Electrohydrodynamic Atomization of Viscous Liquids

Anatol JAWOREK\textsuperscript{1}, Wamadeva BALACHANDRAN\textsuperscript{2}, Andrzej KRUPA\textsuperscript{1}, Janusz KULON\textsuperscript{2}, Wojciech MACHOWSKI\textsuperscript{2,3}

\textsuperscript{1}Institute of Fluid Flow Machinery, Polish Academy of Sciences, Fiszera 14, 80-952 Gdansk, Poland. Telephone: (048)58 3460881 ext.151, Fax: (048)58 3416144, jaworek@imp.gda.pl

\textsuperscript{2}Department of Systems Engineering, Brunel University, Uxbridge UB8 3PH, UK. Telephone: (044) 1895 274000, Fax: (044) 1895 81255, e-mail:

\textsuperscript{3}present affiliation: Visual Information Laboratory, Mitsubishi Electric Europe, Guildford, U.K.

Abstract

The liquid sprayed by the electrohydrodynamic (EHD) method is atomized only due to electrical forces without additional mechanical energy applied. The EHD spraying is an effective method for generating electrically charged aerosol. The droplets generated by this method are electrically charged up to a fraction of the Rayleigh limit that allows to control the droplets motion by electrostatic fields. The atomization process depends on physical properties of the liquid, the nozzle-extractor geometry, the voltage at the nozzle, and liquid flow rate.

The investigations of the effect of liquid viscosity on the spraying process, the transition between spraying modes, jet diameter, and the droplet size in the cone-jet mode are reported in this paper. The effect of viscosity on electrohydrodynamic spraying of liquids is more complex problem than predicted by any theoretical consideration. Experimental results presented in the literature are not conclusive because viscosity of a liquid can not be changed with remaining other important parameters constant.

The experiments presented in the paper were carried out for stainless steel hypodermic needle placed 7 mm above a grounded ring electrode of inner diameter of 9 mm. Various concentrations of distilled water and ethylene glycol mixtures, which have similar surface tension and conductivity, were used as test fluids of different viscosity. The viscosity of the mixtures changed in the range of 1mPa\textperiodcentered s to about 22mPa\textperiodcentered s.

The spindle and the cone-jet modes were generated by the spray system used. The size distribution of the spindle mode is bi-modal: large droplets have most probable diameters varying in the range from 200 to 500 \(\mu m\), and smaller satellite droplets are usually finer than 50 \(\mu m\). The number of smaller droplets increases with increasing viscosity, especially for high flow rate of the liquid.

In the cone-jet mode, the diameter of the jet is of about 140 \(\mu m\) for distilled water, and decreases with the increase in liquid viscosity to about 90 \(\mu m\), for ethylene glycol. The most probable diameter of the droplets decreases with the increase in liquid viscosity. It was also observed that with the increase in voltage the jet becomes thinner, transporting the liquid with higher velocity. It was noticed that transition of the spindle mode to the cone-jet mode takes place for lower voltages as the liquid viscosity increases.

From theoretical considerations and experiments can be concluded that viscosity has only small effect on jet formation. It was experimentally shown that the increase in the liquid viscosity causes the jet diameter to slightly decrease (Fig.1) and the jet length to increase. Also the diameter of the generated droplets slowly decreases with the liquid viscosity increasing (Fig.2). The cone-jet mode develops from the spindle mode for lower voltages as the liquid viscosity increases.
Fig. 1. The effect of liquid viscosity on the jet diameter in the jet mode. DC potential of the nozzle 10 kV.

Fig. 2. The effect of liquid viscosity on the droplet diameter in the jet mode. DC potential of the nozzle 10 kV.