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Research on the Aerodynamic Characteristics of Sawtooth Annular Surface Dielectric Barrier Discharge Actuator under AC Excitation

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Surface dielectric barrier discharge (SDBD) can generate ion wind, and its aerodynamic characteristics are of great significance for flow control and drag reduction of aircraft. In this paper, the equivalent thrust and airflow distribution generated by SDBD under AC excitation have been studied, and a sawtooth annular SDBD actuator is designed to achieve better flow control and drag reduction effects. Experimental results show that under the AC power supply, the discharge area can be divided into three regions, namely A (discharge areas at the electrode edge), B (discharge areas on both sides of the sawtooth), and C (discharge areas at the sawtooth tip), due to the structure of the sawtooth annular electrode. The electric fields in each region are significantly different. When the streamer channels meet, the Coulomb repulsion makes the boundaries between each region clear, which also restricts the plasma from diffusing downstream, thereby increasing the density of excited-state particles in the discharge zone, forming a memory effect, and promoting the generation and development of subsequent stream channels. The increase in the number of sawteeth effectively reduces the discharge current in the negative half-cycle of the voltage, which indicates that the accumulation of positive charges on the dielectric surface far from the exposed electrode is reduced, facilitating the generation of more oxygen negative ions in the negative half-cycle of the voltage and promoting the induced airflow. This can also be verified in the thrust measurement. Compared with smooth edges, the sawtooth can increase the saturation value of the thrust-to-power ratio, but the optimal number of sawteeth varies under different voltages. This is because when the voltage is low, such as 6 kV, the interaction between discharge channels is not obvious, and all the current pulses generate ion wind to inject momentum into air molecules. However, as the voltage increases, the competition between different discharge channels occurs, the discharge channels compete, and their external electric fields cancel each other out, thereby suppressing the micro-discharge on both sides of the sawtooth and reducing the momentum transfer efficiency. In terms of flow field distribution, the increase in the number of sawteeth does not affect the height of the flow field, but makes the flow field more concentrated and narrower in the horizontal direction. This is because the airflows generated in regions A and B interfere with each other near the dielectric surface, causing the synthetic airflow to become disordered and the airflow radius to increase. And the increase in the number of sawteeth makes the discharge energy more concentrated at the sawtooth tips, resulting in a more concentrated flow field distribution. The above findings provide theoretical and experimental data support for the parameter design and practical application of sawtooth annular SDBD structure in flow control and aircraft drag reduction.

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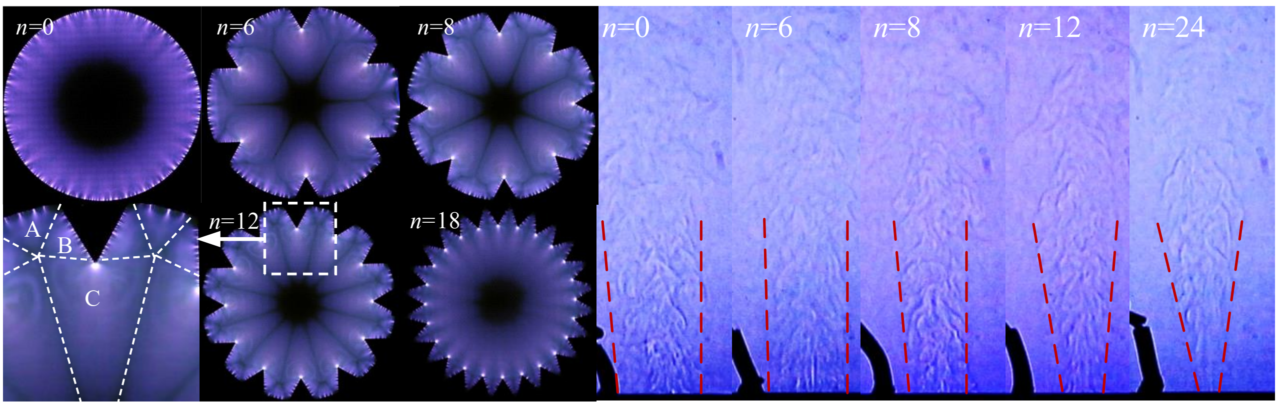

Figure 1. Discharge images and flow field distributions under different number of saws