The plasma candle: A promising device for a wider treatment area

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Abstract: The challenges faced in obtaining a wide plasma jet from a single tube are discussed, and new approaches are applied to address these challenges, which resulted in the development of a new device called the plasma candle. It is found that the presence of porous material with high dielectric inside the tube is essential to modify the gas flow and intensify the electric field, which are important factors required to be controlled to obtain a wide plasma jet. Finally, a guideline for obtaining a wide plasma jet from a single tube is presented.

Keywords: Plasma candle, wide plasma jet, crucial factors, scaling parameters

1. Introduction

Recently, considerable attempts have been implemented to design controllable and scalable plasma jet devices to expand the treatment area for industrial applications. Owing to the many drawbacks in the conventional upscaling techniques using bundle arrays of multi-tubes, designing a source to generate a wide plasma jet from a single tube is great of interest. However, the tube diameter has a significant effect on the flow dynamics and plasma characteristics, and subsequently, affects the jet formation.

Thus, in this study, we presented a thorough investigation to determine the main challenges faced in obtaining a stable and uniform plasma jet from a single tube with a diameter of up to 30 mm. Furthermore, we provided new approaches and techniques to address the challenges of upscaling the plasma jet. Moreover, we presented the characteristics of the launched wide jet under different operating conditions and electrode arrangements in order to derive scaling parameters that can be used as guidelines for launching a wide jet from a single tube. The interaction of the wide plasma jet with different targets is presented to show the applicability of the launched jet.

2. Experimental setup

Details of the experimental set-up and plasma jet device experimental set-up are described in [1-3]. Acrylic tubes with different inner diameters (D = 10–30 mm) were used. Two copper tapes are used as high-voltage and ground electrodes. The electrode gap and distance to the tube nozzle were systematically varied. A commercial porous material with an average pore size of ~400 μm was used as a gas diffuser to modify the gas flow inside the outlet tube. The formation and characteristics of the plasma jet were investigated by means of fast photography and electrical measurements at different operating conditions.

3. Results and discussion

The deep analysis of the results showed that a sudden expansion of the gas occurred through the delivery of the gas from the gas pipeline to the wide tube. As a result, the gas moves inside the tube in turbulence, which mitigates by increasing the flow rate (Fig. 1). The sudden expansion effects were eliminated using a porous material at the inlet of gas to the wide tube, as it indicated by Schlieren images (Fig.1).

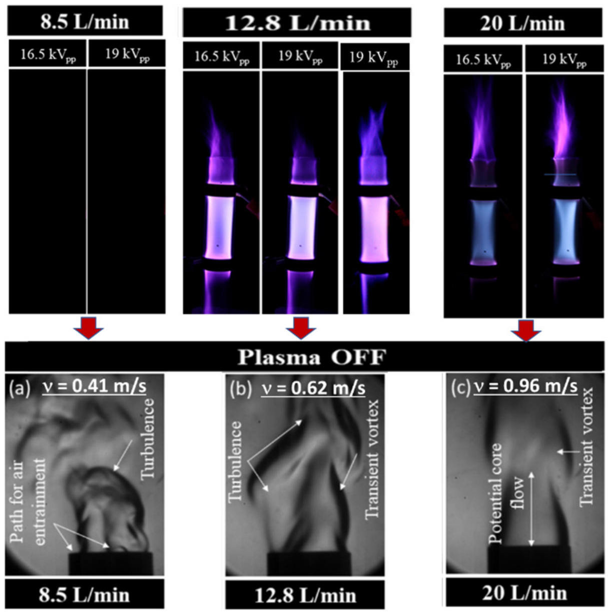

Fig. 1. The upper photos shows the dependence of the jet formation on the flow rates at tube diameter = 21 mm. The lower photos show Schlieren images of the cases presented in the upper photos.

Moreover, adjusting the frequency was crucial to obtain a stable plasma jet. A very weak discharge with no noticeable jet was observed in a wider tube at frequencies less than 5 kHz, while a jet with a brush-like shape was observed at much higher frequencies. This indicates that the time between the successive discharges is sufficiently long to decay the produced species in a wide tube. Adjusting the electrode arrangement showed also a significant effect on the jet properties.

The analysis of the obtained data indicated that there is a threshold of the gas velocity to launch a stable jet, and it increased linearly with increasing D, and it was associated with a linear increase in the optimum gap. Moreover, the threshold power to launch a stable jet increase linearly with D at the optimum electrode arrangement and constant gas velocity. Combining all these key parameters led to general scaling parameters to launch a stable jet.

By considering the above parameters and using a porous material with high dielectric constant to intensify the electric field, a novel device called plasma candle was developed, as shown in Fig. 2. The unique configuration of the device resulted in distinctive discharge patterns. Homogenous discharge was generated in the electrode gap and followed by a swirling discharge toward the tube nozzle.

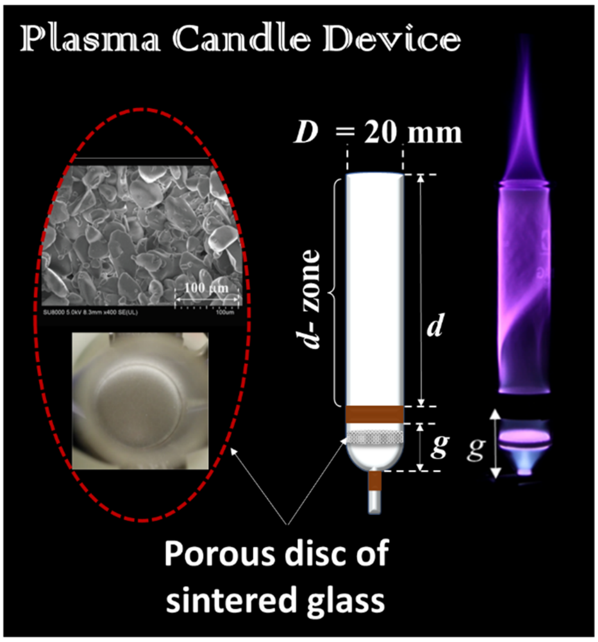

Fig. 2. Photos of the porous disc used in the plasma candle, schematic of the plasma candle device, and a photo shows the discharge and jet shape of the plasma candle.

4. Conclusions

Obtaining a stable, uniform, and wide plasma jet from a single tube to treat a wider area is possible now using the plasma candle device. The device provided new has unique characteristics promising for industrial applications.

5. Acknowledgment

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6. References

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