Phase I Project Summary

Firm: Creare Incorporated
Contract Number: NNX13CC27P
Project Title: A Novel Plasma-Based Compressor Stall Control System

Identification and Significance of Innovation: Modern gas turbine engines utilize highly loaded airfoils in both the compressor and turbine to maximize performance while minimizing weight, cost, and complexity. However, high airfoil loading increases the likelihood of flow separation at lower mass flow rates. Dielectric Barrier Discharge (DBD) plasma actuators have been shown to be a very promising technique for compressor stall control. DBD devices, installed directly on compressor endwalls, offer the ability to control rotor tip flow and inhibit spike-type stall inception in compressor inlet flows. However, several fundamental challenges exist in implementing this system, including management of high-voltage waveforms and delivering appropriate electrical waveforms to the devices. Creare designed, developed, and demonstrated an innovative DBD actuator charging circuit topology which (1) generates substantially higher voltages than previous systems, (2) implements a unique excitation waveform that optimizes thrust production by DBD actuators, (3) uses commercial-off-the-shelf (COTS) components, and (4) avoids impedance matching issues associated with other DBD charging circuit topologies.

Technical Objectives and Work Plan: Based upon a detailed review of existing DBD plasma modeling data in the literature, a theoretical excitation waveform was developed that showed the potential for substantially improving the performance of DBD actuators using an excitation circuit that is significantly more compact and energy efficient, and can be more easily integrated into existing turbine compressor systems. On Phase I, we built a proof-of-concept DBD actuator excitation circuit that applies this novel actuation technique, and demonstrated this circuit in a series of characterization tests and flow control demonstrations using airfoils equipped with our improved actuators.

All the Phase I objectives were achieved: we identified an optimized excitation profile for improved DBD actuator performance; we successfully designed, fabricated, and demonstrated a proof-of-concept DBD actuator excitation circuit which provided the desired profile; and we used this proof-of-concept circuit in multiple DBD actuator facilities at the University of Notre Dame to demonstrate the improved flow control potential of the resulting system.

Technical Accomplishments: In this project, Creare developed a new concept for efficient and effective DBD actuation, based upon existing modeling studies in the literature, that was expected to substantially improve produced thrust over comparable excitation systems previously demonstrated. We then designed a novel actuation circuit, fabricated a proof-of-concept system, and demonstrated this actuator in both benchtop characterization and flow control demonstration systems. When tested with thin Kapton dielectric acutators, this proof-of-concept DBD actuator excitation circuit provides substantially improved thrust over existing actuator systems (a factor of 6–8 improvement), and potential for generation of equivalent thrust forces using lower applied voltages. When tested as a leading edge thin film actuator on an airfoil exposed to transonic flow, the use of these DBD actuators results in a significant (7%) increase in produced lift, but no clear indication of stall control was found. The resulting circuit is efficient and robust, and should be easy to integrate into existing turbomachinery facilities for testing and demonstration in Phase II.

NASA Application(s):
This technology supports NASA's mission to help improve the performance of commercial aviation through development of advanced gas turbine engine systems. The technology also has the potential for enabling improved gas turbine engine performance for applications as far reaching as Unmanned Aerial Vehicles (UAVs) proposed for extraterrestrial exploration. An efficient DBD actuator system can provide active stall control for compressor blading and low-pressure turbine blades. Implementation of a practical DBD actuator system, including the necessary driving and control electronics, should allow significantly improved low mass flow operation of turbine engines, as well as greatly increased operational envelopes.

Non-NASA Commercial Application(s):
In addition to military and NASA customers, a fully developed active flow control technology for turbomachinery may also prove useful in commercial applications in which separation phenomena are known to cause performance issues, including turbine engines (for both power generation and aircraft use), aerial vehicles, and wind turbines, all of which are under active research by U.S. universities. The implementation of an effective and efficient compressor stall control system or improved separation flow via DBD actuation, have the ability to improve the operational envelopes for these systems.

Name and Address of Principal Investigator:
Richard W. Kaszeta, Ph.D.
Creare Incorporated
16 Great Hollow Road
Hanover, NH 03755

Name and Address of Offeror:
Creare Incorporated
16 Great Hollow Road
Hanover, NH 03755