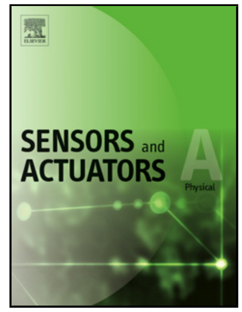

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Experimental Investigation of the Aeroacoustics of Synthetic Jet Actuators in Quiescent Conditions

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Highlights

- Jet noise of a synthetic jet actuator is isolated from its diaphragm noise to assess aeroacoustic characteristics
- The actuator aeroacoustic response, in the form of audible whistling, is found to occur in a similar Strouhal number range as other pipe and orifice flow systems
- A threshold in the jet Reynolds number is established for the onset of flow-induced sound
- Good agreement between the acoustic spectra, velocity spectra and Schlieren visualisation of the synthetic jet

Abstract

In this paper, the aeroacoustic characteristics of a circular orifice, synthetic jet actuator in quiescent conditions is investigated. Electromagnetic actuation, in the form of a shaker-driven actuator with latex diaphragm, proved to be desirable over piezoelectric actuation for this work due to the reduced diaphragm noise contribution to overall actuator self-noise, hence making it easier to identify jet-related noise. Acoustic and velocity data, collected from microphone measurements in an anechoic chamber and hotwire measurements respectively, were compared for correlation. Schlieren visualization was also used to show synthetic jet development near the orifice. Flow-induced sound in the form of an audible whistling was found to occur for a Strouhal number range of $0.24<St<0.50$. A threshold in the jet Reynolds number of $600<Re_j<750$ was established for the onset of whistling from the actuator for all drive voltages. Coherence between the acoustic spectra and velocity power spectra is shown, with evidence of a feedback mechanism consisting of vortices shed at a frequency that coincides with acoustic modes of the actuator.

Keywords

Synthetic jet actuator; aeroacoustics; Pfeifentone; whistling; noise

1. Introduction

Synthetic jet actuators (SJAs) use an oscillating diaphragm to displace small volumes of air within a cavity to generate periodic jets that enter and exit the cavity through an orifice. These jets formed at the orifice, composed of vortex structures, have potential to be applied in the delay of flow separation on aircraft [1]. To minimise actuator size and weight, piezoelectric diaphragms, such as ones made of a lead zirconate titanate (PZT) patch bonded to a thin brass substructure, can be used instead of larger and heavier electromagnetic actuators [2,3]. In previous work that use active flow control to reduce flow-generated noise it was found that although the flow-generated noise source can be attenuated, the actuator self-noise outweighs any acoustic benefits [4-6]. The need to reduce SJA self-noise to make these devices viable for consideration in commercial applications is prevalent.

For a SJA, regardless of the actuation method used, there is a mass displacement of air during its operation and it can therefore treated as a monopole acoustic source that represents a pulsating sphere [5]. Sound generated by turbulence in an unbound flow, such as a synthetic jet, is generally referred to as aerodynamic sound [7]. Turbulence typically occurs in motion of fluid over a surface or due to flow instabilities, where a very small fraction of the rotational kinetic energy of the flow results in acoustic radiation. Lighthill discusses the mechanism behind aerodynamic sound that is produced as a by-product of airflow [8]. In jets emanating from a pipe-orifice system, instabilities in the jet flow cause periodic vortex shedding. If the time scale of these vortices matches an