COMSOL® Analysis for Duct Acoustic

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Introduction: Thermo-acoustic instabilities constitute a major issue in various applications such as combustion chamber and aircraft afterburner. Therefore, the goal of the present work is to predict the frequencies and mode shapes of the excited instabilities that were investigated experimentally by NASA Jet Propulsion lab [ref.1]. The experiments was conducted on a rectangular duct as shown in Figure1.

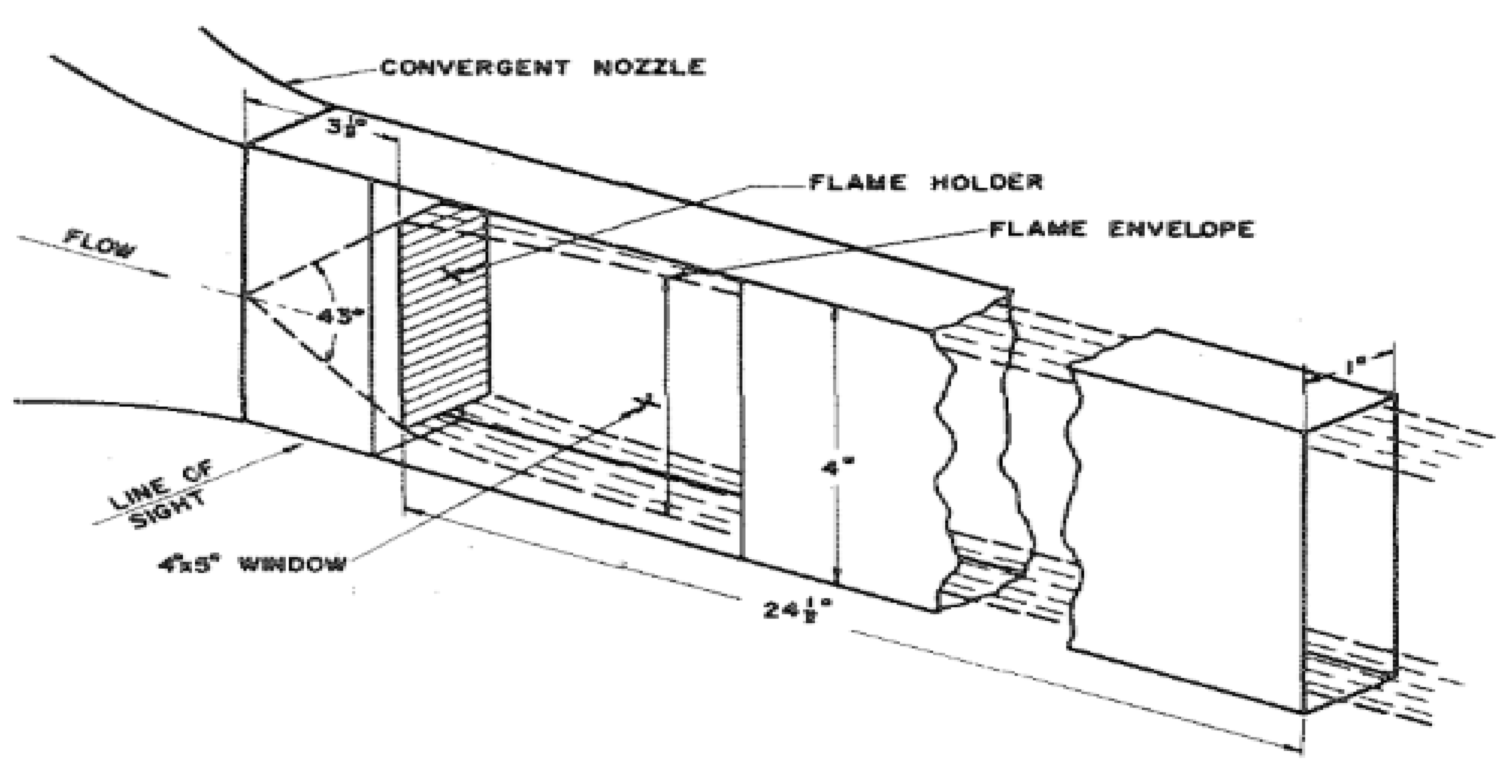

Figure 1. Schematic diagram of the combustion duct

Computational Methods: The Pressure Acoustic, Frequency Domain interface was used for simulation. The interface solves the Helmholtz equation (eq.1) in the frequency domain for given frequencies, or as an eignfreqeuncy or model analysis study.

$$\nabla * \left(-\frac{1}{\rho_c}\left(\nabla p_t - q_d\right)\right) - \frac{k_{eq}^2\, p_t}{\rho_c} = Q_m \quad \text{(eq.1)}$$

$$p_t = p + p_b$$

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

$$\omega = 2\pi f$$

the assumption made here that the test section is “acoustically” closed in both ends.

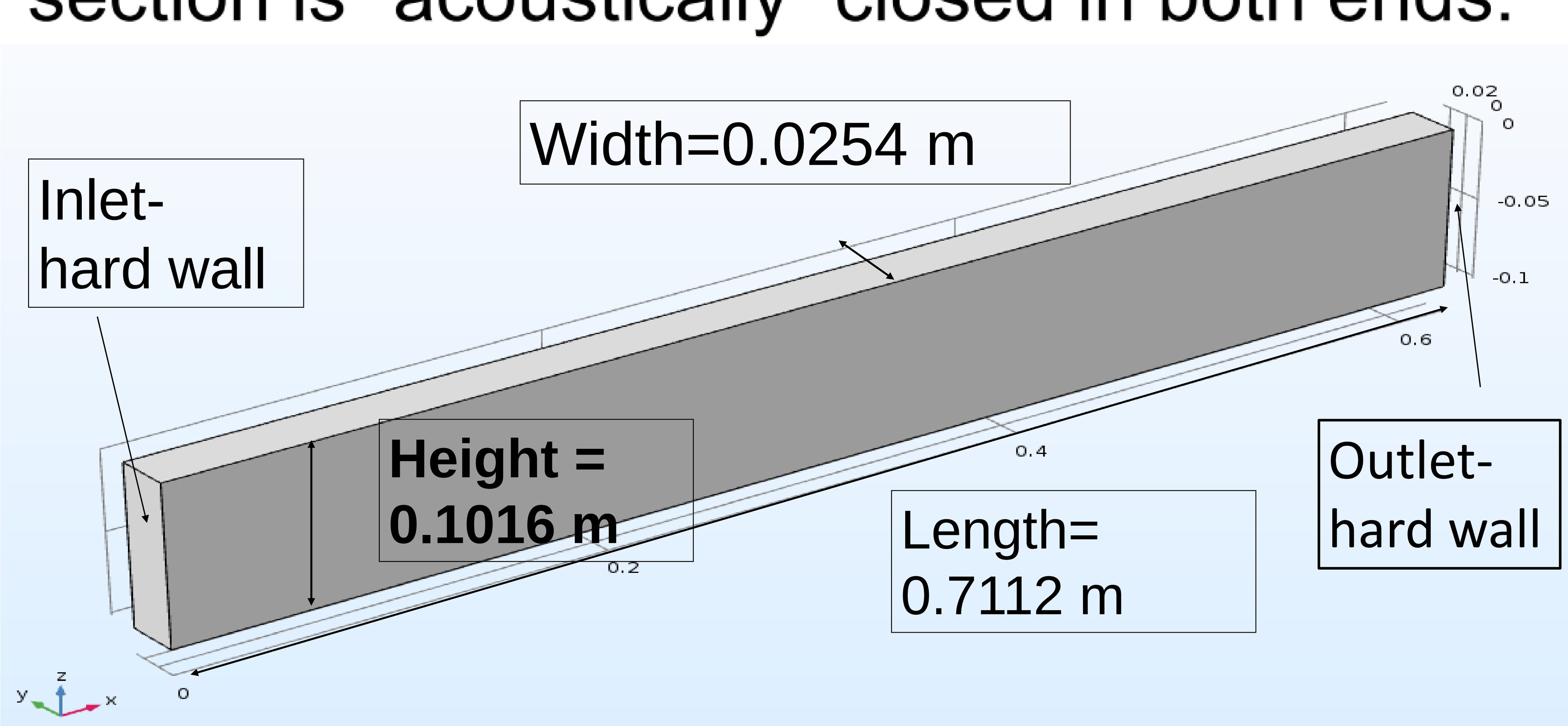

Figure 2. COMSOL model of the duct

Results: COMSOL software was able to find the excited instability frequencies, sound pressure level (SPL), and the 3D shapes of each mode. In addition, COMSOL enabled us to find the point where the pressure wave at its maximum amplitude (antinode). This point is important because it indicates the onset of the instability according to [ref.1].

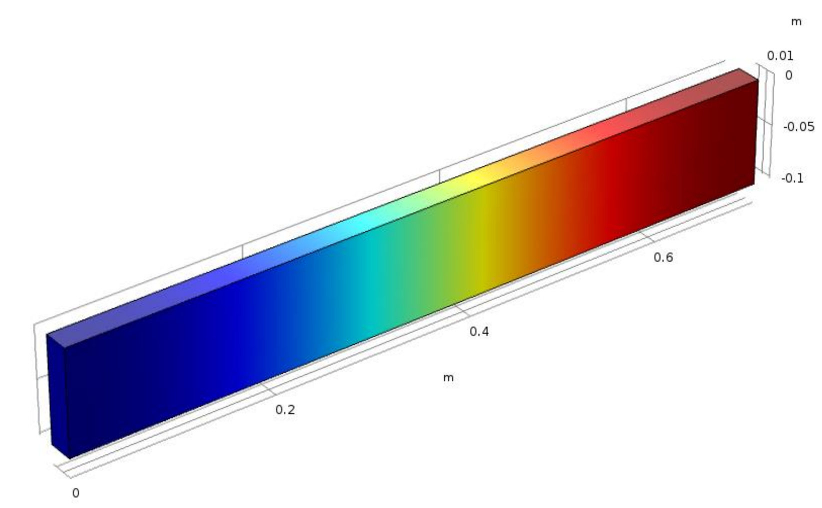

Figure 3. The low-frequency oscillation mode around 279 Hz.

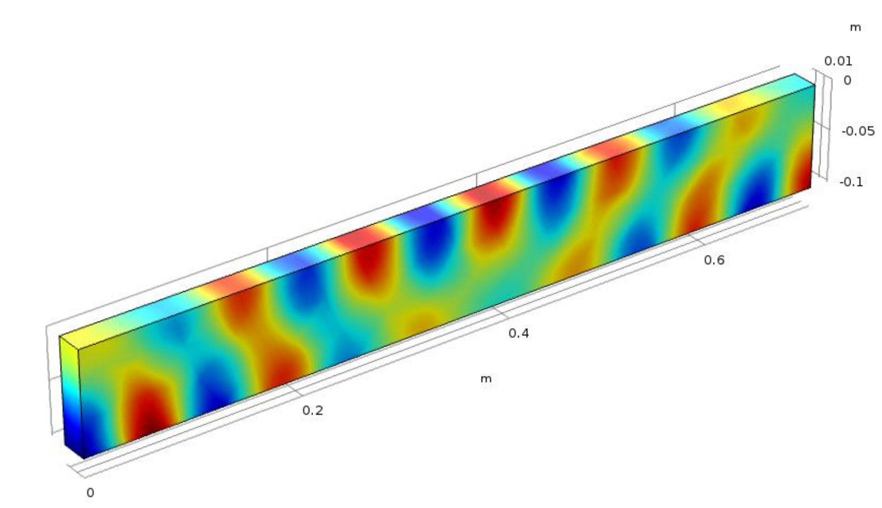

Figure 4. The high-frequency oscillation mode around 3678 Hz.

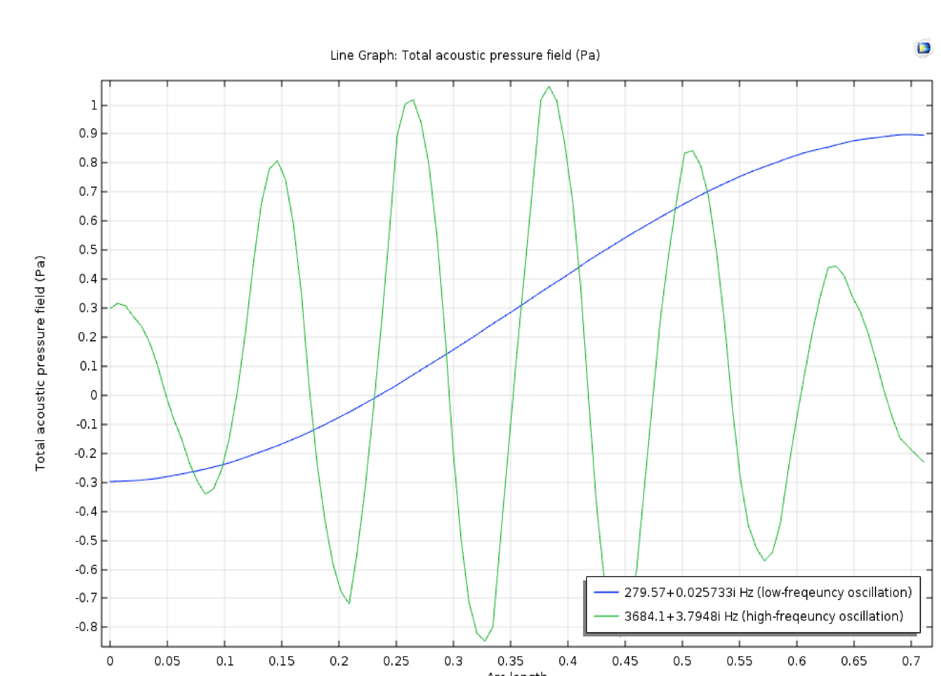

Figure 5. The acoustic pressure waves of the instability modes along the duct.

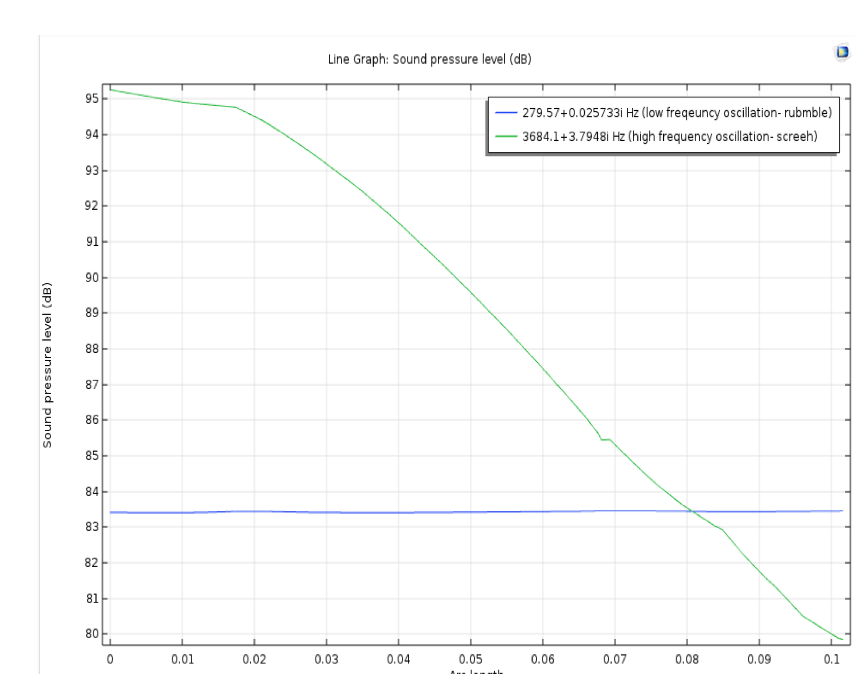

Figure 6. The 3678 Hz mode has the highest SPL around 96 dB across the 0.1016m dimension of the duct

Conclusions:The results of the experiments were in a great agreement with COMSOL results, as shown in the table below. Additionally, the low-frequency was found to be the fundamental longitudinal mode, and high-frequency mode “screech” was found to be an antisymmetric transverse mode along the 0.1016m dimension of the duct. Finally, these COMSOL simulation results combined with the experimental data can lead to a solution of the thermo-acoustic instabilities in combustion and afterburner ducts.

	Low-frequency oscillation	High-frequency oscillation
Experiment data	285 cps	3800 cps
COMSOL results	279.57 Hz	3684 Hz

References:

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