Flow control by using plasma actuators on a circular cylinder

Thesis

The project aims to focus on the flow control mechanisms of the DBD plasma actuators. The previous researches of DBD plasma actuators analyzed data collected by experiments to find the efficient way of controlling mechanisms, but still have some other aspects that need to be promoted. In this project, we will use ASOP and Tecplot to simulate the instantaneous flow in the field under duty-cycle actuation, find the specific principle and reason of field forming to make up for the previous experiments, and complete the theoretical analysis.

Purpose

Dielectric barrier discharge (DBD) configuration used for plasma actuators consists of two electrodes, one uncoated and exposed to the air and the other encapsulated by a layer of dielectric material. The electrodes are supplied with AC voltage to weakly ionize the air above the covered electrode. In the presence of the electric field produced by the electrode geometry, the ionized air results in a body-force vector field that acts on the ambient air. The body force is the mechanism for active aerodynamic control. For these actuators, the mechanism of flow control is through a generated body-force vector field that couples with the momentum in the external flow. The body force can be derived from first principles, and the effect of plasma actuators can be easily incorporated into flow solvers so that their placement and operation can be optimized.

According to the research of my faculty mentor, we can use a pair of plasma actuators which is placed at a ±90 deg azimuth angle of the cylinder in 2 dimension to form a synthetic direction jet combined by two different directions of the adherent jet. By controlling the frequency and duty-cycle ratio, the result shows that the total momentum induced by the duty-cycle actuation mode even can exceed that by the steady actuation mode with both actuators on, which saves energy and generates larger body force.

Through software simulation, we can directly see the constantly changing flow in the field to find the cause of the flow field, explain the causes and results of the change, and try to improve the existing results and get practical application. What is more important, we will try to experiment with 3D circular cylinder, collect and analyze data, explore the flow field theory, find the optimal control mechanism of DBD plasma actuators, and apply it to the real world, such as flow to a slender forebody at high angles of attack, the application of simulation method to the aircraft wings or other structures. Based on the success of 3D experiment and simulation, we will also try to use machine learning to control the duty-cycle actuation mode, which saves a lot of time to find the optimal control mechanisms.

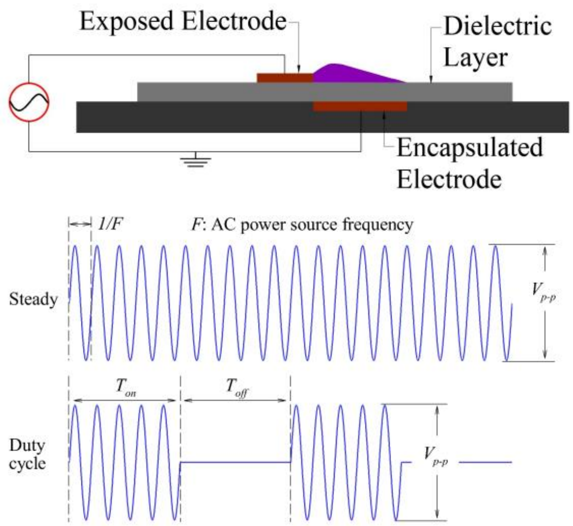

Figure 1: Structure of a DBD plasma actuator and AC power input forms for the steady and duty-cycle operation modes.

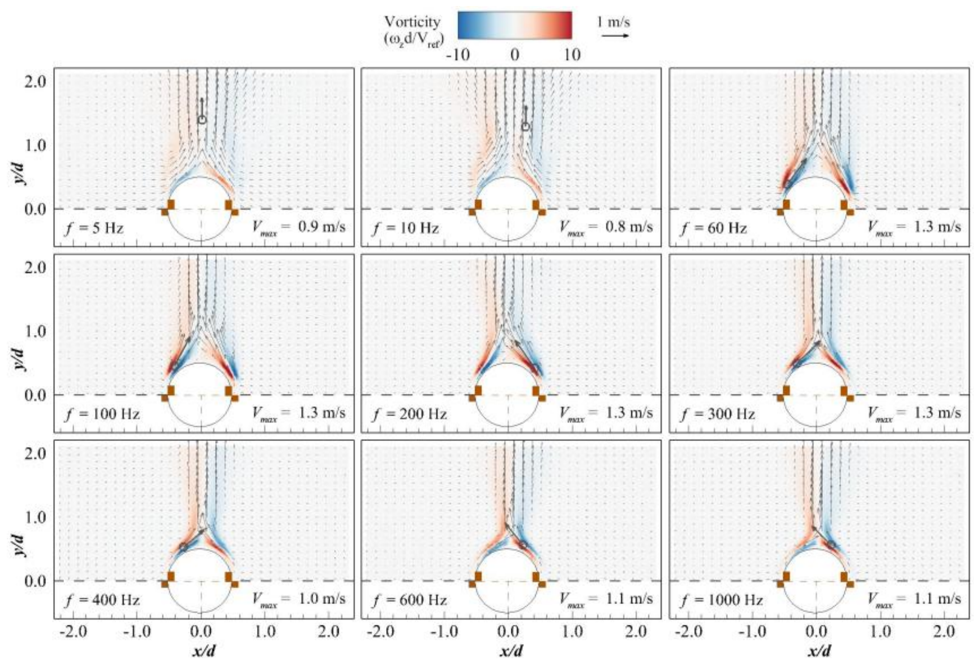

Figure 2: Time-averaged velocity vectors overlapped with vorticity for duty-cycled actuation for duty-cycle ratio = 0.50

Objective

My Professor's team has collected data from experiments and analyzed mechanism of controlling process. I will use ASOP to simulate the flow filed in the experiment to observe and collect the flow field shape and data at very small-time intervals, and use Tecplot to get the trend of various coefficients over time, like is it is convergence or divergence. I have taken courses of MAE130A and MAE130B, which are related to fluid dynamics and this research thesis. Through analyzing data and figure, I can use the knowledge I have learned to analyze figures and data, and find out the theoretical principle that can explain the phenomenon. That's a great opportunity for me to apply my theoretical knowledge to practice, to check it with actual results.

This project investigation will enable me to experience the study and life of a graduate student as an undergraduate. I will have the opportunity to learn new ways of thinking through the communication with the instructors, understand the specific work of graduate students and the professional knowledge related to fluid dynamics, so as to provide valuable experience and guidance for my future development and research direction. At the same time, for the analyzing process might involves thermodynamics, I can combine what I've learned from MAE91, MAE115, MAE120 with fluid dynamics, to better understand the magic of interdisciplinary subjects, and lay a good foundation for my future graduate study.

Responsibilities

- ASOP Simulation
    a. Inviscid flow on a 2D circular cylinder
    b. Laminar flow on a 2D circular cylinder
    c. Inviscid flow on a 3D circular cylinder
    d. Laminar flow on a 3D circular cylinder
- Tecplot analysis
    a. Velocity, momentum
    b. Use principle to prove the analysis result
- Mechanical Learning
    a. Find the optimal control mechanisms.

Weekly meetings will take place with faculty mentor. During these meetings, we will discuss our data, progress, and any potential obstacles. Time spent on the project is estimated to be 8h/week.

Timeline

Scheduled	

Month	October	November	January	February	March	April
Inviscid flow simulation on a 2D circular cylinder						
Laminar flow simulation on a 2D circular cylinder						
Inviscid flow simulation on a 3D circular cylinder						
Laminar flow simulation on a 3D circular cylinder						
Tecplot Analysis						
Mechanical Learning						

Itemized Budget

The basic needs for this research projects are:

Software Components: Licenses for software

Hardware Components: Solid State Drives

Others: Articles, Books needs for research

UROP Proposal Budget	
Item	Budget Amount
512GB Solid State Drives	$100.00
Copying/Printing	$100.00
Articles, Books, Software needs for research	$300.00
UROP Total	$500.00

References

1. Meng Xuanshi, Hui Weiwei, Abbasi Afaq Ahmed and Liu Feng. “Flow induced by a pair of plasma actuators on a circular cylinder in still air under duty-cycle actuation.” Web
2. Corke, Thomas C, C. Lon Enloe, and Stephen P Wilkinson. “Dielectric Barrier Discharge Plasma Actuators for Flow Control.” Annual Review of Fluid Mechanics 42.1 (2010): 505–529. Web.
3. Zhang Xin, Yong Huang, and Huaxing Li. “Flow Control over a Circular Cylinder Using Plasma Actuators.” Lìxué xuébào 50.6 (2018): 1396–1405. Web.