Experimental investigation on the air plasma ignition in kerosene-air mixture

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Plasma provides an unprecedented opportunity for combustion and emission control owing to its unique capability in producing active species, heat and modifying transport processes[1-2]. In the past two decades, particular interests in applications of plasma to the problem of assisted ignition and combustion have been observed [3-4]. The plasma ignition has been shown the special advantages in shorting the ignition delay time, extending the ignition limit, improving the reliability, reducing the NO_x emissions. Until now, the plasma-assisted combustion has been explored for applications on varies of engines such as internal combustion engine, turbo engine, scramjet and pulse detonation engine[5].

This paper designs an air plasma jet igniter, the plasma jet ignition of air-discharge arc is investigated. Through the air plasma jet ignition experiments, we investigated the ignition limits of plasma jet ignition and spark ignition in kerosene-airmixture. The results show that the air plasma jet ignition could ignite the mixture easily. The air plasma jet ignition can extend the ignition limits of kerosene-air mixture obviously.

1. The air Plasma igniter design

This air plasma jet igniter is non-transfer arc, using lateral inlet. When plasma igniter working, the air enters into the ignition cavity. Then, under the role of the swirler, the air changes to rotating airflow. After swirling, the air through the channel between the anode and cathode. The air is breakdown by high voltage connected between the anode and cathode. The arc discharge is formed, and arc will heat the air to high temperature. Then plasma jet is formed.

With plasma jet igniter feedstock flow rate 60 g/min, supply output current of the driven power 25A, the plasma igniter in discharge state is shown in Fig.1. An obvious white arc is generated at the exit of the igniter. The arc is about 45 mm long. The plasma igniter's working atmosphere is ambient atmosphere.

Fig.1. Plasma igniter (F/8, 1/10 s)

As a result of using the swirler, the plasma jet is showed by turbulent state. The plasma jet can be devide into three zones, transition zone, diffusion region and contraction zone. In transition zone, close to the anode outlet, air plasma is injected by the igniter cavity wall chamber channel. Because of bounding by the inner wall surface of the anode channel, the diameter of jet and the nozzle diameter are about the same. In diffusion region, air is heated by arc, expansion rapidly. Because of the entrainment to cold air, the diameter of plasma jet become larger. In contraction zone, in the head region of the jet, due to away from the heat arc zone, as well as exchanging the heat while mixing with the surrounding cold air, the plasma jet's temperature become low, jet diameter becomes gradually smaller.

2. Results and discussions

2.1 Ignition limits of plasma jet ignition and spark ignition

The kerosene/air mixtures ignition limits of plasma and spark ignition is shown in Fig.2. The plasma jet igniter's feedstock flow rate is 60 g/min, driven power supply output current is 25A.

In this experiments, the variation rule of kerosene/air mixture's lean and rich ignition limits are similarity for plasma jet ignition and spark ignition. With the increasing of inlet flow rate, ignitable excess air coefficent range gradually is gradually shrinking. From Fig.4 we can see that ignition spark can ignite a maximum inlet air speed of 21.4 m/s. The plasma ignition can ignite a maximum inlet air speed of 53.5 m/s. The plasma jet ignition could increase the maximum inlet air speed by about 2.5 times.

Thus, for the plasma jet ignition, the lean and rich limits of kerosene/air have been expanded respectively, especially ignitable maximum air flow speed has been improved greatly. When the plasma jet ignition, high temperature, high speed plasma jet injected into the combustion section, high temperature flame core formed directly, and the flame core area is much larger than that of the spark ignition. The plasma jet can igniting surrounding combustible mixture directly. The flame at a faster rate spread to unburned area. The ignition delay time can be shortened by plasma jet.

2.2 The influence of the currents

With plasma jet igniter feedstock flow rate 60 g/min, driven power supply output current varies from 25A to 35A, the ignition limits of plasma ignition is shown in Fig.3.

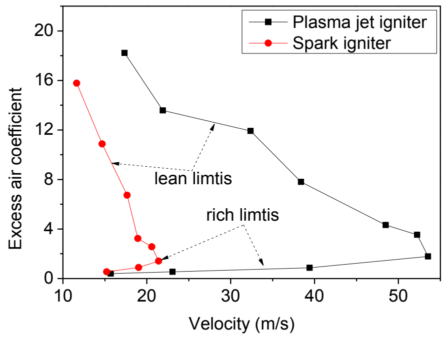

Fig.2.The ignition limits of plasma and spark ignition

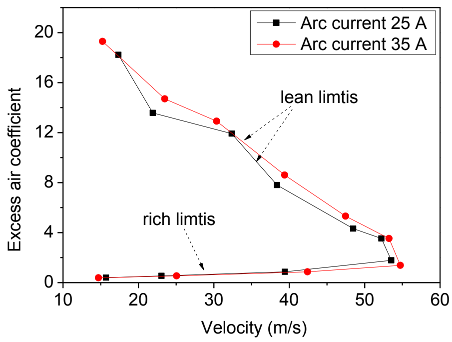

Fig.3.The ignition limits with different arc current

As shown in Fig.3, ignition limits have been expanded with increasing arc current. At arc current 35A, The plasma ignition can ignite a maximum air speed of 54.7 m/s. Compare with arc current 25 A, the maximum air speed increased by 2.24%.

The mechanism of the influence of arc currents on ignition limits is that with the increasing arc current, the energy applied to the air plasma jet by arc discharge is increased too. The increasing energy will make the temperature of the jet rising. Depending on the gas state equation, the temperature rise will result in the expansion of gases. The density decreases, the volume and speed of the plasma jet increases, part of the internal energy is converted into mechanical energy. By increasing the flow velocity of the outlet, the torch length is increased so as to increase the ignition region. This will create more turbulence in the ignition area. Therefore, the plasma jet ignition is more efficient. Thus, the larger ignition limits is obtained.

2.3 The influence of the jet igniter feedstock flow rate

With plasma jet igniter driven power supply output current 25A, the igniter with different feedstock flow rateas 40g/min, 60g/min and 80g/min, the ignition limits of plasma ignition is shown in Fig.4. From Fig.4 we can conclude that with increasing of the feedstock flow rate, the ignition limits have been reduced gradually. This is because that with increasing of the feedstock flow rate, enhanced cooling effect on the plasma arc, the heating power to the arc will reduce. Thus, ignition ability weakened gradually, the ignition limits is shrinking.

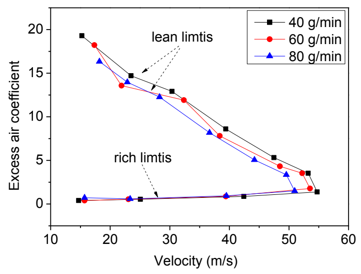

Fig.4.The ignition limits with different feedstock flow rate

3. Conclusions

(1) the air plasma jet ignition could ignite the mixture easily. The air plasma jet ignition can extend the ignition limits of kerosene-air mixture obviously. The results show that the spark ignition can ignite a maximum air speed of 21.4 m/s, the plasma ignition can ignite a maximum air speed of 53.5 m/s, the plasma jet ignition could increase the maximum air speed by about 2.5 times.

(2) At arc current 35A, The plasma ignition can ignite a maximum air speed of 54.7 m/s. Compare with arc current 25 A, the maximum air speed increased by 2.24%. Ignition limits have been expanded with increasing arc current.

(3) With increasing of the feedstock flow rate40g/min, 60g/min and 80g/min, the ignition limits have been reduced gradually.

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