Phase 2 Project Summary

Firm: Tech-X Corporation
Contract Number: NNX11CA46C
Project Title: Simulation Tool for Dielectric Bar Discharge Plasma Actuators at Atmospheric and Sub-Atmospheric Pressures

Identification and Significance of Innovation: (Limit 200 words or 2,000 characters whichever is less)

An optimization of DBD plasmas used for actuators using efficient, comprehensive, physically-based DBD simulation tool for different operation conditions would allow NASA researchers to more quickly evaluate designs. In this project, we developed a DBD plasma actuator simulation tool for a wide range of ambient gas pressures. The tool treats DBD using either kinetic, fluid or hybrid model, depending on the DBD operational condition. The tool is validated by comparison with the experimental and numerical data. The tool takes advantage of parallel computing to allow computationally intensive simulations to complete more quickly. We further demonstrated the capability to couple these detailed simulations to a CFD simulation to allow one to bridge the disparate time scales involved in the performance of a DBD actuator.

Technical Objectives and Work Plan: (Limit 200 words or 2,000 characters whichever is less)

We had four objectives for this project: i) extend the chemistry and discharge models in VSim, ii) extend the hybrid capabilities of VSim, and iii) enhance the computational speed of VSim, and iv) validate the tool against experimental data at a range of DBD operational conditions. Our work plan was to improve the chemistry and collision database, to add a photoionization model, to improve hybrid fluid-kinetic modeling, to improve the multilevel meshing and adaptive timestepping, to improve an electric circuit model, and to perform simulations and validate against data.

Technical Accomplishments: (Limit 200 words or 2,000 characters whichever is less)

Our accomplishments are: we extended an air-chemistry and collision database for DBD plasma actuator modeling (including a new capability to track momentum and energy deposited into a fluid background gas), we implemented a photoionization model in VSim benchmarked for DBD modeling, we enhanced the hybrid fluid-kinetic capabilities of VSim, we integrated the concept of multilevel meshing for DBD simulation into VSim, we developed an approach for adaptive timesteps in DBD modeling by coupling VSim with a commercial CFD modeling tool, we implemented an electric circuit model for DBD simulations, we performed simulations of a DBD plasma actuator over a range of pressures, and we validated VSim against data from Princeton University researchers.

NASA Application(s): (Limit 100 words or 1,000 characters whichever is less)

The primary NASA applications of this DBD simulation tool are active flow control concepts for both subsonic and hypersonic flights. Predictable active flow separation control, achieved using this tool, could benefit many NASA Projects, such as Subsonic Fixed Wing Project, Subsonic Rotary Wing Project and Hypersonic Project. In addition to the flow separation application, this tool can be used for a number of NASA problems, associated with gas discharges at different pressures. For example, DBD simulation tool can be used for the description plasma-assisted combustion for the reduction of carbon emissions.

Non-NASA Commercial Application(s): (Limit 200 words or 2,000 characters whichever is less)

Active flow control using DBD plasma actuators is of interest to a number of government agencies, private industry and universities. This tool will be beneficial for subsonic/hypersonic programs which involve active flow separation control. These programs include, but are not limited to, flow separation control at commercial airplanes during take-off or landing, increase in lift for tiltrotor aircrafts, improvement of engine performance, active flow control at hypersonic vehicles. Besides the primary application for a description of DBD operation, this tool can be used for a wide range of plasma aerodynamics applications, such as plasma-assisted combustion, flow control using different types of discharges, reduction of carbon emission, optimization of air vehicle operation, MHD and EHD application. Finally, the medical sterilization industry is a growing industry where DBD plasma activation is an emerging tool.

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