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CONSEQUENCE OF SUB-GRID SCALE MODELING ONTO THE PREDICTION OF ACOUSTIC NOISE EMISSION

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The acoustic noise generated by aircrafts is disturbing and sometimes even harming the living population in the surroundings. Therefore, acoustic noise reduction is studiously investigated by many researchers, experimentally and numerically. Direct numerical simulations exhibit the entire information of the flow field and therefore, the simulation data are often utilized to investigate details in the flow leading to acoustic noise radiation. However, resolving all the turbulent scales in a numerical simulation of realistic applications is computationally too expensive even for downscaled geometries. Thus, Large Eddy Simulations (LES) are usually performed, where the flow scales up to a large proportion of the inertial subrange are resolved and the smaller scales are modeled by a Sub-Grid Scale (SGS) model.

Predicting numerically the acoustic noise emission of a realistic geometry is sensitive to the distribution of numerical and physical, i.e. turbulent, dissipation, since the inherent dissipation governs the evolution of the flow structures, which are related with the acoustic noise generation. Furthermore, details of flow structures can be suppressed or artificially generated, when the dissipation in the simulation differs from a realistic amount. The acoustic noise generation is sensitive to the inlet boundary conditions determining the shear layer thickness of the jet [1]. Von Kármán vortex shedding downstream of the inner co-axial nozzle lip can provoke a spectral tone, which can represent a relevant contribution to the acoustic noise emission spectra [2]. The amplitude of the acoustic noise generation by such phenomena can be wrongly estimated or even missed, when an inappropriate amount of dissipation is used. The effect of different filter size in SGS models combined with the inherent dissipation of the discretization scheme influences the level of acoustic noise emission [3].

In this study, a jet exhausting a geometrically downscaled co-axial nozzle is simulated, which is shown in Fig. 1. The equations governing the compressible flow phenomena, i.e. conservation of momentum, mass, and energy, are simulated numerically using a finite volume code. A low-storage four-stage Runge-Kutta scheme is used for the time integration, where time advancement is performed with a constant time step. A second order central difference scheme is used for the spatial discretization of the convective terms. A second order approach, decomposing the viscous stresses into a thin-layer and a tangential part, is used for the diffusive terms. Three different approaches, i.e. the Smagorinsky SGS model, the Yoshizawa k-equation SGS model, and an implicit approach, handling the SGS stresses in the LES simulation have been applied. A consistent grid sensitivity study and comparison to experimental data the validity of the study.

The consequences of the different dissipative behavior onto the acoustic noise generation are investigated. Therefore, the resultant flow field obtained by three different approaches handling the SGS terms are compared. Figure 1 illustrates the density gradient contours of the jet exhausting the co-axial nozzle. The von Kármán vortex shedding in the shear layer downstream of the inner nozzle exit lip can be seen. With low dissipation in the numerical simulation, this phenomenon is visible over a rather long distance, whereas with higher turbulent dissipation this phenomenon is only visible over a rather short distance. This is notable in the acoustic noise estimations. Further, a location shift of the source terms of an acoustic analogy is observed, when different dissipative SGS models are used. The amount of dissipation and therefore the choice of SGS approach in the numerical simulation influences the amount of predicted acoustic noise production emitted from a turbulent jet in a LES simulation.

Figure 1: The density-field gradient contours of the high subsonic jet exhausting a coaxial nozzle is shown.

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