Question 6

Q: What is acoustic impedance? How does the acoustic impedance boundary condition work in analysis?

A: Acoustic impedance of a material is a measure of how much the material resists the flow of sound waves. By setting a proper acoustic impedance at the boundary between air and water, it is possible to achieve a state where sound waves can continue to propagate without reflection through the endless space of air or water.
Please refer to the next slide.

Additional Information

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Acoustic impedance, Z, is a measure of how much a material resists the flow of sound waves. It is defined as the value of pressure, P, divided by volume speed, Sv. By setting an acoustic impedance at the boundary between air and water, the analysis can take into account the resistance of air or water.

$$Z = P/Sv\left[\frac{Pa}{m2 \cdot \frac{m}{s}}\right] = P/Sv[\frac{Pa \cdot s}{m3}] \quad (1)$$

If acoustic impedance is set to a boundary condition, it is given as a value per unit area. It is shown below.

$$Z = P/v\left[\frac{Pa}{\frac{m}{s}}\right] = P/v[\frac{Pa \cdot s}{m}] \quad (2)$$

In harmonic analysis, acoustic impedance can be expressed using the equation shown below, where p and v are related through an equation of motion, ρ represents density, and c represents the speed of sound in the medium.

$$Z = \rho c\left[\frac{kg}{m3} \cdot \frac{m}{s}\right] = \rho c\left[\frac{\mathrm{kg}}{\mathrm{m2} \cdot \mathrm{s}}\right] = \rho c\left[\frac{N \cdot s2}{m} \cdot \frac{1}{m2 \cdot s}\right] = \rho c[\frac{Pa \cdot s}{m}] \quad (3)$$

Equations (2) and (3) coincides in their unit. It indicates that equation (2) is expressed as equation (3).

For your information, the acoustic impedances of air and water are shown below.

（Example）Acoustic impedance of air

Z = 1.205[kg/m3]*340[m/s]=409.7[kg/(m2・s)]=409.7 [N・s/m3]

*In SI unit system, 1.0[N]=1.0[kg・m/s2] is used in Equation (3).

（Example） Acoustic impedance of water

Z = 997[kg/m3]*1500[m/s]=1.496e6[kg/(m2・s)]=1.4596e6[N・s/m3]