Overview of M.G. Prasad’s 1983 paper on Acoustical Studies on Louver-Type Orifices

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Overview

- ✓ Investigate louver type orifices like those in mufflers.
- ✓ Compare to the better understood square and circular orifices.
- ✓ Nonlinear behavior is anticipated in the orifice.
- ✓ Measured the attenuation through the orifice, power reflection coefficient, and impedance.

Attenuation

The attenuation in the linear regime

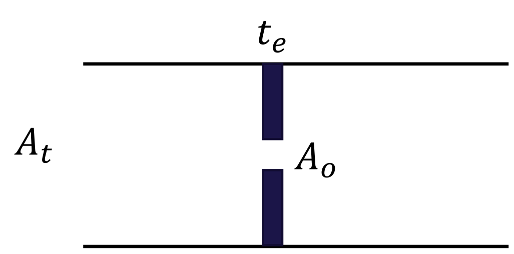
$$\Delta L_p = 10 \log_{10}\left(1 + \left(\frac{A_t}{A_o}\right)^2 (k t_e)^2\right)$$

where t_e : effective thickness ($t_e \propto r_o$)

A_o : area of orifice

A_t : area of duct

k : wave number

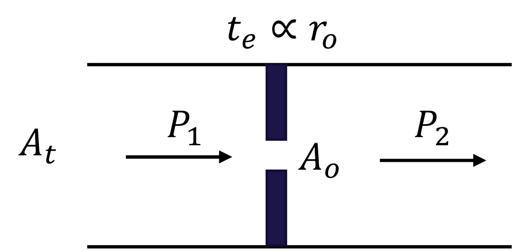


Ingard, 1970

Impedance

- ✓ In the linear regime, the resistance is negligible, and impedance can be approximated by the reactance ($X \gg R$).

$$|z| \cong X \cong \rho c \frac{A_o}{A_t}\left[\left(\frac{P_1}{P_2}\right)^2 - 1\right]^{\frac{1}{2}}$$



- ✓ In the non-linear regime, orifice reactance is small as compared to the resistance ($X \ll R$).

$$|z| \cong R \cong \rho c \left[\frac{A_o}{A_t}\left(\frac{P_1}{P_2} - 1\right)\right]$$

where $R = \rho u_o$

Ingard and Ising, 1967

Power Reflection Coefficient

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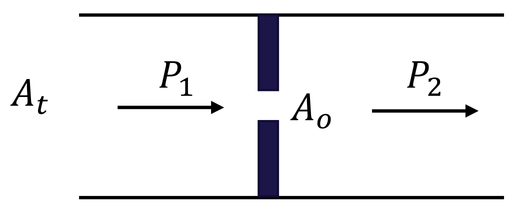
- ✓ Power reflection coefficient

$$R_I = \frac{I_R}{I_I} = 1 - \left[\frac{4}{4\cos^2(kt_e) + \left(\frac{A_o}{A_t} + \frac{A_t}{A_o}\right)^2 \sin^2(kt_e)} \right] \approx 1 - \left[\frac{4}{4 + \left(\frac{A_t}{A_o}\right)^2 (kt_e)^2} \right]$$



Kinsler and Frey, 1962

Typical Louver Configuration

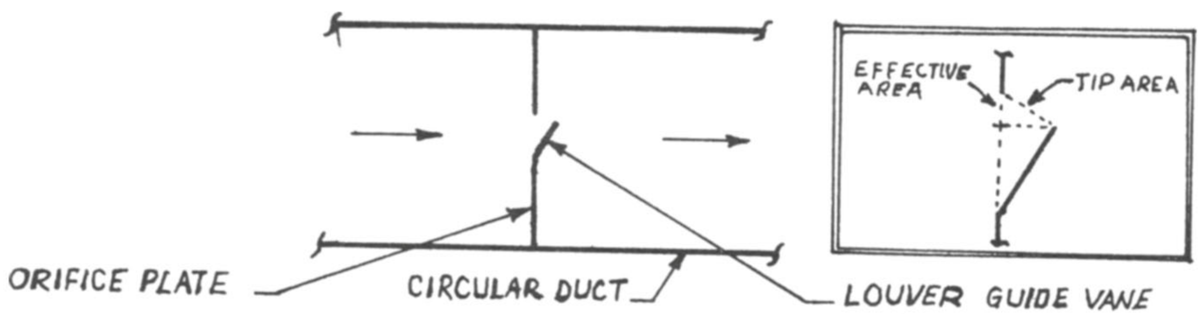
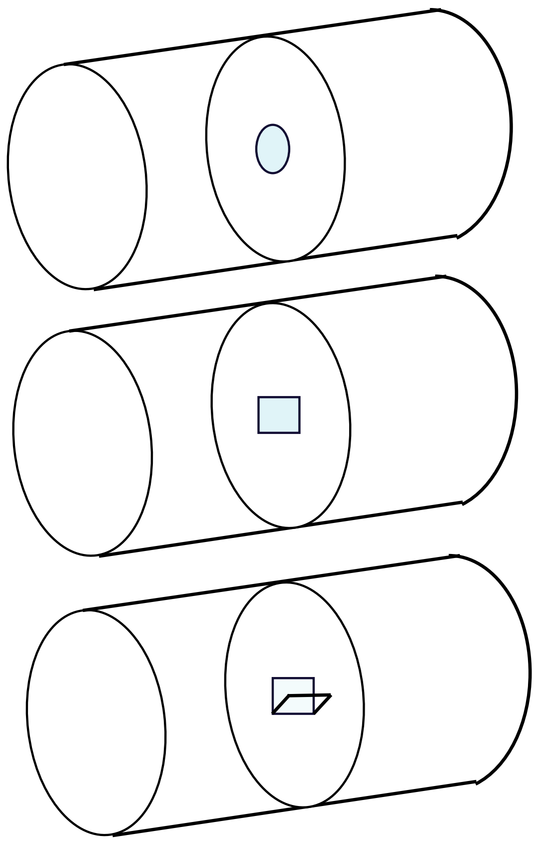


Fig. 1 A Typical Louver Configuration

Experiment



Circular Orifice (CORFCE)

$A_t = 1810\ \mathrm{mm}^2 \quad A_0 = 38\ \mathrm{mm}^2$

Square Orifice (SRTORF)

$A_t = 1810\ \mathrm{mm}^2\ A_0 = 20.16\ \mathrm{mm}^2$

Single Louver (SLOUVR)

$A_t = 1810\ \mathrm{mm}^2\ A_0 = 10.8\ \mathrm{mm}^2$

Experiment

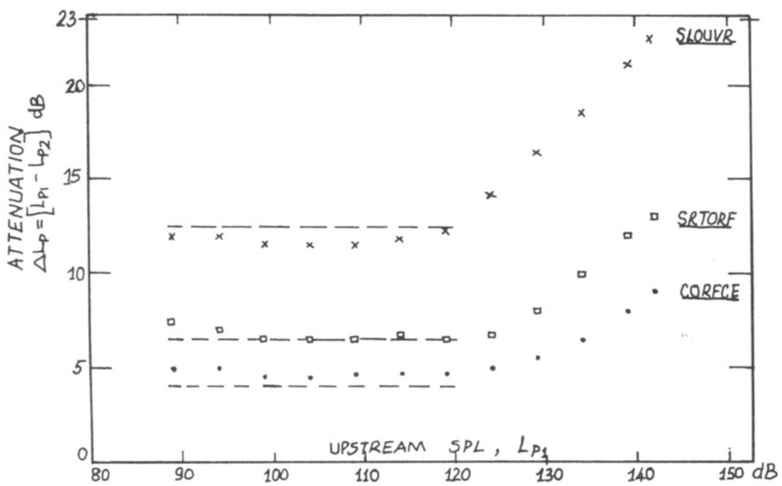


Fig. 2 Measured Attenuation at 205Hz,---Predicted ΔL_p.

SLOUVR – Single Louver (X)

SRTORF – Single Rectangular Orifice (☐)

CORFCE – Circular Orifice (◯)

Experiment

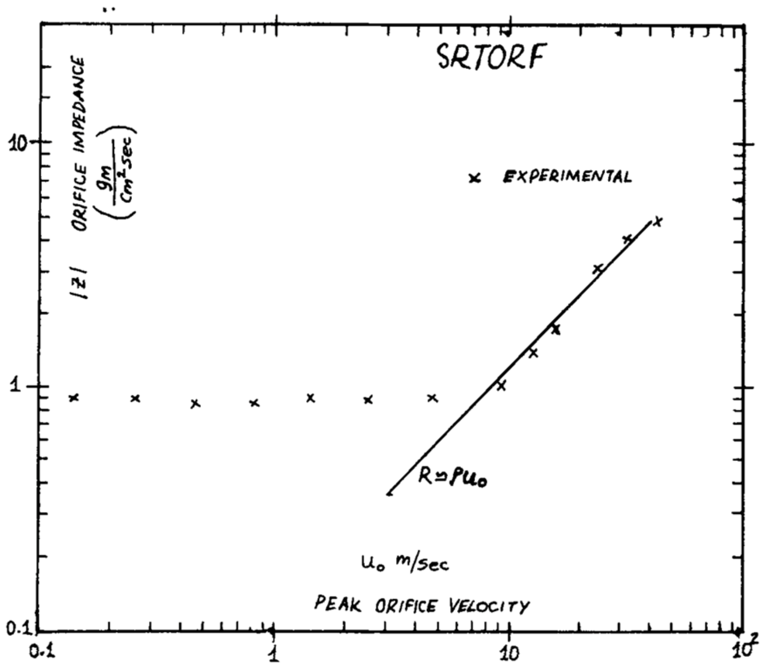


Fig. 3 Orifice Impedance Obtained From Measured L_{p1} and L_{p2}

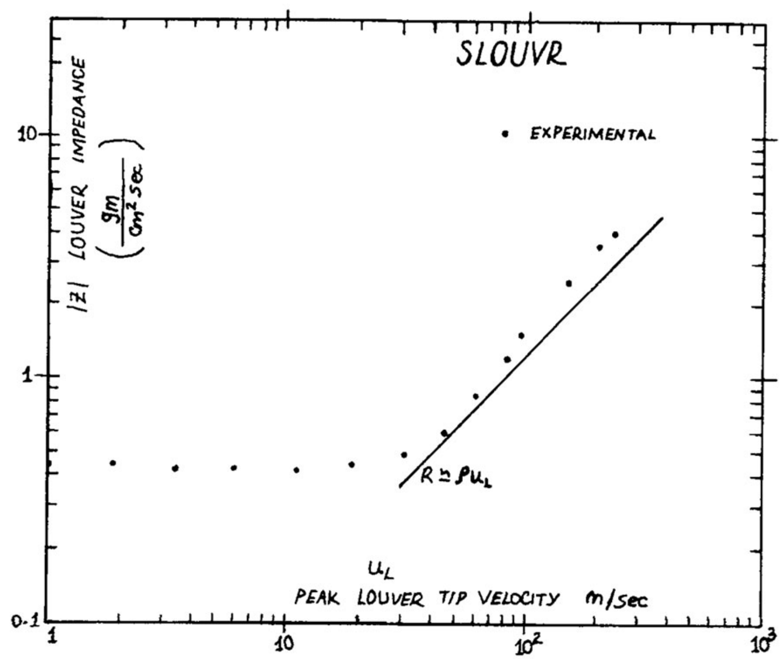


Fig. 4 Louver Impedance Obtained From Measured L_{p1} and L_{p2}

Power Reflection Coefficient in Linear Regime

CORFCE

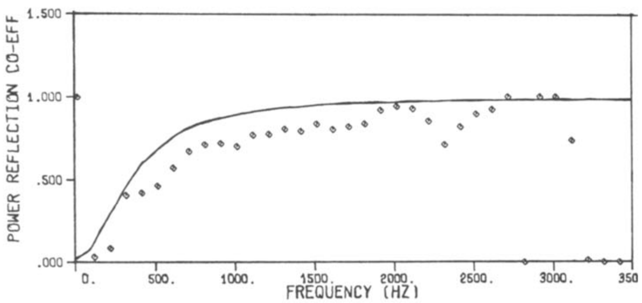


Fig. 5 Power Reflection Co-efficient of a Circular Orifice

—Theory; ◇Experiment

SRTORF

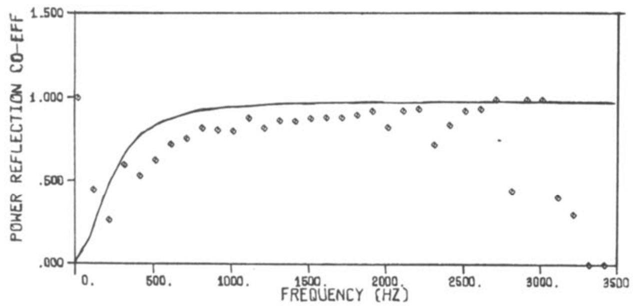


Fig. 6 Power Reflection Co-efficient of a Rectangul

Orifice

—Theory; ◇Experiment

SLOUVR

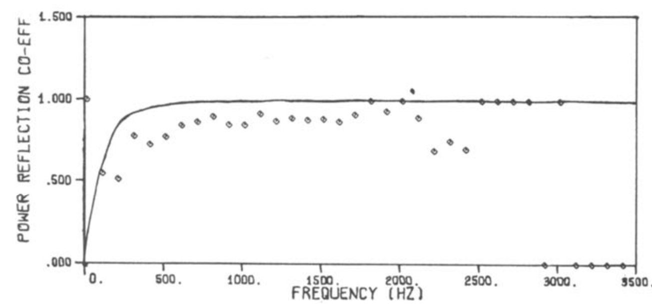


Fig. 7 Power Reflection Co-efficient of a Single Louver

—Theory; ◇Experiment

Normalized Impedance

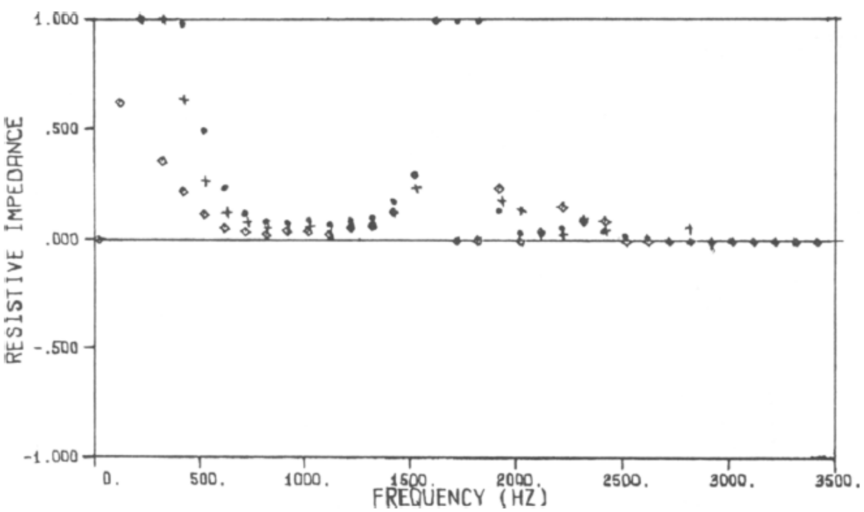


Fig. 10 Comparison of Measured Values of Normalized Resistive Impedance
— Theory for a closed end; ◇ SLOUVR, + SRTORF, • CORFCE

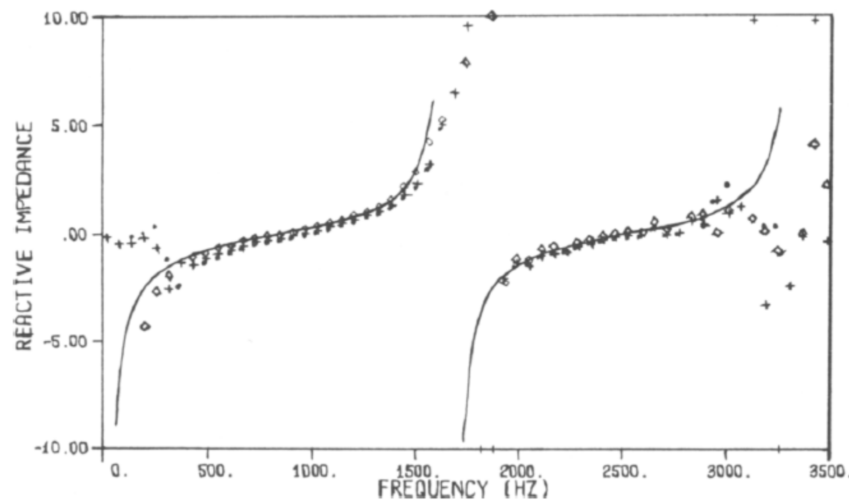


Fig. 11 Comparison of Measured Values of Normalized Reactive Impedance
— Theory for closed end; ◇ SLOUVR, + SRTORF. • CORFCE

Discussion

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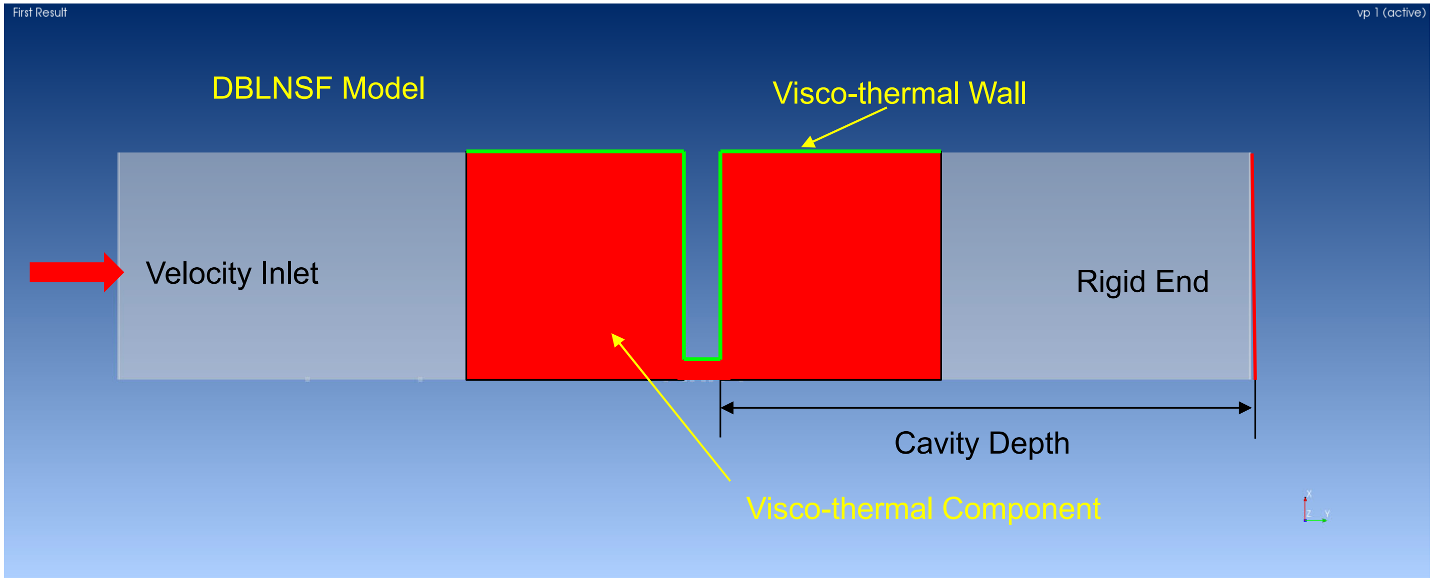
- ✓ Louver is similar to a planar orifice, but the guide vane leads to different values of the sound power reflection coefficient and impedance.
- ✓ However, louver because of its guide vane has different values of power reflection coefficient and impedance.
- ✓ The results are based on studies for normal incidence and zero mean flow conditions.

Additional Work-FEM Simulation (Recently)

Xin Yan (2020)



Single Orifice FEM Model in Actran

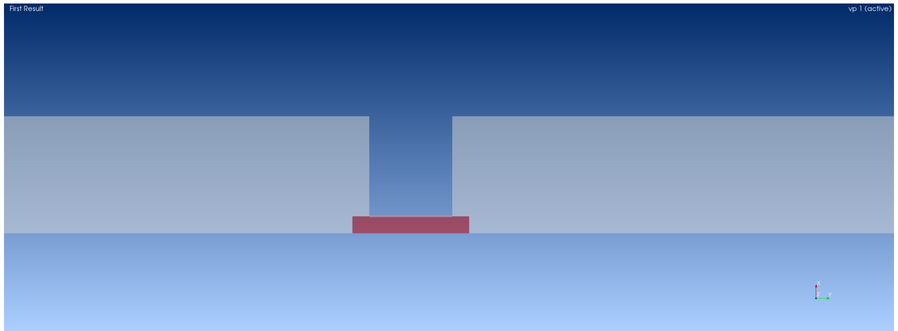
Additional Work-FEM Simulation (Recently)

Xin Yan (2020)

- MSC Actran has two simplified models to simulate the visco-thermal effects.

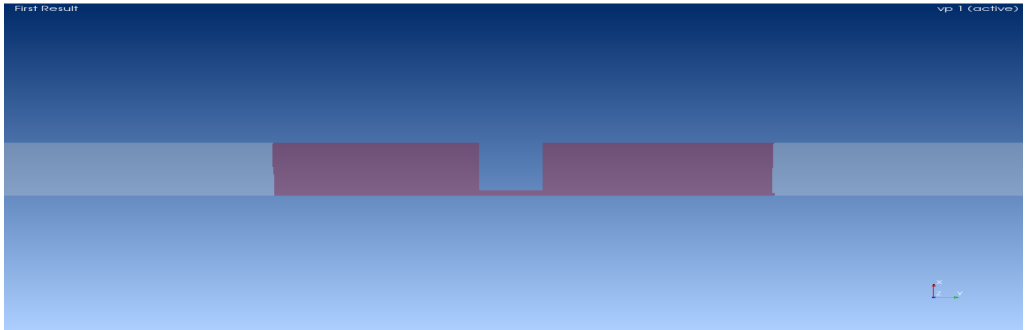
Low Reduced Frequency (LRF) Model

Uses closed form equations to model the small tubes. Geometry should be regular (cylindrical or rectangular). The code identifies the geometry and then assigns appropriate equation to represent it.



Distance-Based Linearized Navier-Stokes-Fourier (DBLNSF) model

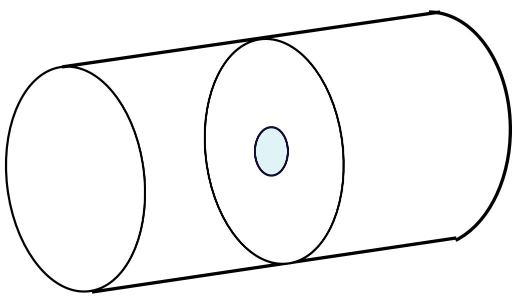
Determines visco-thermal effects using a simplified Navier-Stokes-Fourier model. Geometry may be arbitrary.



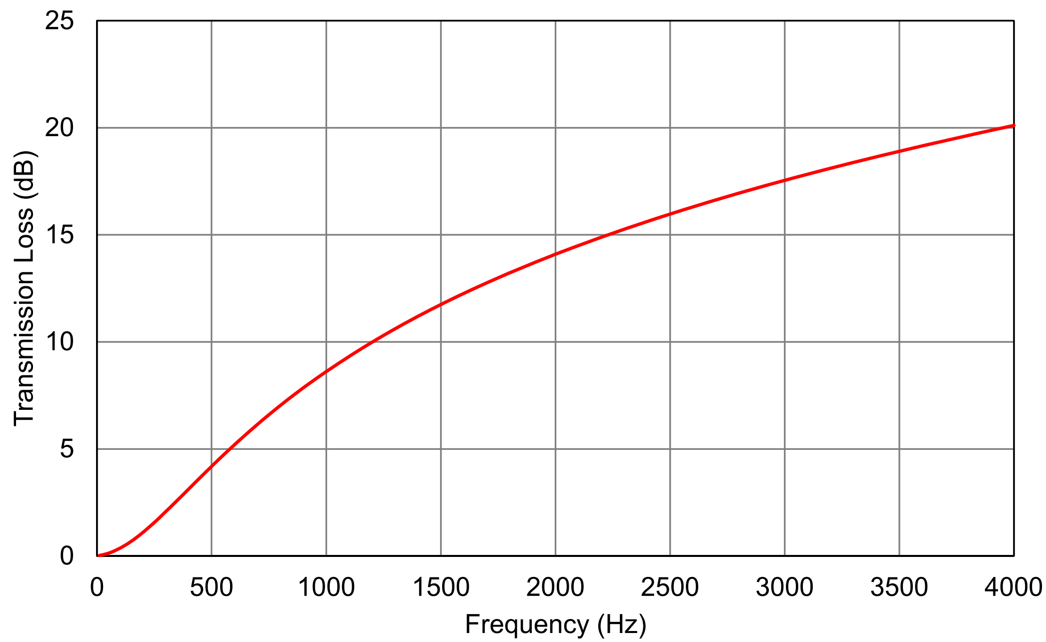
Additional Work-FEM Simulation (Recently)

Xin Yan (2020)

Cavity Depth	A_t	A_o	Perforation Rate	Thickness
10 cm	1810 mm^2	38 mm^2	2.0%	1 mm



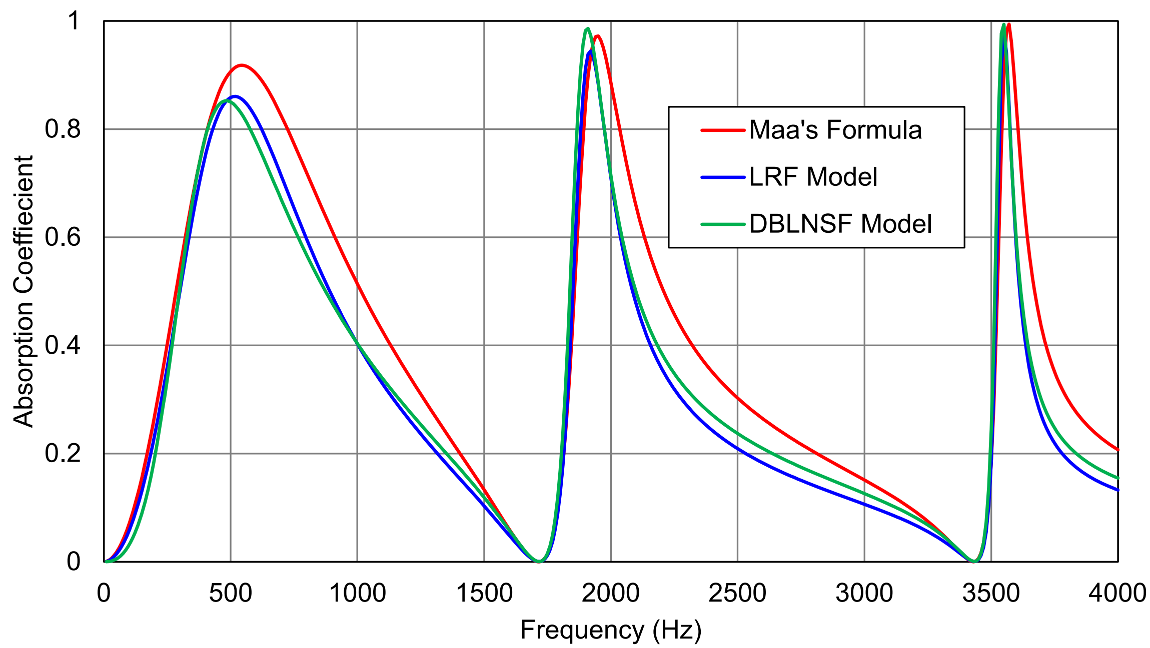
Circular Orifice (CORFCE)



Additional Work-FEM Simulation (Recently)

Xin Yan (2020)

Cavity Depth	Hole Diameter	Model Diameter	Perforation Rate	Thickness
10 cm	0.4 mm	2.8 mm	2.0%	1 mm



Summary

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- ✓ CFD and FEM simulation can now be used to evaluate problems of this type in the linear regime.
- ✓ Nonlinear effects are important in many applications.