 Paper ID: 71991

IAF SPACE PROPULSION SYMPOSIUM (C4)
Electric Propulsion (2) (6)

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EXPERIMENTAL ASSESSMENT OF A MEMS SURFACE DBD PLASMA ACTUATOR FOR ACTIVE FLOW CONTROL IN AIR-BREATHING SPACE VEHICLES

Abstract

Several passive and active flow control techniques have been proposed to manipulate a flow field to improve efficiency or performance to delay/advance transition, suppress/enhance turbulence, or prevent/promote separation. Among different active flow control (AFC) techniques, surface dielectric barrier discharge (SDBD) plasma actuators have gained increasing interest during the past decade thanks to their high response time, high frequency, no moving parts, easy and cheap installation, and relatively low power consumption, which make them ideal for efficient real-time control. They are electrically driven devices where high frequency/high voltage feeding is applied to different electrodes separated by a dielectric barrier. Consequently, the gas molecules above the actuated region are ionized by a strong electric field. This ionized gas (plasma) extends from the edge of the upper exposed electrode to the trailing edge of the lower insulated electrode. Consequently, SDBD causes a local transfer of momentum to the flow passing above the region as moving charged particles collide with other neutral particles of the gas surrounding the actuator. In addition, they induce local heating (thermal effect) in combination with the production of new radicals and ionized species (chemical effect). The resulting benefits include drag reduction, lift enhancement, mixing augmentation, heat transfer enhancement, and flow-induced noise suppression. The effective use of SDBD can provide higher efficiency fluid-dynamic control.

When applied to control the internal flow into air-breathing space vehicles operating at low Earth orbits (LEOs), the working pressure falls between 0.01 Pa and a few pascal. Under such rarefied pressure conditions, the plasma discharge behavior occurring onto a SDBD is still unexplored. The present work provides an experimental investigation of a novel MEMS SDBD plasma actuator based on quartz substrate as dielectric barrier material (AF32@Schott 0.3 mm-thick) and two titanium-tungsten electrodes owning a thickness of 210 nm, undergoing sinusoidal plasma actuation. Experiments are conducted in a vacuum chamber over a wide pressure range, from ambient conditions to values of reduced pressure of 0.01 Pa. Intensified CCD visualizations, electrical signals (current/voltage/power) and direct measurement of local

pressure, velocity, and solid temperature define the diagnostic toolbox. The aim of the work is the investigation of the effect of the operating low pressure on the plasma discharge morphology and dynamics, in combination with the performance of the SDBD.