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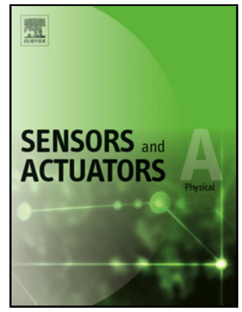

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Dynamic characterization of piezoelectric micro-blowers for separation flow control.

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Abstract

A micro-blower device, made by Murata™ Manufacturing Co. and originally designed for cooling electronic microprocessors, is used in the present study as an actuator for separation flow control. The dynamical performance of the device, working in pulsed mode, is experimentally investigated to deduce its abilities and limitations regarding active flow control. Both the device design and its dynamical characterization are addressed in the paper, paying particular attention to its ability to control flow. Both Hot-Wire Anemometry and Particle Image Velocimetry have been employed to investigate the dynamical evolution of the pulsed jet and allow the identification of the jet organized flow structures. The phase-averaging technique is applied to distinguish the large scale structure dynamics induced during the ejection phase. An array of active devices is also used to evaluate the flow control efficiency by forcing frequency strategy in order to reduce the separation area of a back facing step flow.Results show good performance in open loop flow control and applicability of such actuator for further closed loop flow control research.

Keywords: Flow control; Dynamical characterization; Pulsed jets; Micro-blowers; open-loop.

1. Introduction

The control of fluid flow is a central component of fluid mechanics, since it holds great promises for manipulating the inherent behavior of a fluid system [1]. The objective of flow control may be to delay/advance transition, to suppress/enhance turbulence, or to prevent/promote separation ([2]–[5]). Flow control involves passive and active devices causing beneficial changes including drag reduction, lift enhancement, mixing augmentation, heat transfer enhancement and flow-induced noise suppression [6]. In passive methods, the flow is modified without external energy expenditure. Some advantages of passive control are less moving parts, simple and less expensive devices. However, they often do not work well at off-design conditions. That is why, during the last decade, emphasis has been on the development of active control methods, in which energy, or auxiliary power is introduced into the flow. In general, all the active devices have two primary advantages for flow control that are not achievable by passive techniques. First, active control techniques are able to adjust the actuation if it is necessary, and secondly, they can be used to control complex, dynamical processes.

Classification of active flow control methods is based on the control strategy used. Then, active control schemes can be divided into predetermined or interactive methods. A predetermined method of control involves the introduction of steady and unsteady energy inputs without consideration for the state of the flow field. The control loop for the interactive method can be either a feedforward (open) loop or a feedback (closed) loop. The first one does not use feedback signals to control the actuator output. The second one includes at least one flow state sensor and a feedback control algorithm. This approach is the most expensive in terms of hardware and complexity, but it offers the greatest adaptability for changing flow conditions and potentially the lowest power consumption. In the past few years, numerical and experimental investigations have been done concerning open and closed loop control with active devices ([7], [8]), which highlighted the importance of actuators for active control strategies. There are three major classifications for active flow actuators: Fluidic, Moving surface and Plasma ([9], [6]). The first group contains the ZNMF (Zero Net Mass Flux) actuator [10], pulsed jets and combustion actuators. The second includes the piezoelectric flaps [12] and active dimples. And the last group is an agglomerate of different plasma actuators. It is important to know the actuator transfer function when designing a closed loop control algorithm. That is why, it is vital to characterize the actuator that will be used for flow control. Focus has been put on developing an integrated and compact device capable of efficient flow control.

Furthermore, previous experimental studies employed different electro-mechanical actuator design for closed-loop flow control. Some authors studied a fast-switching Festo MH-2 row of solenoid valve units (commercially

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