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

Reduction of power consumption for quasi-DC discharge applied for combustion control in supersonic airflow

Aleksandr A. Firsov[1], Evgeniy V. Dolgov[1], Ruslan G. Rakhimov[1], Sergey B. Leonov[1,2]

Abstract

The plasma-assisted ignition and flameholding based on surface DC discharge is a known and undemanding method for organizing combustion in a supersonic flow [1-2]. It can be used for ignition of gaseous hydrocarbon fuel at wide range of flow conditions without employing mechanical flameholders in a supersonic combustion chamber. And one of the next steps at the study and development of such discharge systems is reducing the power consumption that makes this technology more suitable for use in a real supersonic combustion chamber. This experimental and computational work presents a plasma system, which should reducing the total energy consumption and extending the life cycle of the electrode system.

Keywords: *plasma-assisted combustion, supersonic flow, quasi-DC discharge*

1. Experimental setup

The test section contains fuel injection area with 9 orifices ø1.5 mm located on the wall in line cross the flow with 5mm spacing and DC-discharge actuator based on four 5 mm gaps with 7 mm spacing between pairs located 70 mm downstream of orifices. Typical images of discharge created between two pairs of electrodes are presented in figure 1. Flow Mach number is M= 2 and fuel flow rate is in a range of 0.5-4 g/s of C_2H_4.

2. Experimental results

It was found that for presented geometry the plasma loops share the grounded electrode, as it is shown in Figure 1(b). Such switching of discharge allows the discharge to stretch more along the flow, because the gap between electrodes is higher in this case. As a result an increase of voltage and power release up to 45% (because of constant current mode) was obtained for one loop in comparison with expected mode, as it is shown in Figure 1(c).

Comparison of ignition by different modes of discharge operation was performed for fuel mass flow rate 4g/s. The mode1 consists in two spaced loops: 1st and 3rd discharge gaps were used in this case. The mode2 consists in two loops (2nd and 3rd) with shared ground. It was found that at the same discharge power ~5kW the mode2 provide a stable ignition and combustion, while mode1 result in medium pressure increase that corresponds to the cold flame [1] or incomplete combustion. For understanding the reason of such result and determination of the effect of the discharge length and the double current to shared ground on ignition the mode3 was also tested. The mode3 consists in two loops with 7mm gap. Comparison of pressure distribution for mode1 and mode3 is presented in figure 2. It was found that at the same discharge power 5.6kW mode3 results in stable combustion while mode1 resuls in some pressure increase. But at such power mode3 has a greater length of discharge and lower current (I=2.7A), compared with mode1 (I=3.8A), so we can conclude that length of discharge has a more important factor in comparison with power and current. Mode3b with one loop based on 7mm gap was also tested. For this case a stable ignition was obtained for 3.5kW power at I=3.9A, while the discharge loop of 2.8kW and I=2.7A results in only some small pressure

[1] *Joint Institute for High Temperatures of the Russian Academy of Sciences (JIHT RAS), af@jiht.org*
[2] *University of Notre Dame, USA*

increase. Such a result can be explained by the mutual influence of discharge filaments on gas dynamics in the heating region, since each plasma filament creates a conical shock wave: an increase in the number of loops to change the flowfield, or an increase in power is required for stable ignition. In conclusion it should be noted that combustion was obtained at relatively low plasma power 5.6kW (mode3) and 3.5kW (mode3b) in comparison with typical power Wpl =12–18 kW for close experimental conditions [1], and one of the key factors of power reduction is the increase in the length of the discharge.

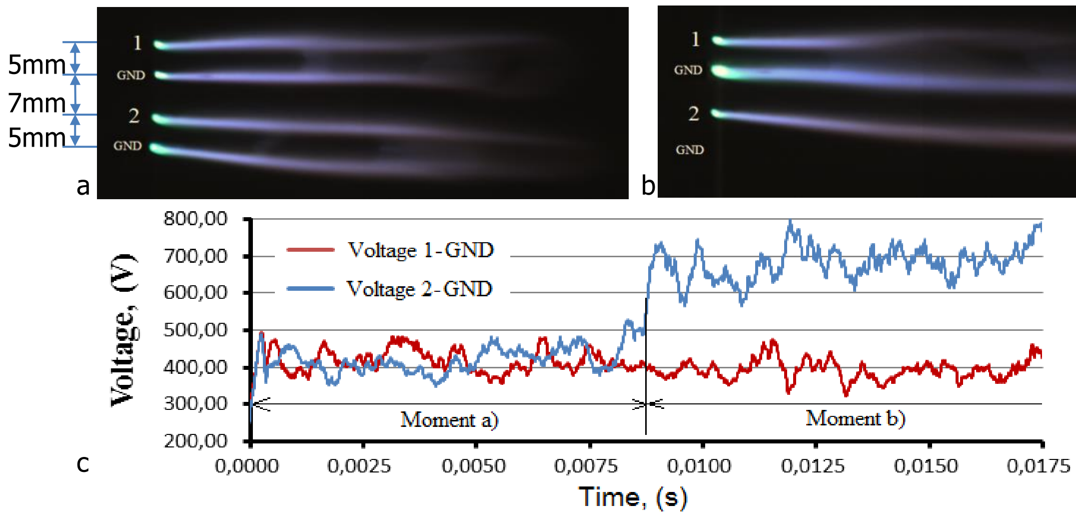

Fig 1. Modes of discharge operation. a – expected mode1; b – mode2 with shared ground electrode. Flow is from left to right. c – filtered voltage for 1st and 2nd plasma loops for time moments corresponding to images (a) and (b).

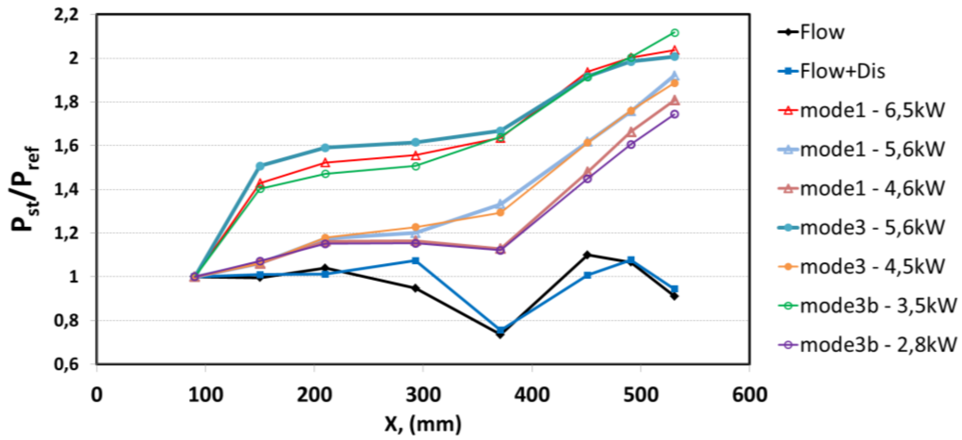

Fig 2. Pressure distribution along test section for different discharge modes.

Acknowledgments

This work is supported by Russian President Grant MK №1734.2017.8

References

1. Firsov A.A., Savelkin K. V., Yarantsev D.A., Leonov S. B.: Plasma-enhanced mixing and flameholding in supersonic flow. Phil. Trans. A 373, I.2048 (2015) http://dx.doi.org/10.1098/rsta.2014.0337
2. Leonov S.B., Savelkin K.V., Firsov A.A., Yarantsev D.A.: Fuel ignition and flame front stabilization in supersonic flow using electric discharge. High Temp. 48, I.6, pp.941-947 (2010) http://dx.doi.org/10.1134/S0018151X10060179