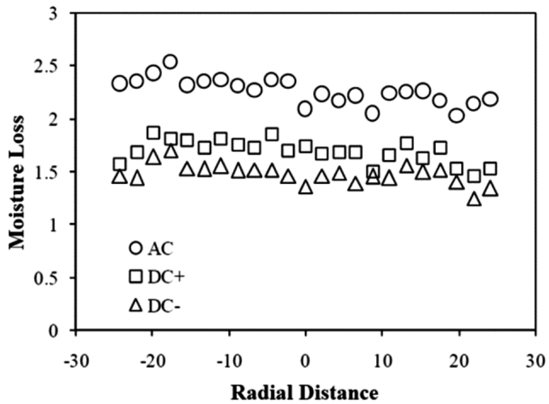

Fig. 8 — Effect of polarity on water evaporation rate

force).[52] They had experimented with variable cross-flow velocities and observed that it assists in drying enhancement, but its effectiveness becomes insignificant as the water level in the sample container starts reducing. They also concluded that at lower cross-flow velocity ($u \leq 0.7 - m/s$), the rate of drying enhancement was non-linear, but for higher velocities ($u \geq 1.0 - m/s$), it becomes linear. A similar observation was made by Lai *et al.*[48], that the evaporation rate was lower in the presence of large cross-flow as it tends to suppress the corona wind, affecting the drying enhancement significantly, whereas the drying rate increased linearly in the absence of cross-flow.

To summarize the effect of cross-flow velocity (forced convection), a low velocity was found to assist in drying enhancement as it does not suppress the corona discharge, and it would also contribute to the evaporative drying process; for ($N_{EHD} > 1$), the effect of EHD drying enhancement was found to be significant as compared to the one with ($N_{EHD} < 1$).[17,48] And a low cross-flow velocity with higher voltage discharge resulted in higher drying rates as compared to the one in the absence of cross-flow (forced convection).[53]

Effects of AC and DC Applied Voltage

Direct current (DC) or alternating current (AC) can both cause corona discharge in EHD drying applications. The polarity of the applied voltage determines whether the DC corona discharge is positive or negative. In comparison, the applied voltage in an AC corona discharge changes polarity with each cycle, leading to a discontinuous discharge. But the performance efficiency of AC corona discharge-driven EHD drying applications is more than the DC corona discharge[45–54] (Fig. 8).

Fig. 9 — Specific Energy Consumption as a function of the electrode gap

Hashinaga *et al.*[42] validated that AC applied voltage had the potential to enhance the water evaporation rate, and the electrode gap (d) has a critical role to play in the enhancement process. Yang & Ding[54] observed that the drying rate increase with the increase in applied voltage, an observation which has been quoted by many for both AC and DC applied voltages. Ding *et al.*[55] reported that irrespective of applied field intensity, the thickness of the drying sample would retard the drying rate, reducing overall drying efficiency.

Yang *et al.*[56] while experimenting with variable discharge gap (d), for similar operating conditions of AC and DC corona discharges, respectively, found that the drying rate in the case of both AC and DC applied potential was pretty much the same, but the specific energy consumption (Fig. 9) in the case of AC applied potential was much higher as compared to the DC for all the discharge gaps (d). They concluded that an appropriate combination of DC applied voltage and electrode gap would result in a high drying rate with lesser energy consumption.

AC corona discharge was found to be more effective in drying enhancement, (Fig. 8) as compared to both positive and negative DC corona discharge.[45–54] However, AC corona discharge consumes significantly more energy (Fig. 9) due to the fluctuating nature which results in discontinuous discharge, thus affecting the overall power consumption.[56]

Conclusions

In this paper, the effectiveness of corona discharge under various performance parameters, for a needle to plane electrode configuration and its role in EHD drying enhancement have been discussed. For effective EHD drying enhancement, parameters like applied voltage (AC or DC), polarity (positive or negative), type of needle, electrode geometry, electrode gap (*d*), and cross-flow velocity (forced convection) were discussed for their role in generating efficient corona discharge. These parameters have their individual effects that have been studied by various researchers, yet a large-scale application for commercial drying or industrial implementation has not yet been developed.

An optimized model based upon the above parameters and the observations needs to be investigated thoroughly for the development of the needle-to-plane EHD drying model for industrial application, as it might be able to address the challenges associated with the upscaling of the model. And it can also provide a solution for addressing the non-uniform drying and inefficient mass drying problems, which are associated with the upscaling of experimental models to suit the volume of industrial needs.

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