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Charged spray generation for gas cleaning applications

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A R T I C L E I N F O

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A B S T R A C T

The paper presents results of experimental investigation of properties of charged sprays generated by two types of pressure atomizers with charging by induction. Among other possible methods of charged spray generation, the induction charging has been considered due to its most practical importance. The goal of this research is to optimise the charging process with respect to obtain droplets of required size and charge for their application for exhaust gas cleaning from submicron particles in electrostatic scrubber used for the removal of PM from Diesel engine exhausts. Electrostatic scrubbers use electrostatic forces in order to deposit fine charged particles onto oppositely charged droplets.

1. Introduction

For the abatement of emission of particles smaller than 1 μm from power plants, transport vehicles or other industrial processes, wet electrostatic scrubbers have been investigated as the most effective solution by low running costs. Fine particles are particularly hazardous for human lungs, because they can penetrate the lower airways and diffuse to the blood circulation. Submicron particles from fossil fuels contain higher percentage of heavy metals like: Zn, Se, As, Cd, Hg, Ni, Pb, Cr, Sr, Be, V and U than the larger ones, and from biomass, additionally carcinogenic PAH. In wet electrostatic scrubbers, spray of charged water droplets scavenges oppositely charged dust particles, because of electrostatic Coulomb attraction between them [6]. An efficient operation of electrostatic scrubber requires sufficiently high charges imparted to both, water droplets and dust particles. In order to accomplish the scrubbing process, charged droplets are generated in a form of spray.

Spray is a two-phase system of droplets flowing within a gas. The difference between spray and aerosols is that the droplets may be larger and not suspended within the gas, and that the spray droplets are in motion, while the surrounding gas remains in rest or flows with different velocity. Charged sprays are systems of droplets, which are electrically charged. The electric charge causes electrostatic interactions with other droplets and between the droplets and particles. Usually, mechanical atomizers are used for the spray production. Among the methods applied for droplets charging, such as, ionic-beam charging by externally generated ions, charging by ionic current in an electrical discharge, conduction charging via maintaining an atomizer at high potential, induction charging, and electrospraying, only the induction charging has been tested in this paper because of practical reasons. Induction charging is based on the inducing electric charge by an external electric field on the surface of liquid jet formed at the outlet of a nozzle during liquid atomisation. The electric field is usually produced by high voltage electrode placed nearby the nozzle.

The paper compares two types of water spray atomizers producing hollow-cone and full-cone sprays with respect of charged spray generation for its application to wet electrostatic scrubbing. This research is aimed at the development of a device for an effective cleaning of Diesel-engine exhausts from particulate matter by using sea-water electrostatic scrubber, as a response to new legislations by The International Maritime Organization within the Marpol Annex VI guidelines referring to the emission by ship engines. This research is a part of the FP7 DEECON project, which is aimed at creating a novel, on-board, after–treatment complex system for the reduction of Particulate Matter (PM), SO_x, NO_x, CO and Volatile Organic Compounds (VOC) emission by ship engines [7]. The charging process has been optimized with respect to the maximization of the magnitude of charge imparted to the droplets, determined from the total spray current and the water volume flow rate.

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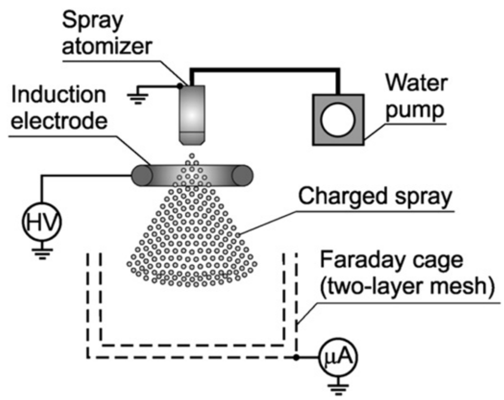

Fig. 1. Schematic of experimental set-up for the measurement of droplets size distribution and spray current.

2. Experimental

An experimental set-up for the measurement of droplets size distribution and mean electric charge on droplets charged by induction is schematically shown in Fig. 1. It comprises spray atomizer supplied with water by a pump, induction electrode supplied with high voltage, and Faraday cage for measuring spray current. For the measurement of droplet size distribution, the Faraday cage was replaced by droplet size analyser, and measurements were carried out by the same experimental conditions.

Two types of atomizers were used in the experiments: pressure atomizer with full-cone spray and pressure-swirl atomizer producing hollow-cone spray. The induction electrode was made in a form of ring of inner diameter of 100 mm, formed from a brass pipe of diameter of 12 mm. The outlet of the atomizer was placed above the upper plane of the ring electrode for five distances 0, 10, 20, 30 and 40 mm. The spray current was measured with a moving-coil microammeter connected to Faraday cage made of a two-layer grid, of dense copper mesh. The distance of the cage inlet to the atomizer outlet was that all spray droplets fell into the cage. The size distribution was measured by droplets size analyser AWK (KμK Poland). Tap water used in these measurements was forced by diaphragm pump Hydra-cell G-03B (Wanner Int.) controlled by frequency inverter Nordac sk 500e (Nord Drive Systems). The flow rate of water was measured by electromagnetic flow metre Promag 50H08 (Endress + Hauser), and the pressure by pressure metre Cerabar M PMC51 (Endress + Hauser). Water temperature was measured by thermometer RTD TR10 (Endress + Hauser). The induction electrode was connected to high voltage supply SL40PN1200 (Spellman) of negative polarity, while the nozzle was grounded. The conductivity of tap water was 0.05 S/m.

The atomizer was mounted on the axis of a cylindrical vertical spray column made of PMMA, of diameter 400 mm with the air flowing downwards. The air flow rate was measured by Vortex Flow Measuring System Prowirl 72W80 (Endress + Hauser), and its temperature by thermometer RTD TR10 (Endress + Hauser). Flow rate of air in column was stabilized at 130 m^3/h to obtain the mean velocity in the column of about 0.3 m/s.

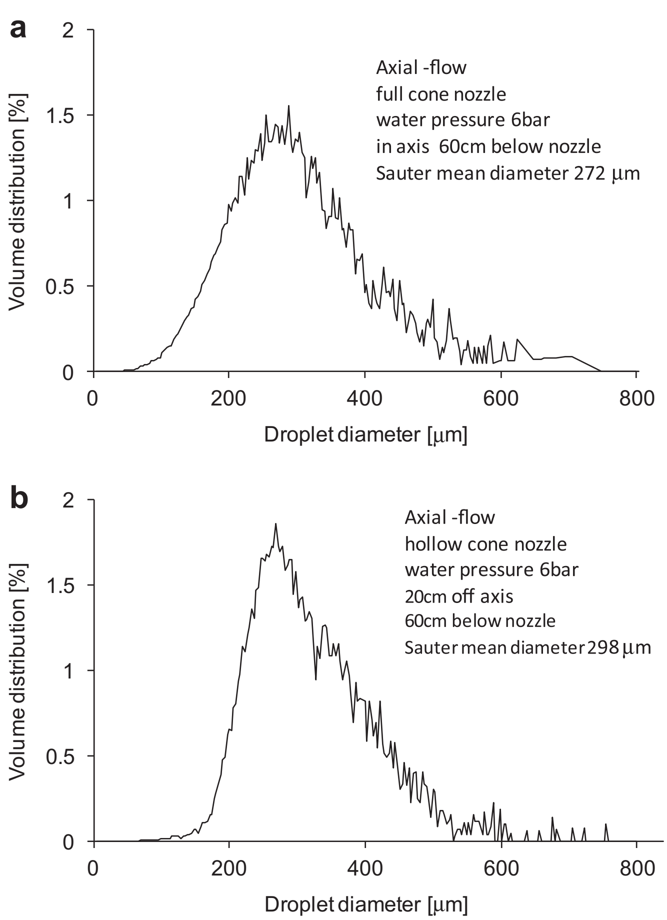

Fig. 2. Volume size distribution of water spray generated by (a) axial-flow full-cone and (b) axial-flow hollow-cone nozzles with induction charging. Water pressure 6 bar, flow rate 1.96 L/min (full-cone nozzle), and 1.72 L/min (hollow-cone nozzle).

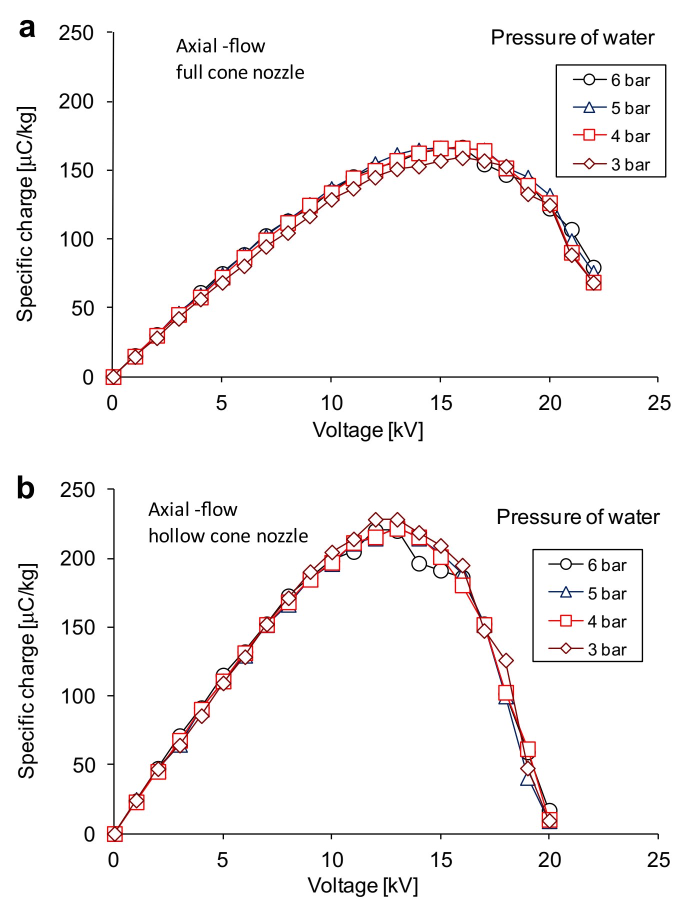

Fig. 3. Specific charge of spray generated by (a) full-cone and (b) hollow-cone nozzles with induction charging, for various water pressures. Distance from the ring electrode to the nozzle is 30 mm.