Simulation of a Concentric-Tube Resonator

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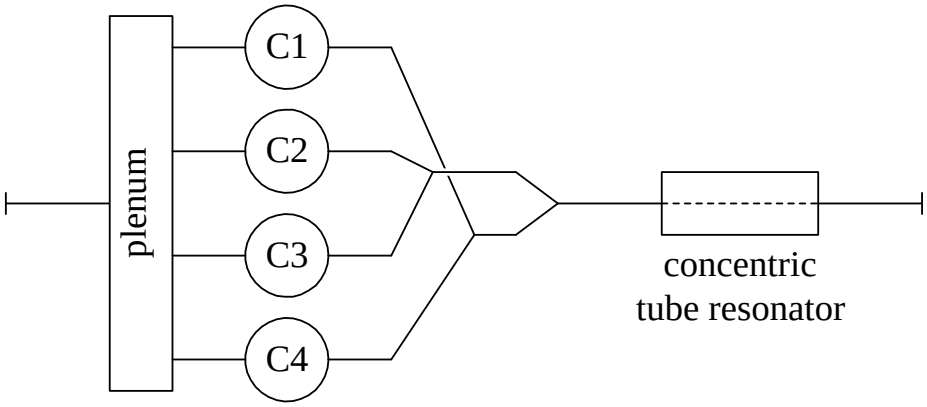
Objective: Accurate modeling and fast simulation of silencers is important for the purpose of their design aiming at reducing engine exhaust noise.

Applications: Manufacturing of exhaust systems, tube-resonators, mufflers.



A four cylinder engine model with silencer.

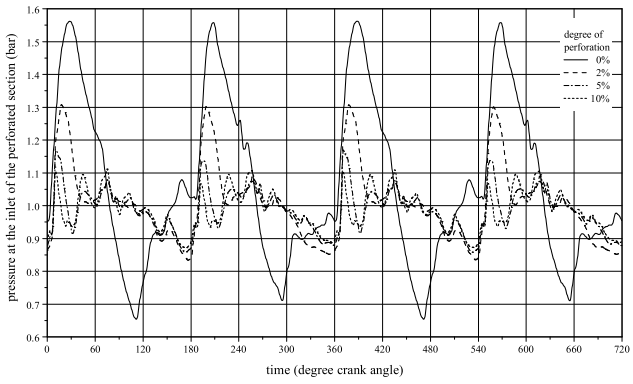
Modeling: At higher excitation frequencies we use a modification of the St. Venant equation for the mass flow rate through the holes of the silencer:

$$\dot{m} = c_d\, p_0 \sqrt{\frac{2}{RT_0}} \sqrt{\frac{\kappa}{\kappa-1}\left[\left(\frac{p}{p_0}\right)^{\frac{2}{\kappa}} - \left(\frac{p}{p_0}\right)^{\frac{\kappa+1}{\kappa}}\right]} - \left(\frac{p}{p_0}\right)^{\frac{2}{\kappa}} \frac{1}{RT_0}\frac{\partial w}{\partial t} l, \tag{1}$$

Used to determine the source terms of the Euler Equations of Gas Dynamics for the flow in the silencer:

$$\frac{\partial}{\partial t}\begin{pmatrix}\rho\\ \rho u\\ e\end{pmatrix} + \frac{\partial}{\partial x}\begin{pmatrix}\rho u\\ \rho u^2 + p\\ u(e+p)\end{pmatrix} = -\frac{1}{S}\frac{dS}{dx}\begin{pmatrix}\rho u\\ \rho u^2\\ u(e+p)\end{pmatrix} - \frac{1}{S}\begin{pmatrix}Q_m\\ 0\\ Q_e\end{pmatrix}, \tag{2}$$

A result: The influence of the perforation on the pressure curve



Pressure at the inlet of the perforated section versus time, expressed in degree crank angle.