HiSST: International Conference on
High-Speed Vehicle Science Technology
26–29 November 2018, Moscow, Russia

Active Flow Control of Wide-envelope Air-breathing Engine Inlet

Wang Jianlei[1]*, Li Tiangang*[1]*, Wei Zhen*[1]*, Chen Bing*[1]*, Gong Chunlin*[1]*, Gu Liangxian*[1]

Abstract

Wide-envelope spacecraft need to operate at the Mach number far away from the design point. For better engine inlet performance at those operation states active flow control technology is needed to be used. Both NS-DBD plasma flow control and jet flow control methods were studied. Results shows both methods and improve the engine inlet performance. The flow rate and total pressure recovery ability is increased and drag is reduced. More results with unsteady control and optimized control parameters will present in the final article.

Keywords: Wide Envelope Inlet, Active Flow Control, NS-DBD Plasma Flow control, Jet Flow Control

1. Introduction

Wide-envelope spacecraft usually has wide Mach number range from 0 to 5 or even more. The design point of the wide-envelope spacecraft is often set at cruise Mach number and altitude to achieve the requirements of drag reduction, thermal protection and other requirements. However, its engine inlet performance will be drastically deteriorated when the aircraft's operating status is far away from the design point. Active flow control is highly needed to improve the aerodynamic performance of the aircraft while the aircraft is working away from the design point. Both NS-DBD plasma flow control and jet flow control studied in this paper.

Flow control with plasma actuators has been widely studied for its unique features, such as no moving parts, fast response time and low power consumption [1,2]. Recently, much attention has been put into the nanosecond dielectric barrier discharge (NS-DBD) plasma actuators. This type of actuator has similar configurations as an AC-DBD device, but driven by high voltage pulses with typical rise and decay time of several to tens of nanoseconds. Roupassov et al. [3]first reported airfoil flow separation control by NS-DBD plasma actuators at Mach numbers between 0.05 and 0.85. Later, Little et al. [4,5,6] demonstrated the capability of repetitive NS-DBD plasma actuators for controlling flow separation on an airfoil leading edge with a flow Reynolds number up to 1×10^6 (62 m/s). These results have shown high efficiency of NS-DBD plasma actuators in boundary layer separation control and even in acoustic noise reduction.

There are two categories of jet flow control, synthetic jets control and continuous jets control. Synthetic jets work by using an oscillating diaphragm to create vortices within the boundary layer [7]. Continuous jets, sometimes referred to as fluidic actuators, can be classified into steady and unsteady (or oscillatory) blowing [8].

The primary focus of this work is to improve the engine inlet performance of wide-envelope spacecraft while its operating status is far away from the design point. To increase flow rate and total pressure recovery capability. Avoid unnecessary shock wave in the engine inlet is another purpose of this work. Only some preliminary steady NS-DBD plasma flow control and jet control results are showed in this abstract. More results with unsteady control and optimized control parameters will present in the final article.

---

[1] *Shaanxi Aerospace Flight Vehicle Design Key Laboratory, School of Astronautics, Northwestern Polytechnical University, Xi'an 710072, China, wangjianlei@nwpu.edu.cn*

2. NS-DBD plasma flow control

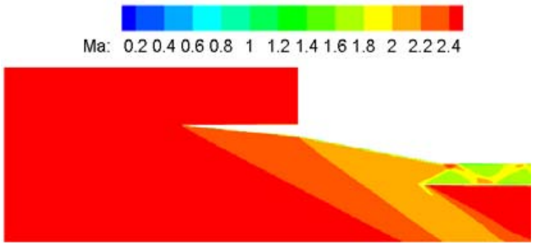

Fig 1. Flow filed without flow control, Ma=2.5

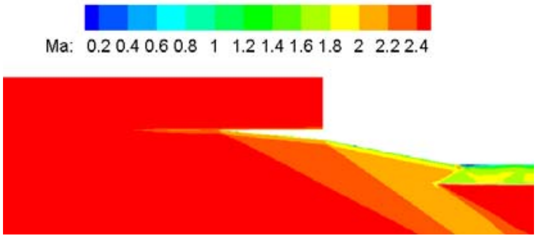

Fig 2. Flow filed with NS-DBD plasma flow control, Ma=2.5

In this part, a NS-DBD plasma actuation will be applied to the nose of the spacecraft. The actuation of the NS-DBD plasma actuation will create a series of shock wave around the actuator. The shock wave perturbation will interact with free flow and make the shock wave change. Let the engine intake shock structure be under ideal conditions at any flight Mach number, even the Mach number is far away from the design point.

Figure1 and 2 shows the flow filed without and with NS-DBD actuation at Mach number 2.5. After the NS-DBD plasma actuation the flow rate coefficient increased by 8% from 0.59 to 0.64. And drag coefficient reduced by 10% from 0.3 to 0.27.

Very strong shock waves are appeared inside the inlet isolator, which is very undesirable for the inlet design. The shock waves inside the inlet isolator is much wakened under the NS-DBD plasma actuation.

3. Jet flow control

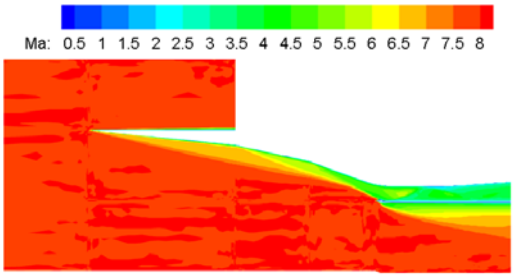

Fig 3. Flow filed without flow control, Ma=8

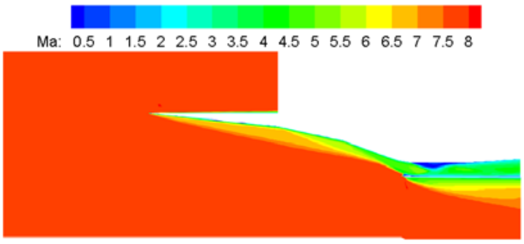

Fig 4. Flow filed with jet flow control, Ma=8

In this part, a steady air jet will be applied at the lower surface of the inlet right after the nose of the spacecraft. The jet perturbation will interact with free flow and make the shock wave change. Let the engine intake shock structure be under ideal conditions at any flight Mach number, even the Mach number is far away from the design point.

Figure3 and 4 shows the flow filed without and with jet actuation at Mach number 8. Under the jet actuation the total pressure recovery coefficient increased by 7% from 0.176 to 0.189. And drag coefficient reduced by 3% from 0.35 to 0.34.

References

1. Moreau, E., "Airflow Control by Non-Thermal Plasma Actuators," Journal of Physics D: Applied Physics, Vol. 40, 2007, pp. 605-636.
2. Corke, T. C., Enloe, C. and Wilkinson, S. P., "Dielectric Barrier Discharge Plasma Actuators for Flow Control," AnnualnReview of Fluid Mechanics, Vol. 42, 2010, pp. 505-529.
3. Roupassov, D., Nikipelov, A., Nudnova, M., and Starikovskii, A., "Flow Separation Control by Plasma Actuator with Nanosecond Pulsed-Periodic Discharge," AIAA Journal, Vol. 47, No. 1, 2009, pp. 168–185.
4. J. Little, K. Takashima, M. Nishihara, I. Adamovich, and M. Samimy, "Separation control with nanosecond-pulse-driven dielectric barrier discharge plasma actuators," AIAA Journal, Vol. 50, no. 2, 2012, pp. 350-365.
5. Rethmel, J. Little, K. Takashima, A. Sinha, I. Adamovich, and M. Samimy, "High lift airfoil leading edge separation control with nanosecond pulse driven dbd plasma actuators," AIAA paper 2011-487, 2011.
6. Little, K. Takashima, M. Nishihara, I. Adamovich, and M. Samimy., "High lift airfoil leading edge separation control with nanosecond pulse driven dbd plasma actuators," AIAA paper 2010-4256, 2010.
7. De Giorgi, M. G., et al. "Comparison between Synthetic Jets and Continuous Jets for Active Flow Control: Application on a NACA 0015 and a Compressor Stator Cascade," *Aerospace Science and Technology*, Vol. 43, 2015, pp 256 – 280.
8. Gad-el-Hak, M., Pollard, A., Bonnet, J. P., "Flow Control: Fundamentals and Practices," Springer, 1998, pp 3.