot the pressure field at 100, 400, 700 and 1000 Hz with and without scattering. **(1 Point)**



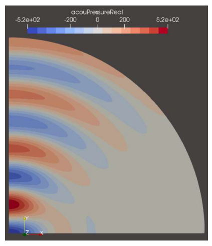
At 100 Hz
without the
solid scatterer



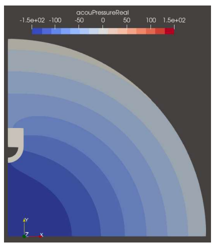
At 400 Hz
without the
solid scatterer



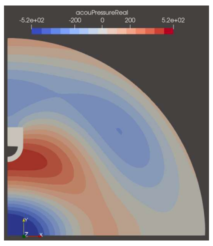
At 700 Hz
without the
solid scatterer



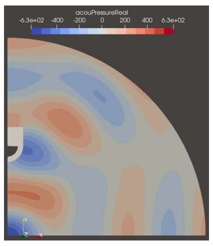
At 1000 Hz
without the
solid scatterer



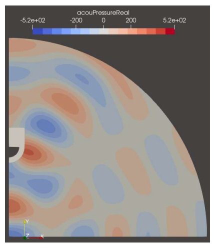
At 100 Hz with
rigid scatterer



At 400 Hz with
rigid scatterer



At 700 Hz with
rigid scatterer



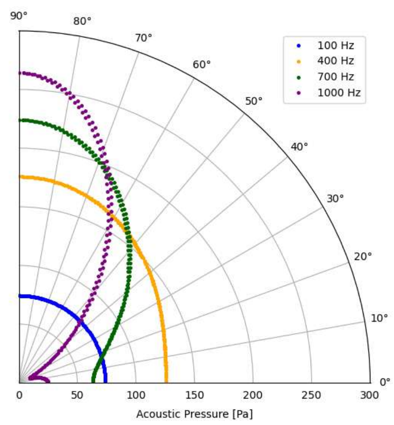
At 1000 Hz with
rigid scatterer

- Animate the field results and comment on the differences in the wave propagation (e.g., at 1000 Hz).**(1 Point)**

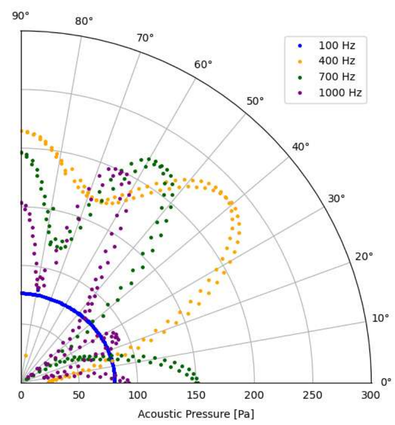
In the animation shown earlier, the scatterer messes up the waves that moves freely, causing them to mix with waves that bounce back or get changed by the scatterer (creates interference).

- At the mentioned frequencies, create polar plots of the acoustic pressure amplitude at a radius of 1 m around the excitation. **(2 Points)**

When the sound wave interacts with the scatterer, the pressure changes and the signal isn't smooth anymore, except when the frequency is 100Hz. This happens because the highest point of the wave is outside the domain and doesn't interact with the scatterer. When we look at how the wave spreads into the open field, we can see a small shift for the higher frequencies.



Acoustic pressure amplitude without scartterer



Acoustic pressure amplitude with scartterer

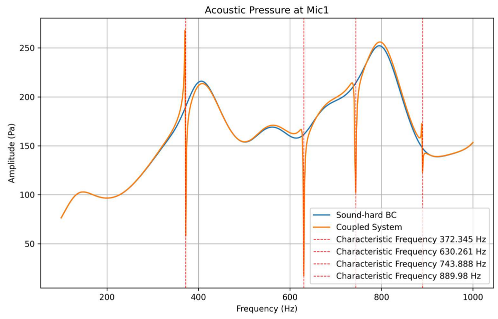
- At what frequencies is the effect of the solid body on the acoustic field more pronounced? Discuss possible reasons. **(2 Points)**

At 400 Hz, 700 Hz, and 1000 Hz, we observe greater disturbances. This is primarily due to the fact that as the frequency increases, the wavelengths become shorter. Consequently, we can observe more peaks in the acoustic pressure, leading to an increase in the occurrence of interferences. These frequencies excite modes of vibration in the solid body, leading to pronounced effects on the acoustic field.

3. Solid coupling

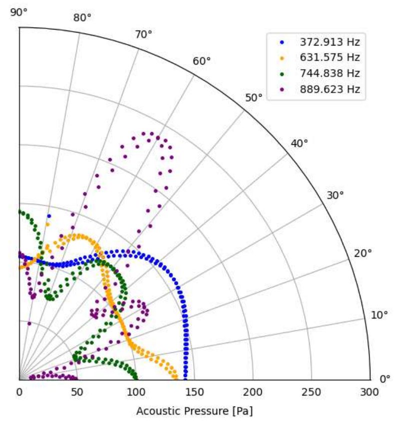
Solid interaction is included in this section. Perform a solid-acoustic coupled simulation and answer the following questions.

- Plot the acoustic pressure at mic1 (x = 0 and y =1) over frequency for both sound-hard BC and the coupled system. Find the characteristic frequencies at which the results differ. **(2 Points)**

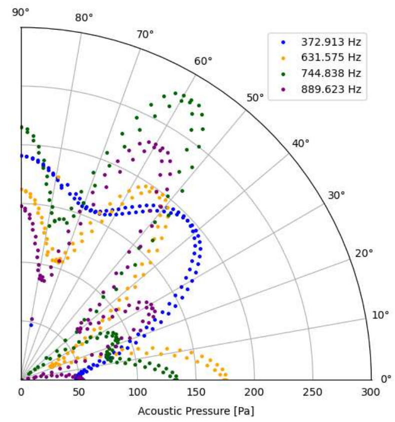


- Similar to the previous step, create a polar plot of the acoustic pressure at the radius of 1 m around the excitation and compare it to sound hard BC (at characteristic frequencies). **(1 Point)**

The soundhard scenario differs due to the absence of solid excitation, with only boundary reflections occurring.



Acoustic pressure for coupled



Acoustic pressure for sound hard

- What are these characteristic frequencies hinting at? (hint: perform the eigenfrequency study of the solid) **(2 Points)**

The eigenfrequencies obtained [372.913, 631.575, 744.838, 889.623] are the characteristic frequencies. Each eigenfrequency corresponds to a specific mode shape, which describes the deformation pattern when it vibrates at that frequency. The low-frequency vibrations produce larger wavelengths.

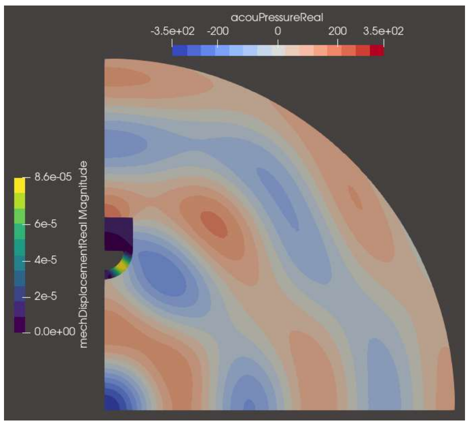
```
-> partially regular
++ Creating PDE 'mechanic' for analysis 'eigenFrequency'

     Frequency in Hz |           Errorbound
----------------------------------------
             372.913 |            1.1554e-13
             631.575 |           5.40773e-14
             744.838 |           3.67366e-14
             889.623 |           2.51688e-14
             1065.46 |           1.86906e-14
             1140.77 |           2.12672e-14
             1359.58 |           1.33719e-14
             1555.11 |            7.4309e-14
             1749.42 |             4.603e-10
             1851.67 |           2.39118e-08
```

- Discuss the results from the eigenfrequency study and compare them to the harmonic results. Why do low natural frequencies not seem to impact the pressure field? **(1 Point)**

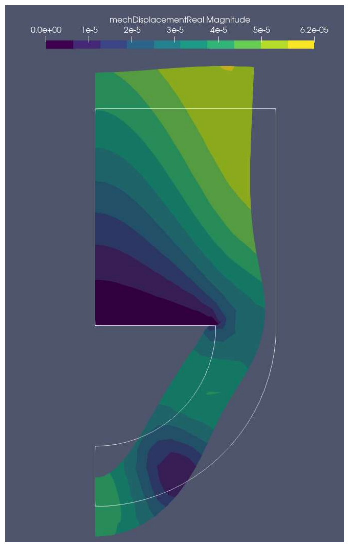
The eigenfrequency study focuses on the inherent vibrational behavior, while the harmonic study examines the response of the system to external excitations. When comparing these two, the peaks in the harmonic response occur near the eigenfrequencies. Also low natural frequencies don't seem to significantly impact the pressure field. This can be attributed to the nature of acoustic waves. Acoustic pressure is a measure of the energy carried by the sound waves. Low-frequency vibrations tend to have larger wavelengths and lower energy, which may not significantly impact the pressure field. On the other hand, high-frequency vibrations have shorter wavelengths and higher energy, leading to more noticeable effects on the pressure field.

- Plot the pressure field and the deformed solid at one of the characteristic frequencies. **(1 Point)**

Below is the plot at the eigen frequency of 631.575 Hz.



Pressure Field



Deformed solid at 631.575 Hz

4. Setup transient analysis

Perform transient simulations with normal velocity excitation of sinBurts with 3 periods value, 0.5 fade in and fade out at 624 Hz in two cases.

1. With rigid body scatterer
2. With flexible body scatterer

Compare the results by answering the following questions.

- What time step is necessary to solve these problems? **(1 Point)**

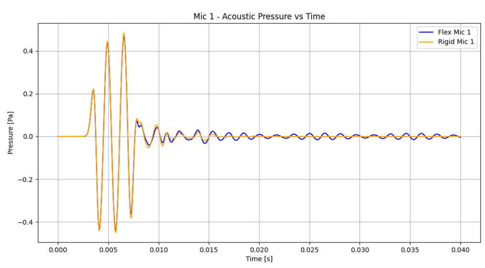
Time steps can be calculated by;

$$\Delta t = \frac{1}{f_{\max} \times 20} = 8 \cdot 10^{-5} sec$$

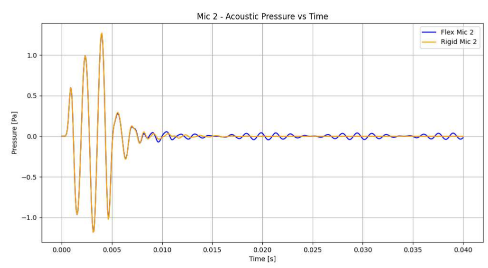
where,

- Δt is the time step
- $f_{\max}$ is the highest frequency component in the signal which is 624 Hz.
- Plot the acoustic pressure or potential at mic1 and mic2 (x = 0 , y = f/16) for both cases. **(1 Point)**

We can see from below plots for rigid system the the acoustic pressure signal progressively approach zero. However in a flexable system oscillations are observed for both mic1 and mic2. We can also see that since mic2 is closer to the source of excitation it catches the signal first.

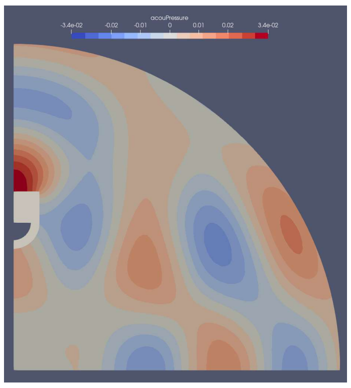


Acoustic pressure at Mic 1

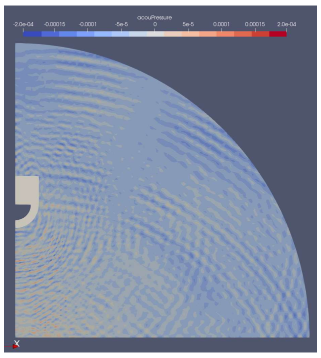


Acoustic pressure at Mic 2

- Animate the wave field and plot the field at t = 0.034s. **(0.5 Point)**



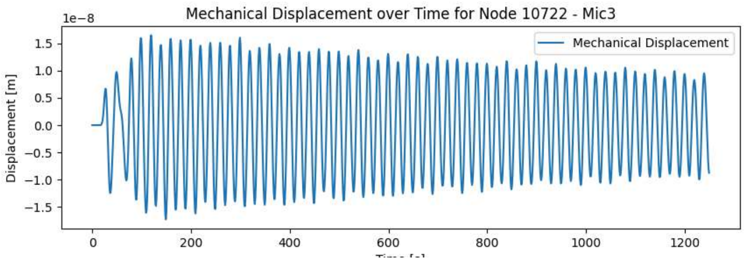
Transient Flexible at t = 0.034s



Transient Rigid at t = 0.034s

- Plot time signal of the solid displacement at mic3. Do you observe any signs of damping? **(1 Point)**

Upon examining the amplitudes of mechanical displacement for mic3, a subtle indication of damping becomes apparent. The amplitudes show a tendency to decrease, suggesting the presence of damping effects.



- Describe the field results and the differences between these two cases. Discuss possible reasons that cause the differences. **(1.5 Points)**

The signal experiences a more rapid damping effect when encountering a rigid scatterer. This can be attributed to the behavior of the rigid body, which tends to reflect a greater portion of the incident waves compared to the flexible scatterer. The increased reflection from the rigid body results in more pronounced destructive interferences, where the reflected waves interfere with the incident waves in a way that diminishes their amplitudes more rapidly. Essentially, the rigid scatterer contributes to a quicker attenuation of the signal in the wave field compared to the flexible counterpart.