Velocity Measurement of EHD Flow Produced by Pin-Multi Concentric Ring electrodes Generator

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Velocity Measurement of EHD Flow Produced by Pin-Multi Concentric Ring electrodes Generator

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Abstract. Study of EHD flow by using corona discharge generator has been conducted. Corona discharge was generated by using of pin to multi concentric rings (P-MCR) and pin to single ring (P-SR) electrodes configurations. The pin needle was made by stainless steel with a length of 50 mm and a tip diameter of 0.14 mm. The multi-ring electrodes were constructed by three concentric rings iron and its connected one and each other. The diameters of concentric rings were 24 mm, 16 mm and 8 mm and each ring has width of 2 mm and thickness of 3 mm. Single ring electrode has a diameter, width and thickness respectively 24 mm, 3 mm and 2 mm. EHD was generated by using a DC high voltage of 10 kV. Pin as an active electrode of corona discharge and concentric rings multi/single ring electrodes as ions collector and passive electrodes. We measured the velocity of EHD flow P-MCR and P-SR. The velocity of EHD flow was measured by a hot-wire anemometer. We found that the velocity of EHD flow with point to multi-ring concentric electrodes larger than a point to single ring electrode. The measurement of velocity for two cases of electrodes configuration were limited at the certain voltage due to breakdown and arc phenomena. The maximum velocity of the of EHD flow using a pin-multi rings concentric was 0.7 m/s at a voltage of 6 kV.

Introduction

An electrohydrodynamic (EHD) flow, also called wind "corona", "electricity", "ions", or "ions propulsion" generated by the corona discharge significantly improved heat and mass transfer [1] EHD flow can be applied to drug delivery system with EHD technique spraying [2], applied as an integrated chip cooling technique with EHD Pump [3-5]. The EHD is another application for micro fan [6] and as the dryer for the biscuit industry [7,8]. Devices that use ionic wind flow or EHD flow by corona discharge has many advantages. The EHD flow requires no moving parts and provides flexibility in the form of channels and free from mechanical vibration and acoustic noise.

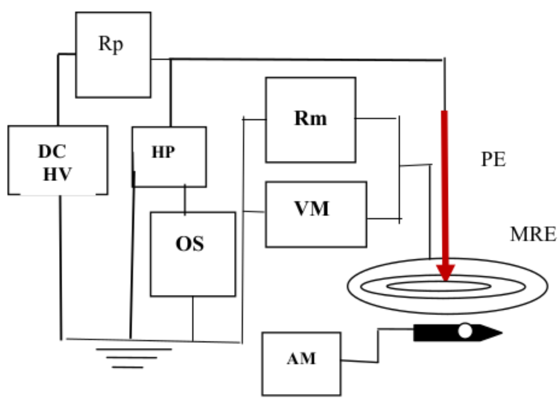
Various attempts have been made to increase the flow rate and optimization of wind ions by modifying the electrodes configuration, such as: needle-ring electrodes configuration of ion wind generator [9], parallel wire non-field [10]. Other researcher obtained that EHD flow rate in needle-grid and ring was` is greater than pin to ring configuration [11]. In the several experiments, researchers used corona discharge with multipoint to ring electrodes configuration in a cylindrical tube [12, 13].

In this research, the study of EHD flow generated by corona discharge with multipins to concentric ring electrodes configuration has been conducted. Corona discharge configuration in this study is different with the study of Rickard et al. [14], Rickard et al. [15], Rickard et al. [9], Moon and Hwang [16]. They used a needle-needle/ring electrodes pairs. On this electrode configuration, the velocity EHD flow was increased by comparison with pin to ring electrode configuration.

The results of these researches can be applied and developed in the food industry and medicine industry as an advanced dryer technology. Excess advanced dryers system based on EHD flow beside as dryers system, in addition it also can kill bacteria and others microorganism.

Experiment

The first step of this research was to design a generator EHD flow. It was in the form a system of corona discharge using electrode a pin-multi concentric ring and pin-ring electrode as control of measurement results. Pin electrodes used had a diameter of 0.14 mm and a length of 50 mm, while multi ring used three concentric ring electrodes. Three concentric ring electrodes have a thickness, width and spacing between the rings the same row each 3 mm; 2 mm and 2 mm. The diameter of the electrode three concentric rings of magnitude, from the smallest ring for the biggest ring were 8 mm, 16 mm and 24 mm. Experimental set-up of this study include the EHD flow generator, high voltage power supply, set of voltage and current measurement tools and a set of measuring tools EHD flow velocity as shown in Fig. 1.



AM: Hot-Wire Anemometer
PE :Pin Electrode
Rp, Rm: Resistor
MRE : Multi Ring Electrode
DC HV : DC HV Source
HP : High Probe
OS :Oscilloscope
VM :Multimeter

Fig. 1. Experiment set-up

The EHD flow generated by using a high voltage DC 10 kV on the electrodes of the corona discharge system with a positive polarity in the pin electrodes and a negative polarity in the ring/ the multi concentric ring. A high-voltage probe 1000:1 has been used and it was connected to the CRO for measurement of voltage in our corona discharge. The ion current was measured by using a multimeter. The velocity of EHD flow was determined by using a devices hot-wire Anemometer that was placed perpendicular under the pin electrode with distance is 15 mm.

Results dan Discussion

The *I-V* characteristics of ions current *(I)* as a function of voltage *(V)* of the measured data with the distance between the electrodes remains a characteristic of EHD flow generator with fixed geometry factors is shown in Fig. 2. In this figure, we show the comparison between I-V characteristics of the EHD flow generator electrodes pin to multi concentric rings configuration with electrodes pin-rings configuration.

The distances between the electrodes were: 4 mm, 8 mm and 12 mm. For the *I-V* characteristics we marked the distance inter electrodes with MCR4 (for distance of 4 mm), MCR8 (for distance of 8 mm), and MCR12 (for distance of 12 mm). Meanwhile, for the *I-V* characteristics using the electrodes pin to single ring, we marked such as: SR4, SR8 and SR12 for distance of 4 mm, 8 mm, and 12 mm, respectively. The *I-V* characteristics on the spacing between the electrodes fixed, the greater the applied voltage then increased the ions current. It occurs either for electrode configuration pin-multi concentric rings or the single ring. This is because the relationship between voltage and current is a parabolic function. The ions current value (proportional to the square of the value of *V*.

Figure 2 shows that in the same value of voltage e.g. V = 3.5 kV, the ions current of the EHD flow generator with pin to multi concentric rings electrodes configuration higher than the pin to ring electrodes configuration. This is because the EHD flow generator that uses pin to multi concentric rings (P-MCR) having flux of electric field greater than pin to single ring (P-SR) electrodes configuration.

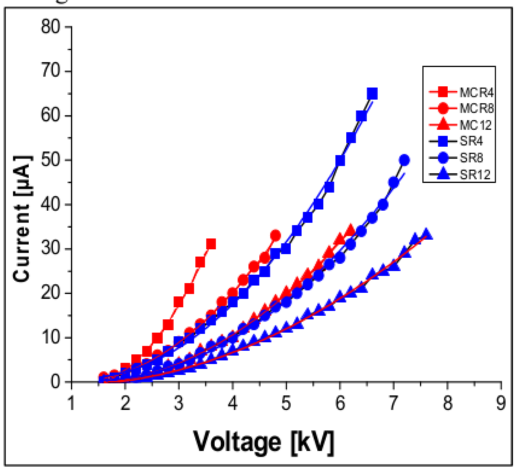


Fig. 2. The I-V characteristics

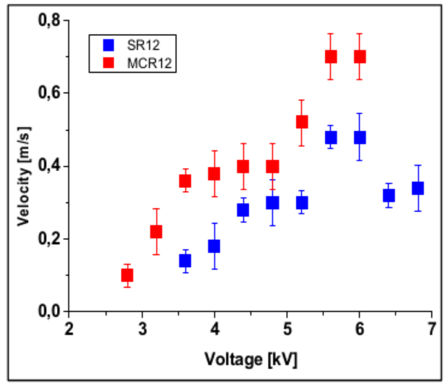


Fig.3. EHD flow characteristics for configuration electrode pin-multi concentric rings and pin-rings on the distance between electrodes 12 mm

The onset voltage was the same value (1.5 kV) for the all distance of our experiment as shown in Fig. 2. At all the distance between the electrodes, with increasing voltage applied to the generator then the greater the ion current that are detected and accompanied by corona discharge, then at the end break down voltage. The ion current during breakdown voltage, using electrodes configuration pin to multi concentric ring is lower than that of using a pin to ring electrodes. The difference in the magnitude of the ions current is due to at the breakdown voltage. The corona discharge with electrode configuration pin to multi concentric rings required more energy than the pin to ring electrode.

The EHD flow characteristics also can be shown in the form of the graph of EHD flow velocity with the applied voltage. The graph of EHD flow characteristics for configuration electrode pin-multi concentric rings and pin-rings on the distance between electrodes of 12 mm as shown in Fig. 3. The increase in voltage leads to increase the velocity of EHD flow for both EHD flow generators by corona dischrge with a pin-multi consentric ring configuartion and with pin-rings configuration electrodes. This is due to the greater applied voltage, the greater the ionization zone and augmented electric fields. The positives ions accellerated by high electric field. In other words, corona discharge produced more number of ions and increased the velocity EHD flow. The EHD flow velocity reached a maximum of 0.6 m/s at a voltage of 3 kV.

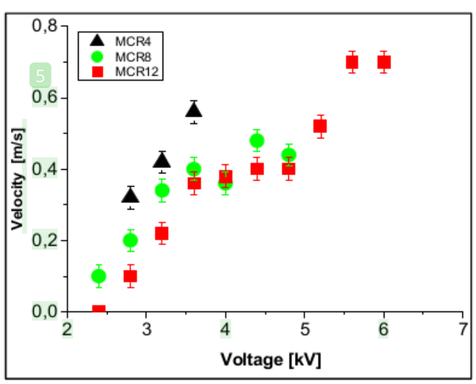


Fig. 4. EHD flow characteristics for configuration electrode pin to multi concentric rings on the distance between electrodes 4 mm, 8mm and 12 mm

In the Fig. 3, we present the velocity of EHD flow as function of applied voltage with same distance between the electrodes of 12 mm for two corona discharge configuration. We found that EHD flow with pin to multi concentric rings (P-MCR) is greater than using pin to single ring electrode. This is due to using the pin to multi concentric rings electrodes has flux electric field density greater than the pin to ring electrode. Ion movement towards multi-ring electrode will collide with neutral air molecules with very high collision frequency. Large momentum transfer from the gas molecules to the positive ions in the region between the electrodes will be large the EHD flow.

In the figure 4, we show the velocity of EHD flow characteristics for pin to multi concentric rings configuration on the distance between electrode 4 mm, 8 mm dan 12 mm. The velocity of EHD flow with distance between the electrodes 4 mm larger than the distance between the electrodes 8 mm or 12 mm. So the smaller the distance/spacing between the electrodes, the greater the EHD flow velocity. This is due to the smaller distance between the electrodes, the greater the electric field. Electric field more accelerated ions and increasing the ionization process. The breakdown voltage is quickly achieved so that the EHD flow rate should be saturated.

Conclusion

The velocity measurement of EHD flow has been conducted succesfully by pin-multi concentric ring electrodes generator. The ions current value is found to be proportional to the square of the value of V. The ion current of the EHD flow generator that uses electrode configuration pin to multi concentric rings is higher compared to that of using the pin-ring electrode. Moreover, the ions current during breakdown voltage, using electrode configuration pin-multi concentric ring is lower than that of using pin-ring electrode. The EHD flow that was generated by corona discharge with pin to multi concentric rings configuration has higher electric field density compared to that with the pin to single ring (P-SR) electrodes. The positive ions were accellerated by high electric field, where the movement of ions contributed to ionic velocity. It means that the corona discharge produced more number of ions and increased the velocity of EHD flow.

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PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7