STATOR-VANE-BASED ACTIVE CONTROL OF TURBOFAN ENGINE NOISE

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Extended Abstract

A significant portion of engine noise for modern transport aircrafts originates from the fan stage, and is expected to be increased further with the introduction of ultra high bypass ratio engines. Traditional ways of noise reduction such as increasing rotor-stator distance and covering part of the duct with acoustic liners are not effective for those engines, and alternative techniques are needed.

Active control is based on the idea to generate a secondary acoustic field for the cancellation of upstream and/or downstream propagating sound waves. This work proposes an active control technique. Actuators are mounted on each of stator vanes, approximated to be flat plate, for the generation of such a secondary acoustic field (see Figs. 1-2). The actuators may oscillate at a dimensionless frequency ω based on the mean radius and steady flow speed of sound. Stator is modeled as an annular cascade inside an infinite coaxial duct. Flow inside the duct is assumed to be subsonic, inviscid and non-heat-conducting. The rotor wake is modeled as a vortical gust imposed upstream. Flow consists of steady and unsteady components, and the latter is assumed to be small compared to the former. Given the steady flow, the unsteady motion is governed by 3D linearized Euler equations which are solved with an explicit numerical technique based on a high-order finite-difference approximation of spacial derivatives. The same technique has been previously used for the analysis of this configuration without actuation[1]. Consider the case when incoming gust is absent and the entire sound field is actuator-

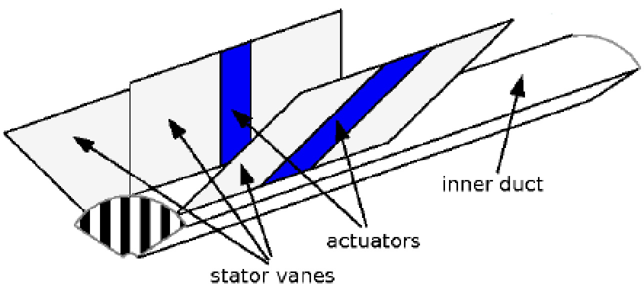

Figure 1 Stator-mounted actuator.

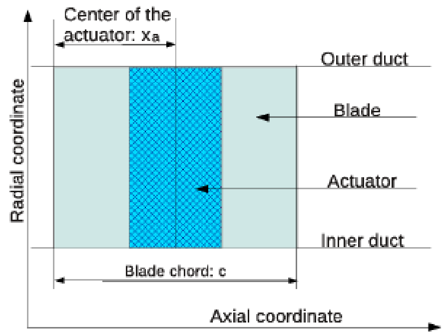

Figure 2 Stator cascade.

induced. A number of parameters are examined. As shown in Fig. 3, given fixed amplitude of actuator oscillation, ω may have a have a significant effect on the ratio (γ) of downstream-to-upstream radiated sound power. The γ is also sensitive to the axial position x_a of the actuator on the vane. A significant difference has been observed between the acoustic responses of suction- and pressure-side actuation, which can be used to control the modal content of radiated noise. The axial span of an actuator has little effect on the modal content of acoustic response, though a larger span corresponds to significantly reduced oscillation amplitude, suggesting higher control efficiency.

An incoming gust [2] was then introduced. For each combination of ω and x_a, the real and imaginary parts of the actuator oscillation amplitude were obtained by minimizing the downstream radiated noise, with the upstream noise radiation maintained below a certain level. Two constraints are used for upstream radiated power, viz. maintaining this power under its original level (without control) and allowing an increase by 10% in the original downstream radiated power. Figure 4 shows that x_a/c has a significant impact on noise reduction, compared with the reference case, i.e. no control, when zero actuation amplitude is applied. Actuation on the pressure side is significantly more effective than on the suction side. Evidently, the control performance is greatly enhanced when actuation is imposed on both sides of the blade. Previous active control results based on jets near the rotor [3] suggested that it could be difficult to achieve a good control performance when the original sound field is composed of multiple modes. In the present investigation there are seven propagating modes. However, a good control performance has been achieved given the right position for actuators. Further investigation is under way to improve the control performance and understand the physical mechanisms behind.

Acknowledgment
Authors wish to acknowledge support given to them from NSFC through grants 51275550 and 11172085.

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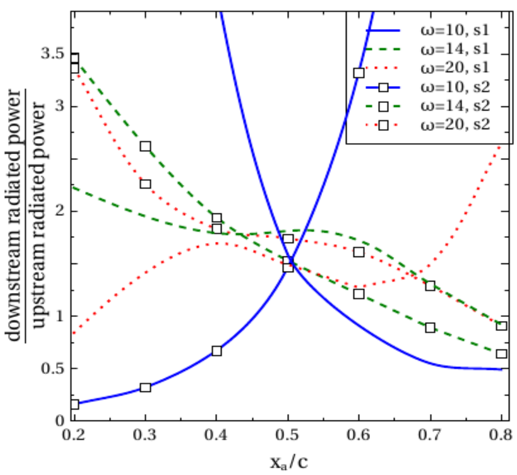

Figure 3 Ratio of downstream-to-upstream actuator-induced power vs. actuator position on the vane, s1 (s2) denotes suction (pressure) side-mounted actuator.

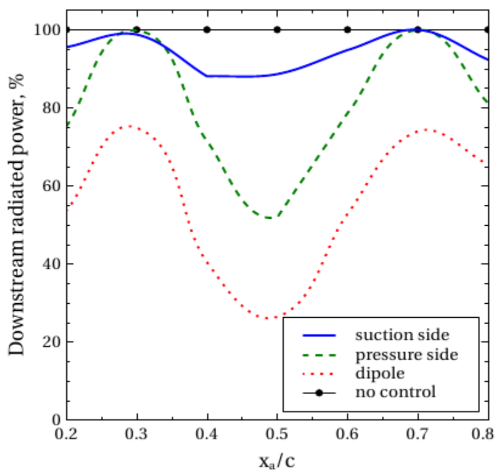

Figure 4 Downstream radiated power under active control (ω = 20).