PREDICTION OF FREE AND SCATTERED ACOUSTIC FIELD OF LOW SPEED FAN NOISE

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The noise generated by low-speed fans is a concern in many industrial applications in terms of comfort and regulations such as energy sector and the transportation industry. The aeroacoustic response of fans is investigated in two branches; tonal and broadband noise. This thesis addresses both tonal and broadband components for acoustical free and scattered field of the fans. Since the concern is the computation of the scattered acoustic field of the fan where the scattering obstacle is mostly located in its near-field, the near-field effects are first investigated. The tonal fan noise is due to the periodic forces acting on the blade and appears at discrete frequencies such as the Blade Passing Frequency (BPF) and its higher harmonics. The closed-form analytical solutions addressing the free-field tonal fan noise at discrete frequencies exist in literature. Both far- and near-field formulations based on rotating sources are first validated against a third method based on an array of phase shifted stationary sources. The scattered field of a low-speed industrial fan operating in a cylindrical duct is investigated in the framework of a national project. The source field provided by the project partner is employed to a commercial Boundary Element Method (BEM) solver and the scattered acoustic field of the fan in the duct is computed. A good agreement is obtained in comparison with the measurements performed by another partner. The effects of the near-field terms are shown to be significant. Once the numerical method (BEM) is validated for low-speed fan noise, it is used as a validation method for analytical solutions. The exact analytical solution for relatively simpler scattering obstacles, such as flat plate and limited number of wedges exist in literature. An analytical approach addressing the scattered-field by a rigid corner is also introduced for tonal fan noise using the circular array of stationary sources. Both analytical solutions are validated against numerical solutions and very good agreement is obtained.

On the other hand, the broadband fan noise results from the random fluctuations of the forces acting on the blade. The noise due to the interaction with the incoming turbulent flow is investigated in the broadband frame. For the simplicity, a stationary airfoil is first investigated. The theory proposed by Amiet addressing the turbulence-interaction noise is employed. The existing theory is extended in order to predict the acoustic field of the airfoil in its near-field where the observer is located in the magnitude of the spanlength of the airfoil. The extended semi-analytical model is compared to the numerical integration based on Monte Carlo integration technique and a very good agreement is observed. Introducing spanwise segmentation and rotation, the free-field acoustic PSD of a low-speed axial fan is computed. The results are validated against measurements performed in the anechoic chamber using an industrial fan operating in turbulent stream **[1]**. In order to predict the scattered-field of the broadband noise due to the turbulence-interaction, an innovative technique is employed in the BEM framework based on Acoustic transfer Vectors (ATV). ATV technique is first validated against the stationary airfoil case against analytical techniques detailed for the tonal fan noise and experiments performed in the anechoic chamber. A very good agreement is observed for all comparison. The ATV approach is then applied to the industrial axial fan used in the free-field measurements introducing a benchmark scattering screen parallel to the rotation axis. Satisfying results are obtained in the comparison between the measurements and the semi-analytical model combined with the ATV approach **[1]**.

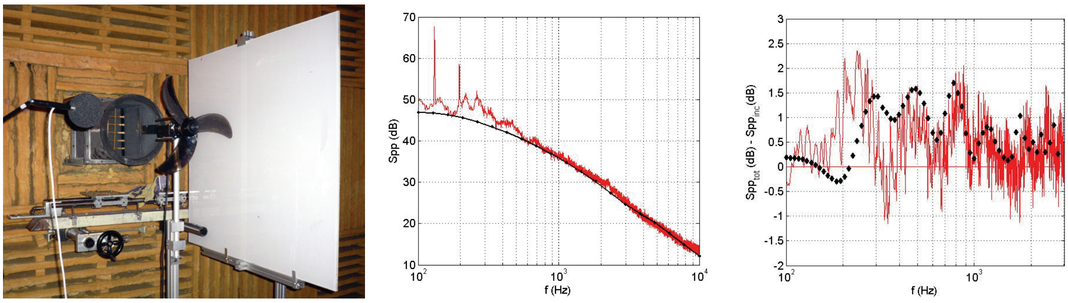

Figure 1: Experimental axial fan-scattering screen mock-up in the anechoic chamber of ECL (left). Acoustic free-field spectra (middle) at z=3r measured (red) and semi-analytical and difference between total and free-field spectra (right). Measurements (line) and semi-analytical model combined with ATV approach (symbols).