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DISPERSIVENESS OF LIQUID DROPLETS SPRAYED WITH COCURRENT GAS FLOW

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Abstract. Pneumohydraulic stand, equipped with a set of aerosol systems laser diagnostics devices, are presented. The results of experimental measurements of the aerosol liquid-drop size distribution in the ejection nozzle spray pattern are provided.

1 Introduction

Technologies of gas-dynamic dispersion of liquid by ejection nozzle are increasingly used to generate aerosol systems in different industries [1]. These technologies are used to produce fine powders from melted metals [2], to create aerosol "curtains" in industrial emergency situations, to develop degasification devices and so on. Among the variety of liquids spraying methods, ejection nozzles technologies are widespread. The ejection nozzles are pneumatic sprayer units. Liquid supply and dispersion in ejection nozzle are perfomed by pressure difference between the sprayed liquid and cocurrent gas flow at the nozzle exit section. The ability to control the spraying process by modifying the nozzle unit elements to form the liquid-drop aerosol with desired characteristics is one of advantages of the ejection nozzles applications. Consequently the research of the laws of liquid spraying by cocurrent gas flow is a challenging issue. The most complete and reliable information on the flow pattern and aerosol system characteristics can be obtained on the basis of cold blow-through model experiments.

In the present paper the laboratory facilities and model experiments results, which purpose was to prove-out of methods of obtaining objective information about the pattern and main dispersiveness characteristics of the liquid-drop aerosol in the ejection nozzle spray pattern, are presented.

2 Pneumohydraulic stand with optical diagnostics system

Experimental study of the structure and the main dispersiveness characteristics of droplets in the ejection nozzle spray pattern were carried out on pneumohydraulic stand with optical diagnostics system (Fig. 1) at cold blow-through conditions [3].

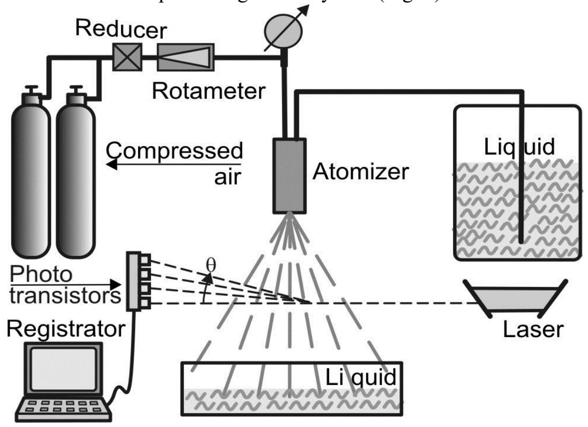

Figure 1. Pneumohydraulic stand with optical diagnostics system.

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The stand includes an ejection nozzle, supply system, liqud and gas flowrate measurement and control systems. The supply system includes a reservoir for process liquid, compressor and gas cylinders battery. Liquid from the reservoir and gas from the gas cylinders battery fed to the nozzle through pipelines. Gas flow measurement in experiments is carried out by rotameter, and the liquid flow rate – by measuring container. To control the pressure manometers are used. Liquid and gas supply control is performed by means of cutoff valves and flow reducers. Pneumohydraulic stand provides tests at operating pressures range from 0.1 to 1.0 MPa, liquid flow rate up to 10.8 kg/h, and air flow rate up to 6.3 m^3/h.

Experimental laboratory facility [4] developed to implement the method of small-angle scattering indicatrix is shown schematically in Fig. 2. Nozzle 1 of interest is mounted on a mount pillar, fixed on a massive frame 2. Probing laser 4 beam is directed horizontally into the measuring volume 5, located on the spray pattern 3 center line. The distance between the nozzle 1 exit section and measuring volume 5 adjusted within the range h = (50 ÷ 150) mm by means of mount pillar (not shown in diagram). This allows measuring the sprayed liquid droplets dispersion in different sections along the length of spray pattern 3. Scattered in the measuring volume 5 radiation is detected by the receiver system 6, which is placed on the cantilever 7. The cantilever 7 is hinged on the frame 2 allowing rotating it in a vertical plane via the bearing 8. Turning the cantilever 7 within the range of an angle θ = ± 10 ° relative to the probing radiation direction is performed by the mount pillar with a micrometer screw 9, which allows to measure indicatrix within this range of scattering angles. A laser pointer 10, placed on cantilever 7 coaxially with the receiving system 6, is used to improve the scattering angle measurement accuracy. With the aid of the laser pointer beam a distance l_1 at measuring scale 11 is recorded. The receiver system 6 includes a radiation detector placed in a cylindrical textolite case. In the case there are three optics stops of the same aperture diameter, successively placed at different distances from the receiver. The inner surface of the case and diaphragm are coated with black mat-finish to prevent the backlight radiation of the detector. The receiving system provides the aperture angle value ~ 1 deg. The probe laser 4, the receiving system 6 and a laser pointer 10 are placed on the coordinate tables 12 with micrometer screws to adjust the optical unit.

Laser module KLM-650/20 is used as a probing radiation source, germanium phototransistor FTG-4 is used as a radiation detector.

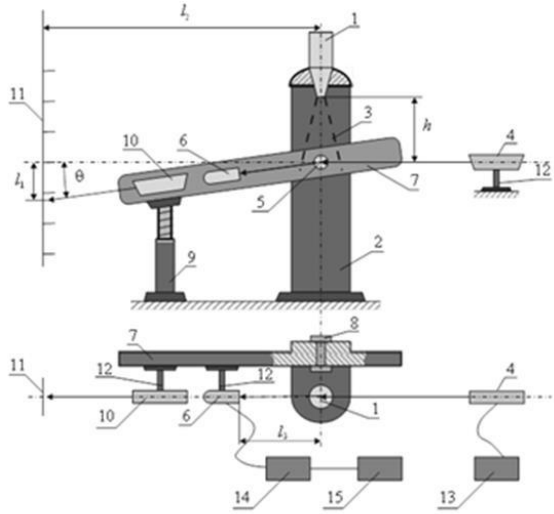

Figure 2. The experimental facility layout for the implementation of method of small-angle scattering indicatrix.

Determination of the droplets concentration spatial distribution in the aerosol was performed by spectral transmittance method [5, 7]. This method is based on measuring the spectral transmission ratio when laser scanning along the chords of the spray pattern in a given section, followed by the solution of the corresponding inverse problem for the Abel equation.

Optical diagnostics system (Fig. 3) was used to determine the radial distribution of aerosol droplets concentration in the spray pattern at the experimental tests in the pneumohydraulic stand.

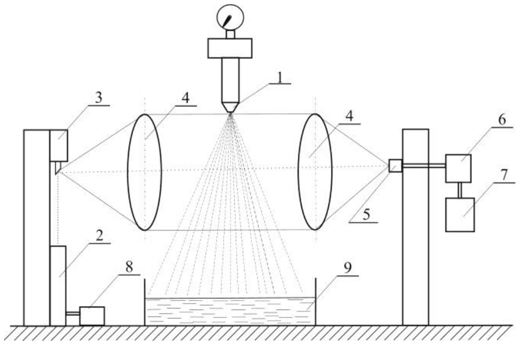

Figure 3. The experimental facility layout for the implementation of spectral transmittance method: 1 - nozzle; 2 - laser; 3 - mechanical system; 4 - optical system; 5 - photodetector; 6 - oscilloscope; 7 - personal computer; 8 - generator unit; 9 - receiving tank.

The probing laser 2 beam is formed by mechanical 3 and optical 4 systems and passing through the nozzle 1 spray pattern on the photodetector 5. The mechanical system 3 includes an electric motor and a rotating reflector (mirror). The optical system 4 consists of two coaxially arranged convex lenses. The laser radiation power is adjusted by generator unit 8. The scan results (signals from the photodetector) passed to oscilloscope 6 with an electronic amplifier. Obtained results are processed on a personal computer 7. To collect deposited liquid droplets there is a receiving tank 9.

3 Results of model experiments

Model experiments were carried out on the pneumohydraulic stand to study the size distribution of the water droplets after the atomization by cocurrent air flow. Figures 4-6 shows typical results of laser diagnostics measurements of the size and spatial distribution of the droplets concentration in the aerosol.

Fig. 4 shows experimental and determined by small-angle method intensity of the radiation $J_p(\theta)$ scattered by polydisperse droplets in the spray pattern of the confuser ejection nozzle. The measurements results of the scattering indicatrix $J_p(\theta)$ is normalized to the maximum value $J_p(\theta)_{max}$ at small angles region (θ <10 °) for clarity.

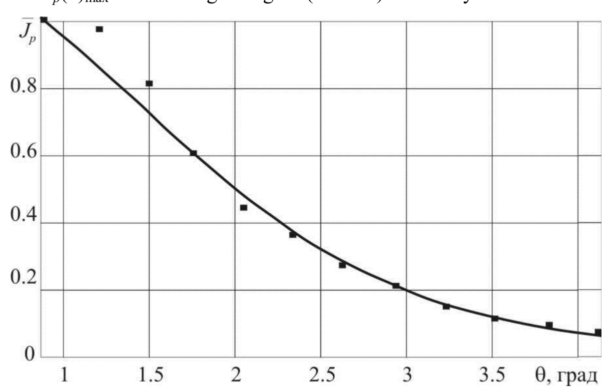

Figure 4. Experimental (points) and calculated (solid line) of the scattering indicatrix for polydisperse aerosol droplets in the ejection nozzle spray pattern.

Fig. 5 shows the differential $g(r)$ and integral $G(r)$ functions of size mass distribution of water droplets in the ejection nozzle spray pattern. Integral mass distribution function qualifies the ratio of the all particles mass, which radius not higher than r, to the total weight of the particles. Median radius r_m is commonly used in practical application of the aerosol systems to assess the range of particle dimensions. The median radius corresponds to the 50% total mass fraction of particles, whose radius not higher than r_m, from amongst the total mass of particles. Experimental median droplet radius calculated using the obtained function $G(r)$ was $r_m \approx 4.8$ µm.

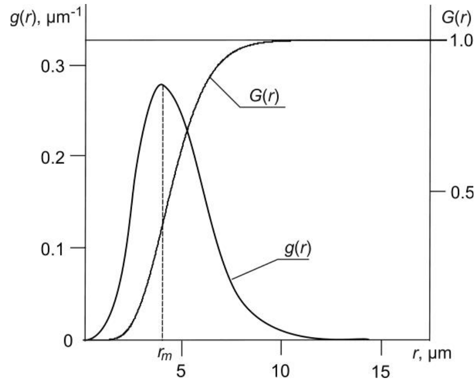

Figure 5. The differential and integral functions of mass droplets size distribution.

Fig. 6 shows the droplets concentration spatial distribution in the spray pattern. Scan conditions is: air pressure applied to the nozzle is 0.1 MPa, the distance from the nozzle exit section to the scanning plane is 30 mm.

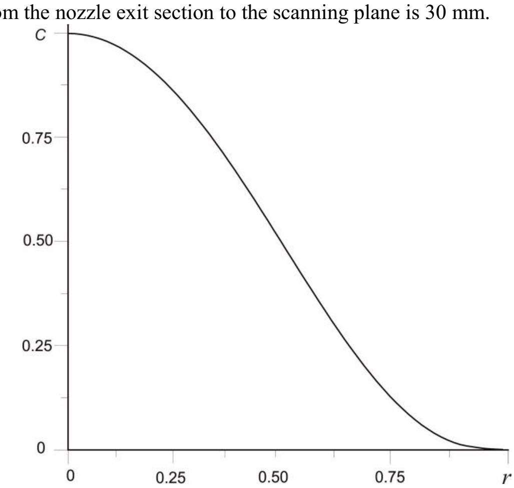

Figure 6 Droplets concentration spatial distribution in the spray pattern.

The validity of the model experiment data is confirmed by satisfactory qualitative agreement with the results [7].

4 Conclusions

1. The contactless optical technique and experimental results of the dispersiveness and radial distribution of the droplets obtained by spraying liquid in the ejection nozzle are presented.
2. The small-angle scattering indicatrix method provides an opportunity to obtain quantitative characteristics of the droplets sizes in the spray pattern – differential and integral functions of droplets size mass distribution.
3. The method of spectral transmittance of spray pattern scanned by laser provides a spatial distribution of the droplets concentration.
4. The measurement results of the dispersiveness characteristics of droplets in the ejection nozzle spray pattern showed that the differential function of the droplets size distribution corresponds to unimodal gamma distribution.
5. The results of the distribution of droplets concentration showed that the radial distribution is monotonic with a maximum on a spray pattern center line.

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