Noise mitigation is an important aspect in aircraft noise, and one of the main sources of noise are the turbofan engines. The noise level generated by the fan, compressor, turbine and combustor is generally higher than allowed by legislations (Motsinger, 1991). Hence, noise suppression is required, and the forward-propagating fan noise is effectively mitigated by installing acoustic liners in the engine ducts (Tam, 2014), as shown in Figure 1 (Mustafi, 2013).

Figure 2 shows the simplest and most common type of liner; a single degree of freedom (SDOF) liner, consisting of a perforated facing sheet, backed with a honeycomb panel and a rigid backing plate, effectively making for a panel of Helmholtz resonators. Due to their simplicity in construction and light weight, this class of liners forms the industry standard (Zhang, Numerical investigation of a honeycomb liner grazed by laminar and turbulent boundary layers, 2016). The recent push for more efficient engines has led to the development of ultra-high bypass ratio (UHBR) turbine engines. Increasing the fan diameter for a fixed engine outer diameter reduces the depth available for liners, and reduces the duct length relative to the diameter, which leads to an overall reduction of space available for the installation of liners (Bake, 2019). Furthermore, the noise spectrum is changed: the increase in fan diameter reduces the tonal fan noise, leading to a relative increase of the broadband turbomachinery noise (Bake, 2019). Therefore, new liner designs are required to provide the required noise suppression in the reduced space.

A liner is characterized by its specific acoustic impedance, which is defined in the frequency domain as the ratio of the unsteady acoustic pressure and normal acoustic velocity on the liner surface. Dividing the acoustic impedance by the medium’s characteristic impedance $\rho_0 c_0$ leads to the normalized specific acoustic impedance. The real part of the normalized specific acoustic impedance is called the resistance $\theta$ and its imaginary part the reactance $\chi$ (Guess, 1975).
The impedance and its resistive and reactive components are effective and simple metrics to express the liner’s performance. The complex value for the impedance is therefore of crucial importance in the development and evaluation of new liners.

Currently, the resistance is poorly modelled in non-linear conditions, caused by high sound pressure levels and freestream Mach numbers. Therefore, more knowledge on the aero-acoustic interaction is required in these conditions. In this thesis, the aero-acoustic response of an acoustic liner is experimentally investigated, using combined aerodynamic (PIV) and acoustic (in-situ) measurements. The aim is to further quantify the onset of nonlinearity, its effect on the acoustic resistance, and the interaction between liner orifices. A novel PIV method will be applied to increase the dynamic velocity range of the measurements, which can be seen as applying the pyramid correlation scheme in a phase-locked setting.

**Bibliography**


