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# Underwater Flow Noise Simulation

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**Introduction**: Underwater acoustics is an area that studies the sound propagation in water and the interactions with other objects and water boundaries. There are many technologies available for acoustic exploration of the ocean. Autonomous Underwater Vehicles (AUV) is a robot used in ocean sciences that travels underwater autonomously and can tow a hydrophone as a mobile sensor to record sound. The turbulent flow induced by the towing hydrophone generates low frequency flow noise which can interfere with the hydrophone recordings. This project uses COMSOL Multiphysics® software to model flow noise recorded by a towed hydrophone.

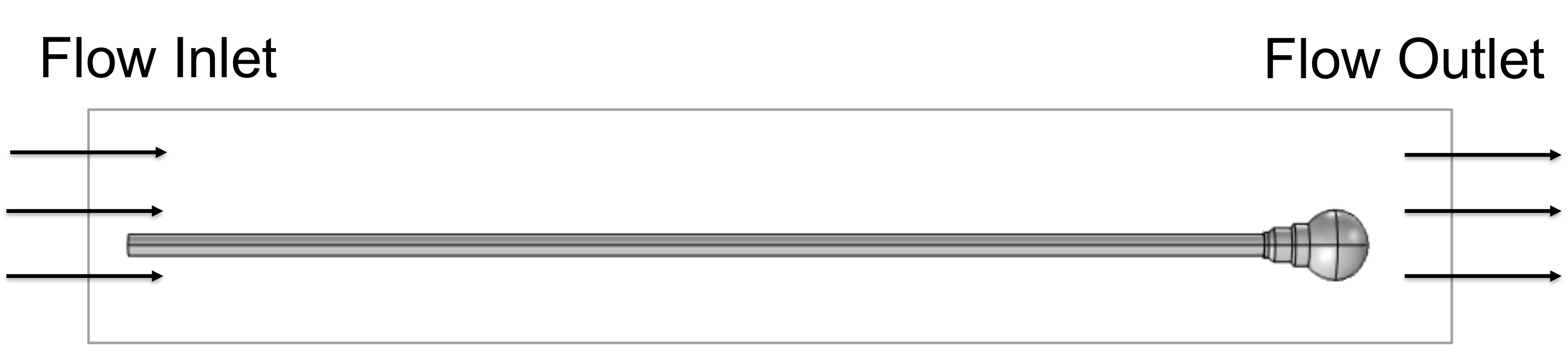


**Figure 1**. Hydrophone Geometry

**Computational Methods**: The physics involved with this simulation is a combination of transient acoustic-solid interaction and turbulent flow.

$$\rho(\mathbf{u}\cdot\nabla)\mathbf{u} = \nabla\cdot\left[-p\mathbf{I} + (\mu+\mu_T)\left(\nabla\mathbf{u} + (\nabla\mathbf{u})^T\right)\right] + \mathbf{F}$$

$$\rho\nabla\cdot(\mathbf{u}) = 0$$

$$\rho(\mathbf{u}\cdot\nabla)k = \nabla\cdot\left[\left(\mu+\frac{\mu_T}{\sigma_k}\right)\nabla k\right] + P_k - \rho\epsilon$$

$$\rho(\mathbf{u}\cdot\nabla)\epsilon = \nabla\cdot\left[\left(\mu+\frac{\mu_T}{\sigma_\epsilon}\right)\nabla\epsilon\right] + C_{\epsilon 1}\frac{\epsilon}{k}P_k - C_{\epsilon 2}\rho\frac{\epsilon^2}{k}, \quad \epsilon = \mathrm{ep}$$

$$\mu_T = \rho C_\mu \frac{k^2}{\epsilon}$$

$$P_k = \mu_T\left[\nabla\mathbf{u} : \left(\nabla\mathbf{u} + (\nabla\mathbf{u})^T\right)\right]$$

$$\nabla\cdot\left(-\frac{1}{\rho_c}\left(\nabla p_t - \mathbf{q}_d\right)\right) - \frac{k_{eq}^2 p_t}{\rho_c} = Q_m$$

$$p_t = p2 + p_b$$

$$k_{eq}^2 = \left(\frac{\omega}{c_c}\right)^2$$

Multiple simulations are undertaken to predict the flow noise level at the variety of Reynolds numbers (i.e. the towing speed). No-slip boundary condition is applied to the hydrophone boundaries.

Pressure and velocity distributions are shown at 0.5, 1, 2, and 3 m/s.

**Results**:

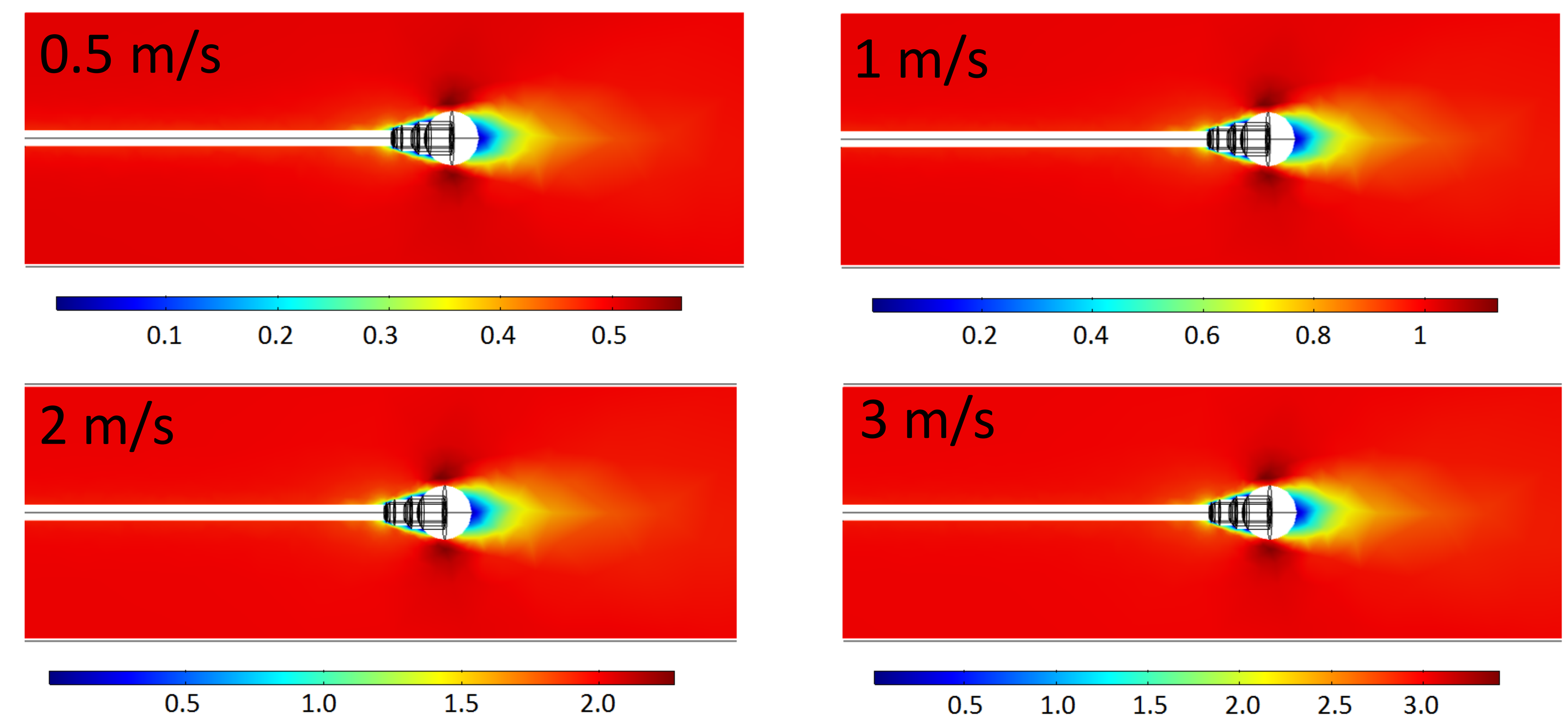


**Figure 2**. Velocity Distribution

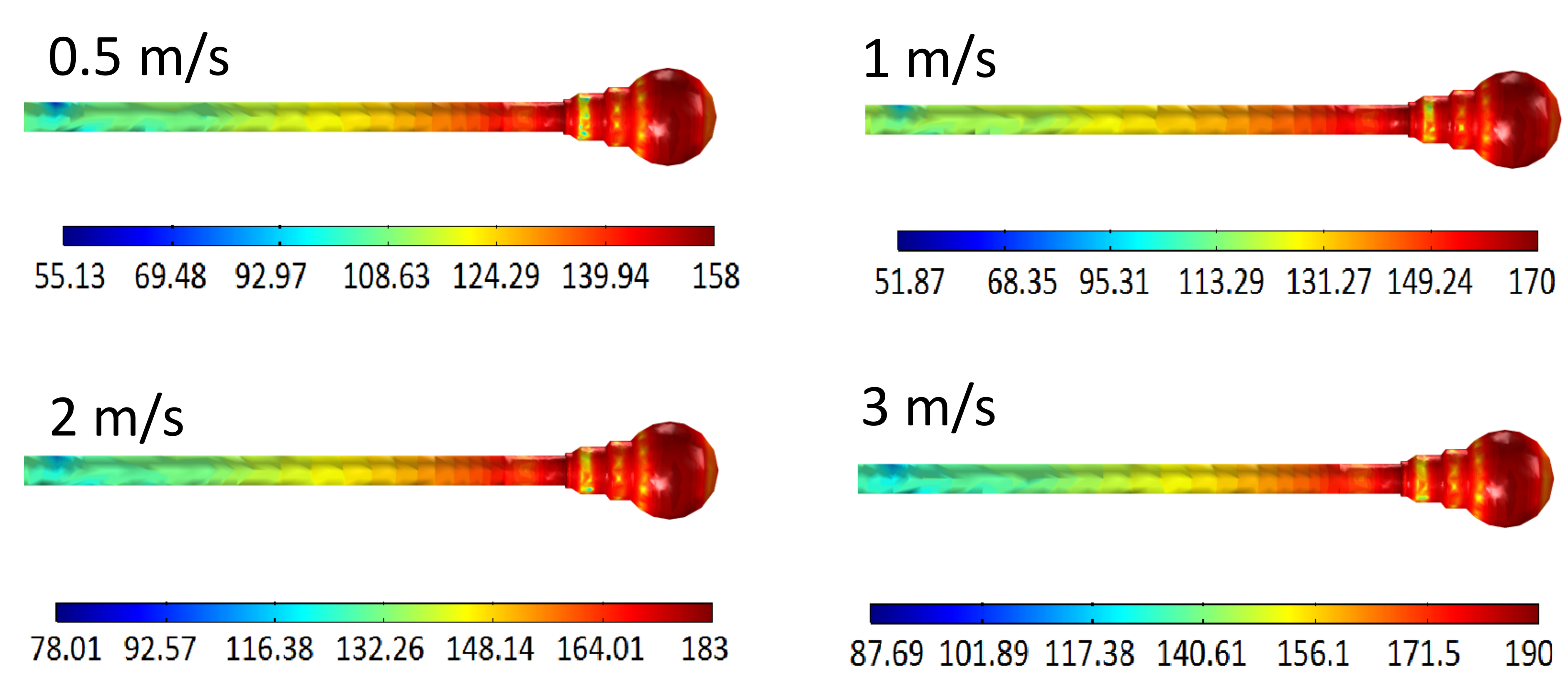


**Figure 3**. Pressure Distribution

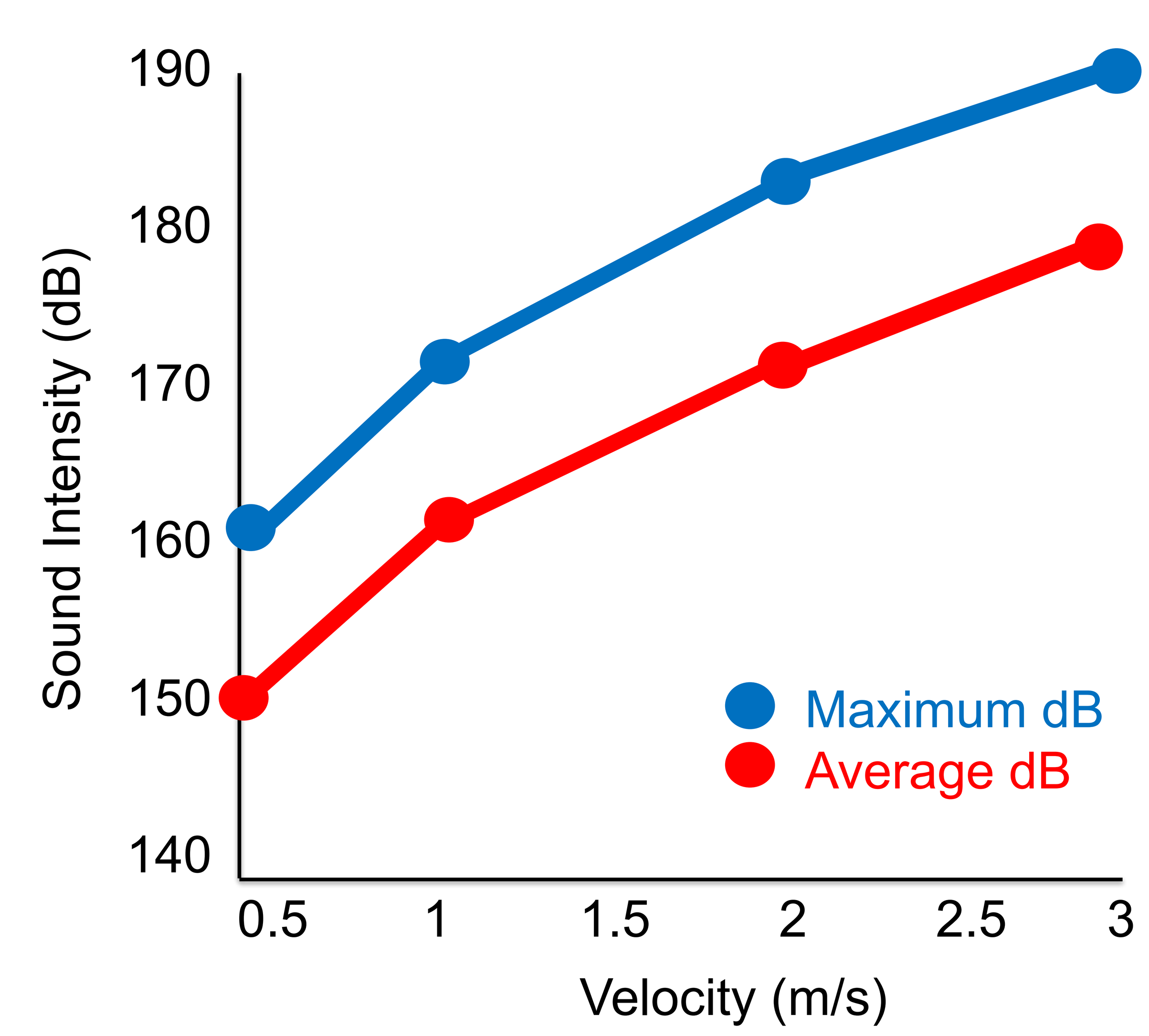


**Figure 4.** Maximum and Average Sound Intensity vs. Velocity

**Conclusions**: COMSOL Multiphysics® software is used to quantify the turbulent flow noise recorded by a towed hydrophone. It has been shown that the maximum and the average pressure around the hydrophone are directly related to the towing speed. Hence, more noise will interfere with the hydrophone recordings at higher velocities.