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EXPERIMENT OF WATER AEROSOL ESTIMATIONS OF DROPLET PARAMETERS

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Abstract. *Recently we developed two types of ultrasonic sprayers, one operating in megahertz domain and the other aimed to work in kilohertz domain. This paper is devoted to droplet sizing for aerosols produced by both apparatuses. Two independent methods of physical characterizations are applied, microscopic method and static light scattering method. We conclude that water aerosols generated with a 1.7 MHz piezoelectric plate are rich with droplets of very fine and fine classes (diameters D < 2 μm). The same is valid for 40 kHz generator, except the relevant groups are those with D < 20 μm. Because our starting intentions was relating to possible applications of aerosols in tobacco industry and similar branches, these result must be evaluated as sufficiently encouraging. In the paper we present data, figures and tables for water as a working fluid, but a comment is made in order to relate conclusions with expected results for other (low-viscous) liquids. Finally, a short remark is done concerning a simple theoretical model of probability functions for droplet sizing in aerosols.*

Key words: *Ultrasound, aerosol, droplet.*

1. INTRODUCTION

Substance spraying methods are in contemporary scientific praxis numerous and important in various fields of the applied physics [1, 2, 3]. Particularly, spraying takes an important place among the ways of changing a physical form of liquids. Transformation of a chosen liquid into a state of many small droplets can be achieved by several means, but the ultrasonic method is often applied as especially efficient and practical [4]. As a result of the functioning of an ultrasonic atomizer one gets liquid particles which hang in the air in a form of mist; such a colloid solution in gaseous dissolvers are known as an aerosol or spray.

Recently, searching for new methods of steady and homogeny aromatization, which are desirable in tobacco industry, we develop two types of ultrasonic atomizers [5, 6]. The construction and functioning of the first of these apparatuses, working in megahertz region (f = 1.7 MHz) is detailed reported in our paper [7]. The essential features of the

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second one, working in much lower frequency domain, at f = 40 kHz, are presented on several conference sessions [1, 4, 6,], and a comprehensive report on this subject we plan to publish soon elsewhere.

In this paper we present data on our measurements of physical parameters of aerosols produced by both ultrasound sources. In every set of measurements we worked with a given liquid of well known and controllable purity, consequently there was no need for any sort of additional chemical analyzes, as it is often necessary, for example, in cases of complex air pollution explorations. In fact, we present in this paper only results concerning water spraying, with brief comments on expectations we believe are realistic if a spraying substance is some low-viscous liquid [7].

2. PHYSICAL CHARACTERIZATION OF AEROSOLS

When we talk about physical parameters of an ensemble of drops, the problem of particle sizes and corresponding distribution function is mainly discussed. There are many factors that could noticeably influence on the exact form of diameter distribution function of droplets in ultrasonically produced aerosols. First of all these are the frequency of transducer vibrations, the surface tension, viscosity and density of liquid, but we also must mention the space distribution of ultrasound field (and its duration as well), temperatures of liquid and air, static pressure of air, steam pressure, heat conduction of liquid, type and concentration of cavitations embryos and so on.

The problem of identification of the proper size distribution function in an aerosol authors met trying to characterize output mists in atomization experiments at various frequencies in wide ultrasonic domain (from several kilohertz to few megahertz) and several sorts of liquids, mainly at room temperatures and normal air pressures.

As well known, aerosol is a dynamical physical phenomenon, which could very fast vary temporary as well as spatially. One must find out some technique to 'catch up' the object of measuring and 'stop' it. The making a preparation of an aerosol sample, needed for a subsequent analysis, is a tiresome task; we proceeded as follows. The method of running a clean previously carefully washed and dried up glass plate through a cloud of a given aerosol in order to deposit particles on the surface gives a systematic error in measurement. A droplet in contact with glass makes the surface wet and spread itself in some extent, changing its diameter. The second great problem is that tiny droplets of a liquid aerosol, having diameters of several microns or so, tend to evaporate very quickly from the glass surface; the preparation would continuously change and the pattern actually disappear in few seconds.

The first problem we have mentioned, namely the spreading and deformation of droplets resting on the plate surface, we avoid by a thin film of paraffin oil covering the glass surface. Droplets embedded in oil could retain its original form, at least during the measuring period. The second problem of fast evaporation of tiny droplets we overcame by covering the preparation (maid as above explained) with another thin oiled plate. Captured liquid particles, being in such a sandwich, stay conserved in oil medium. In our opinion, this procedure is relatively easy to be handled and gives good results for particles less then ten microns, which in overwhelming majority delivers the ultrasonic atomizer beyond the frequency of one megahertz. On the other hand, we do not recommend the two-plate sandwich technique in the case of large particles, with diameters greater than ten microns,

generated in a kilohertz domain, because the covering plate would press down droplets causing their deformations; extremely large drops tend to join itself and make a liquid film which loose original informations relevant to aerosols. Fortunately, an oiled glass plate with larger drops on it could be processed without any additional protection – evaporation runs sufficiently slow in this case. As a matter of fact, there is an additional problem connected with partial resorptions of liquid drops in paraffin oil. Nevertheless, this process is not likely to be very serious in course of first ten or fifteen minutes, which is an interval sufficient for measurements to be done. We proved the influence of resoption on 'old' preparations in forms of less or more opaque contours on pictures.

Preparations made in above discussed ways appear stabile and ready for practical measurements, giving reasonable and reproducible results.

Two different physical methods were applied in studying these preparations: a) Monitoring and photographing patterns by means of a computerized optical microscope accompanied by a digitalized camera, and b) Monitoring and photographing Fraunhoffer diffraction patterns seen in laser red light of a standard helium-neon laser.

In what follows we describe basic phases of two types of measurements and give the experimental results.

3. Microscopic Method

We have used a microscope of the type *Olimpus BX 50* [8]. The microscope image was digitalized by means of a CCD camera (*Sony CCD-Iris/RGB*) accompanied by a lens having the magnification $M = 2$. The camera output signal was accepted by the *Olympus Micro Image 128 Capture Kit* (version 3.2), in *MS Windows 98* environment. We applied the program *Olympus Micro Image – Image Analysis Software* (version 4.0) for the PC image processing [9].

The microscopic images were metrically evaluated. For the metrical analysis we sort the two groups of aerosols: the first originated from the ultrasonic atomizer with the frequency f =1.7 MHz and the second related to the frequency f = 40 kHz; corresponding images were digitalized and memorized as Windows TIFF images.

The first analyzed sample we observed under the objective 40×2×10, without any immersion oil. We treated only the drops located in the focus, avoiding deformed and assembled specimens. The separation of droplets was performed on the computer image by means of hand-made markings of object boundaries.

The second group of samples was observed under the magnification 4×2×10, once again without any immersion oil and applying the methodology explained in previous paragraph.

In course of the quantifications of drop characteristics we evaluated the following metric values:

a) The surface of the drop profile, in 2 μm (AREA)

b) The length of the drop major axis, in μm (AXIS MAJOR)

c) The length of the drop minor axis, in μm (AXIS MINOR)

d) The drop circularity, AXIS MAJORdivided byAXIS MINOR (ROUNDNESS)

e) The maximal diameter of the ellipsoidal curve, in μm (DIAMETER MAX)

f) The drop radius, in μm (RADIUS).

All these variables were estimated using the mentioned software program, according to accepted mathematical expressions.

Let us now present the main experimental results, figures, tables and corresponding statistical data. On Fig. 1 we see droplets of a water aerosol generated by the $f = 1.7$ MHz ultrasonic atomizer, at room temperature and normal atmospheric presser. The sample is of the double, paraffin oiled glass plate type (we would refer to it as the sample No. 1).

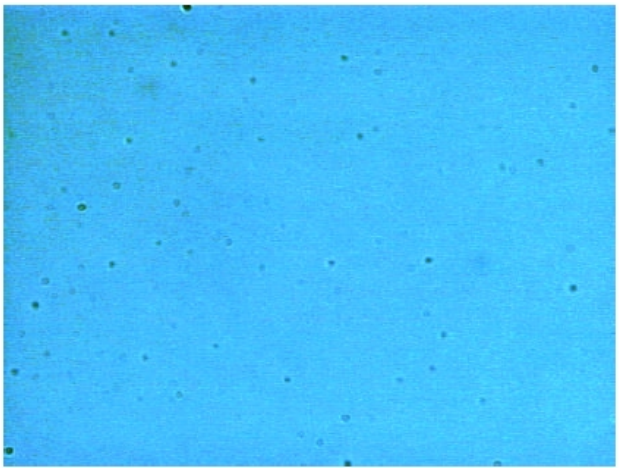

Fig. 1. Preparation N°1, water aerosol droplets generated by $f = 1.7$ MHz ultrasonic atomizer, at room temperature and normal atmospheric pressure. The sample is of the double, paraffin oiled glass plate type; objective 40×2×10 (Sample No. 1).

Table 1 contains the computer processed data from Fig. 1. The six parameters are presented for each of relevant seventeen objects.

Table 1. Computer processed data for objects from Fig. 1

Obj. #	Area	Axis (major)	Axis (minor)	Diameter (max	Radius (max)	Roundness
1	1,635837	1,642340	1,267181	1,482803	0,780662	1
2	1,072969	1,362815	1,001102	1,125369	0,665744	1
3	1,389582	1,387294	1,276762	1,365468	0,700528	1
4	1,231275	1,389073	1,127716	1,306214	0,678004	1
5	1,0202	1,161533	1,119150	1,069265	0,581354	1
6	1,459941	1,380173	1,344954	1,312930	0,675520	1
7	1,424762	1,364037	1,330076	1,258200	0,677419	1
8	0,685996	0,972674	0,899007	0,972674	0,485958	1
9	1,336813	1,405244	1,209461	1,306214	0,703288	1
10	0,879482	1,185310	0,942989	1,061008	0,555497	1
11	0,914662	1,128189	1,029757	0,889682	0,539028	1
12	1,354403	1,450364	1,193056	1,332874	0,738852	1,067699
13	0,756355	1,001434	0,963718	0,956379	0,508952	1
14	1,002610	1,207202	1,057812	1,069265	0,571670	1
15	1,055379	1,410439	0,956653	1,258200	0,679122	1
16	1,371993	1,394203	1,252280	1,365468	0,705984	1
17	0,932251	1,109940	1,065470	1,010049	0,559682	1

We shall now present a set of measurements with aerosols produced in kilohertz domain. Fig. 2 shows our sample No. 3, the image of captured drops of a water aerosol generated by $f = 40$ kHz ultrasonic atomizer. On the figure, large objects, developed from two or more drops joined to a singular volume, are not taken into account.

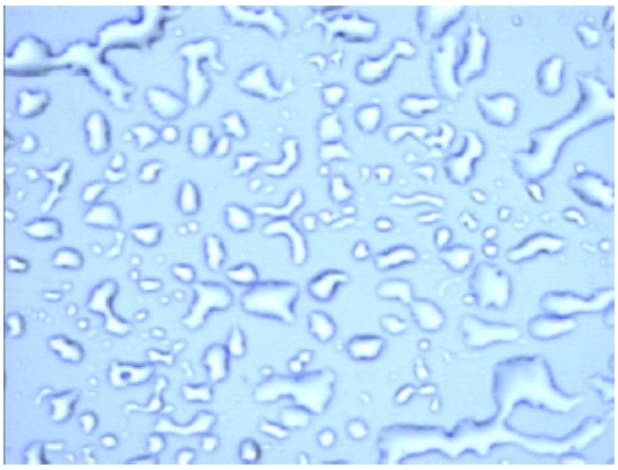

Fig. 2. Preparation N°2, water aerosol droplets generated by f = 40 KHz ultrasonic atomizer, at room temperature and normal atmospheric pressure. Paraffin oiled glass plate with captured objects; applied objective 4×2×10 (Sample No. 2).

The sample No. 2 contains more than two hundred of objects which were individually investigated. The list of data is omitted here as too long (the reader could see it in Appendix) and we give now the corresponding statistics in Table 2:

Table 2. Statistics for drops, sample No. 2

Stats	Area	Axis (major)	Axis (minor)	Diameter (max	Radius (max)	Roudness
Min	19,04432	5,576047	3,956061	5,576047	2,372073	1
(Obj.#)	46	22	41	22	63	2
Max	962,6038	45,16527	33,04769	44,23088	24,24709	1,200845
(Obj.#)	66	66	73	66	66	66
Range	943,5595	39,58923	29,09163	38,65483	21,87502	0,200845
Mean	167,5251	14,45421	11,36958	13,77791	7,046107	1,013675
Std.Dev	201,6740	8,211178	6,327479	7,995347	4,213461	0,033681
Sum	13402,00	1156,336	909,5665	1102,233	563,6886	81,09403
Samples	80	80	80	80	80	80

As other authors do, we can classify all droplets in a spray volume into droplet size classes. These classes could be named as followed: very fine, fine, medium, coarse, very coarse and extremely coarse. Making many trials and comparisons, we have been able to recognize these six categories. Here, let us apply the term tiny droplets for unified very fine and fine classes. Our tables actually deal with these tiny droplets. In kilohertz region, diameters of tiny droplets are not greater then fifteen micrometers, and in megahertz region not greater then one and half micrometers.

Taking this into account, the presented data generally allow us to conclude: a) The ultrasonic atomizer working on the frequency f = 1.7 MHz produces water aerosols with dominating droplet group in the size range 2 to 3μm, b) The ultrasonic atomizer working at the frequency f = 40 kHz produces water aerosols with dominating droplet group in the size range 20 to 30 μm. Both results are in rough agreement with predictions made in [7] where the authors have estimated mean droplet diameters according to the expression

$$D = \frac{1}{3}\sqrt[3]{8\pi \frac{\gamma_0}{\rho_0 f^2}} \tag{1}$$

Here γ_0 and ρ_0 are the water surface tension and density, respectively; this formula is wellestablished and can be found in early references on the subject [10]. The equation is derived applying the theory of molecule forced oscillations on air/water interface. We are fully aware of the fact that in megahertz region there is at least one additional physical effect playing nonnegligible roll in origination of droplets. This is the cavitations process increasingly stimulated in large amplitude, fast varying pressure field which is attached with the ultrasonic elastic wave. Unfortunately, the mathematical model of the phenomenon (as far as we know) is by now only but little developed. However, we know that cavitations tend to contribute to smaller classes of droplets. In fact, it would be more correct in megahertz domain, instead of eq.(1), use a modified formula, maybe of the type $D_c = c\ D$. Here c is a supposed cavitation factor which possible could improve the result which emerges from surface wave theory only. Doubtlessly additional measurements are needed for more clear insight in this question.

As a matter of fact we emphasize that our estimations concern water as a working fluid. For other liquids characterized by parameters γ and ρ, one could expect, at least in low-viscous liquids and kilohertz regions, that the mean droplet diameter D_1 follows the law $D_1 = \delta\ D$, with $\gamma_r / \rho_r = \delta^3$, γ_r being the relative surface tension coefficient (γ / γ_0) and ρ_r the relative mass density (ρ/ρ_0).

3. Laser Light Difraction Method

The microscopic method of small aerosol particles sizing (in micron domain) is not, as a rule, a very precise one. This sort of experimentations is rather a complex task and one could encounter final errors reaching 100%, sometimes even more. We have undertaken another, independent measurement including the laser light diffraction on a mist of aerosol. The basic concept uses the well-known results valid for the diffraction pattern of a small circular hole; the intensity of diffracted light in a point in geometrical shadow region on a distant screen is the same as the intensity stemming from an opaque circular obstacle. This statement can be approved by means of the Babinet's principle [11]. We treat assemble of drops frozen on a glass plate as a stochastically distributed swarm of approximately identical tiny balls. So, the diffraction pattern is likely to follow those of a singular drop, the intensity of light being proportional to the concentration of obstacles at a chosen part of our 'sandwich' preparation. By similar techniques done measurements seam to offer convenient lab possibilities and authors report on results which are fairly reliable (e.g. [12, 13]).

Our light source was (in many labs) familiar 5 mW helium-neon laser emitting light of the wavelength $\lambda = 632.8$ nm. The light beam was spread out by means of a divergent lens located immediately in front of the output laser aperture. Another, convergent lens, removed on the distance of its focal length gives a nearly parallel light beam. This wide beam, fairly homogeneous in its central part, is incident on a collimating hole of diameter $d \approx 1$ cm. Over the hole we expose our preparation and the corresponding diffracted pattern is projected on a distant screen, as shown in Fig. 3.

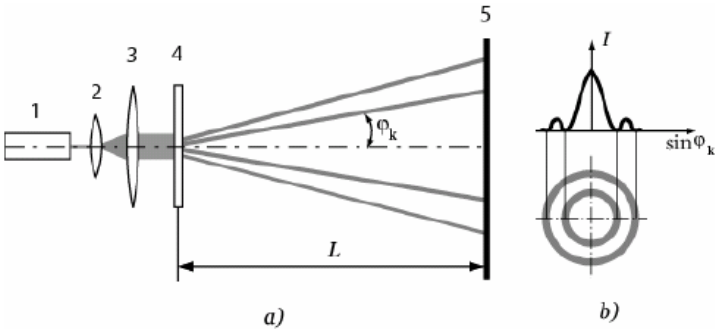

Fig. 3. a) The general lay-out of the experimental set-up; b) diffraction pattern;
1 - He-Ne 5mW laser, 2 and 3 - system of lenses for spreading of laser beam,
4 - aerosol preparation, 5 - screen

The diffracted pattern consists of a bright central spot and several concentric bright and dark rings. The first dark ring has a radius $R_1^{(d)}$ and the corresponding angular measure is $\varphi_1 = \arctan(R_1^{(d)}/\ell)$ where ℓ represents the sample/screen separation [11]. The Fraunhofer theory of light diffraction on a single circular aperture of diameter D gives the result

$$sin\,\varphi_1 = \frac{1.2}{D}\lambda \tag{2}$$

We can use this expression too in the case of the Fraunhofer diffraction on a single ball of the same diameter, having in mind the Babinet's argument here regularly satisfied. The corresponding formula for the first bright ring (we use designation $R_1^{(d)}$) reads

$$sin\,\varphi_2 = \frac{1.6}{D}\lambda \tag{3}$$

The light intensity is rather faint, nearly 57 times smaller than the central spot intensity. These features could be recognized on our photographs, Fig 4.

These color photographs have been taken with MINOLTA XG 1 camera (Objective: *Minolta MD Rokkor* 45 mm 1:2, lens: f = 49 mm). The camera was mounted on a stable tripod nearly 50 cm before the screen and only slightly away of the main optical axes of the setup arrangement, so that the visible ellipticity of fringes can be neglected. Other parameters are as follows: diaphragm position 4, automatic exposure 5 seconds; color film *Conica* 24×36, film sensitivity 100 ASA.

Let us now evaluate the mean droplet diameter. From eq. 3 follows the simple numerical formula

$$D[\mu m] \approx \eta \tag{4}$$

Here we use the abbreviation $\eta = \ell$ [cm]/ $R_1^{(b)}$[cm]. Of course, the above relation holds only for bright fringes. In our measurements, the distance equals ℓ = 130 cm; taking the radius $R_1^{(b)}$ = 3.3 cm (as can be read on Fig 4), we get η = 130/3.3 or the mean (measured) diameter D_{mea} = 39.4 micrometers. Let us try to compare this result with a prediction from eq. 1. For water (in SI units) the density is ρ = 1000, as well as the surface ten-

sion coefficient equals $\gamma = 0.073$. The ratio of this two quantities, so-called kinematical surface tension, is then $\gamma / \rho = 7.3 \cdot 10^{-5}$. So, we get in the case of water a convenient numerical expression of the type

$$D[\mu\text{m}] = 400 \cdot f^{\frac{2}{3}}[\text{kHz}] \tag{5}$$

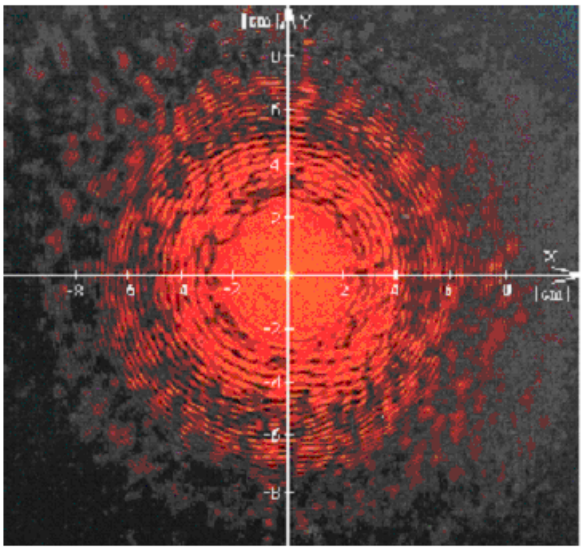

Fig. 4. Fraunhofer diffraction patterns in laser light scattering experiment on aerosol droplets (preparation N°2); graduated axis are seen on figure

With $f = 40$ kHz we immediately get the mean (computed) value $D_{com} \approx 34.9$ μm. So, we see that our measurements confirm the computed predictions within an error of about 11.4%.

3. Coments and Conclusions

Searching for advanced methods in high-quality aromatization of peculiar substances and various products, which are for instance desirable in tobacco industry, we have developed two types of ultrasonic sprayers. In this paper we have presented data on droplet size measurements in aerosols produced by both ultrasound sources. The first of these apparatuses, working in megahertz region ($f = 1.7$ MHz), generates fine, pretty homogeneous clouds of liquid droplets several micrometers in size. The second one, working in much lower frequency domain, at $f = 40$ kHz, continually supplies abundant aerosol volume with a central region in which droplets of several tens of micrometers in size are dominant. More precise, our measurements in megahertz region, by means of microscopic method, reveal the mean water droplet size which tends to be situated between 2 and 3 micrometers. The corresponding limits in kilohertz region are 20 and 30 micrometers.

Laser diffraction method (sometimes referred to as a preferred one for particle size analysis of nebulized aerosols) gives in forty kilohertz spraying the mean droplet size of nearly forty micrometers. Having inadequate equipment and none of modern laser diffractometers [15] we failed to apply the static light scattering methods for sizing droplets of several micrometers

Our theoretical investigations, undertaken to find out the probability function for size of aerosol droplets, lead to its connection with the generalized incomplete gamma function Γ (a, z_0, z_1). Here, the best gests we proved are as follows: $a = 4$, $z_0 = 0$ and $z_1 = 3\times$, where x represents the normalized diameter ($x = d / D$). Now, our efforts to generate a cumulative distribution function, as well as the corresponding probability density function are in progress and the preliminary results seem quite encouraging [14]. What we have by now completed is in consistency with experimentations reported here. More details on these aspects will be published elsewhere.

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15. See, for example: MMC – Aerosol Laboratory Laser Diffractometer (and related Internet sites).

APPENDIX

More comprehensive list of object data for Sample No. 2.

Obj.#	Area	Axis (major)	Axis (minor)	Diameter (max	Radius (max)	Roundness
2	29,43213	9,176086	4,088388	9,176086	4,467775	1
3	19,04432	8,661764	2,654892	8,661764	3,638044	1
4	29,43213	6,933508	5,698505	6,933508	3,650919	1
5	20,77562	5,496791	4,789451	5,496791	2,748395	1
6	27,70083	7,047399	4,950226	7,047399	3,079217	1
7	38,08864	7,310270	6,711757	7,310270	3,720172	1
8	20,77562	5,090872	5,090871	5,090872	2,545436	1
9	34,62603	7,132457	6,203644	7,132457	3,434317	1
11	48,47645	9,607063	6,473389	9,607063	4,352071	1
12	76,17728	10,35369	9,407765	9,210526	5,217423	1
14	167,9362	25,14493	9,183396	22,40708	11,89931	1,739080
16	60,59556	9,265337	8,335537	9,265337	4,440072	1
17	41,55124	8,429246	6,332574	8,429246	4,219701	1
25	72,71468	10,76154	8,655668	10,02075	5,051533	1
26	19,04432	5,789595	4,086105	5,789595	2,894797	1
28	19,04432	5,789595	4,086105	5,789595	2,894797	1
31	41,55124	8,168367	6,456260	8,168367	3,696086	1
34	98,68421	11,56561	10,85218	10,60823	5,563292	1
35	48,47645	8,420023	7,417422	8,420023	4,400782	1
39	77,90858	11,19664	8,902891	11,19664	5,667752	1
40	24,23822	6,271010	4,873651	6,271010	3,135505	1
41	131,5789	13,96426	12,25110	13,15789	7,354204	1,042677
43	38,08864	7,283019	6,581341	7,283019	3,552447	1
44	58,86426	9,310942	8,018640	9,310942	4,283797	1
46	51,93905	10,12817	6,580647	10,12817	5,359656	1
47	109,0720	13,54891	10,43598	13,41847	7,979116	1,060140
48	25,96952	6,104577	5,368327	6,104577	2,873388	1
50	32,89473	7,950103	5,208840	7,950103	3,477769	1
52	100,4155	14,39904	8,891768	13,41847	6,776749	1
53	55,40166	8,542354	8,248618	8,542354	4,390438	1
54	25,96952	6,117862	5,333429	6,117862	2,797407	1
55	53,67036	8,482484	8,003809	8,482484	3,945767	1
56	119,4598	14,27231	10,79016	14,47368	7,566302	1,047825
57	50,20775	9,385730	6,754587	9,385730	4,337730	1
61	19,04432	5,794666	4,193871	5,794666	2,897333	1
62	36,35734	7,355546	6,330103	7,355546	3,864957	1
65	17,31301	5,323745	4,208790	5,323745	2,661872	1
66	32,89473	7,32407	5,674243	7,32407	3,342092	1
67	77,90858	12,05772	8,312864	9,488292	6,054889	1,133155
68	55,40166	9,863582	7,285703	9,863582	4,999736	1
69	57,13296	9,020523	8,128097	9,020523	4,820783	1
70	22,50692	6,111013	4,748440	6,111013	2,976800	1
71	32,89473	6,849839	6,130061	6,849839	3,263669	1
72	24,23822	7,113524	4,394031	7,113524	3,395187	1
74	31,16343	6,748102	5,890021	6,748102	3,219693	1
77	45,01385	8,726577	6,673895	8,726577	4,715175	1
78	32,89473	7,178858	5,894367	7,178858	3,711941	1
79	24,23822	7,788978	3,923842	7,788978	3,670228	1
81	48,47645	8,708391	7,165453	8,708391	4,242101	1
82	38,08864	8,049771	6,122090	8,049771	4,059953	1
83	110,8033	13,21289	10,72725	11,84210	6,257907	1
85	102,1468	12,78333	10,22833	9,488292	6,296518	1

90	36,35734	7,685267	6,265142	7,685267	4,321036	1,029825
91	93,49030	12,53040	9,475423	11,84210	6,287721	1
92	45,01385	9,464386	6,203074	9,464386	4,658338	1,018573
93	138,5041	14,73948	12,00341	14,47368	7,615768	1,005834
94	95,22160	13,41610	9,078134	12,13097	6,803881	1,079416
96	24,23822	6,022664	5,335691	6,022664	3,278741	1
99	95,22160	14,62508	8,600651	13,54688	8,261061	1,243280
100	50,20775	10,70647	6,019897	10,70647	5,306978	1
103	55,40166	12,31150	5,874004	12,31150	6,803825	1,192637
104	32,89473	7,227969	5,902456	7,227969	3,599099	1
107	53,67036	10,03432	6,901099	10,03432	4,984157	1,016512
108	140,2354	15,84711	11,33045	14,71097	8,132196	1,067966
113	79,63988	12,24898	8,265218	10,60823	5,816776	1
114	86,56509	15,88870	6,946847	13,73724	8,29354	1,187357
115	51,93905	11,47150	5,738450	11,47150	4,956145	1
118	65,78947	10,34963	8,174138	10,34963	5,219827	1,004326
123	55,40166	9,394919	7,552473	9,394919	4,487186	1
124	91,75900	13,02646	9,015067	13,15789	6,634202	1,026116
125	93,49030	12,22559	9,754616	10,60823	5,987704	1
127	45,01385	8,832275	6,636278	8,832275	4,750080	1,045849
128	24,23822	5,616272	5,515071	5,616272	2,691320	1
129	19,04432	7,271333	3,338925	7,271333	2,875787	1
130	112,5346	15,46539	9,309916	13,73724	7,919440	1,052006
132	138,5041	19,08823	9,478204	17,89667	10,50086	1,299354
133	98,68421	11,82973	10,67394	11,24211	5,994388	1
134	55,40166	9,113992	7,702926	9,113992	4,233600	1
135	96,95290	13,69483	9,058907	13,22352	6,688995	1,015155
137	19,04432	6,441757	3,873841	6,441757	2,912882	1
138	25,96952	7,807707	4,276456	7,807707	3,508758	1
139	64,05817	11,06175	7,490308	11,06175	5,433068	1,054453
140	29,43213	6,973573	5,401706	6,973573	2,942194	1
141	36,35734	8,679154	5,299934	8,679154	4,430468	1
142	102,1468	11,58841	11,22795	10,60823	5,897407	1
143	22,50692	7,868759	3,626150	7,868759	3,555498	1
144	58,86426	9,809180	7,790747	9,809180	5,048960	1,209012
145	65,78947	13,95384	6,835915	12,95902	8,529525	1,699212
147	55,40166	9,598882	7,432320	9,598882	4,697228	1
148	38,08864	7,677958	6,342333	7,677958	3,710049	1
149	51,93905	9,792306	6,756709	9,792306	4,631089	1
150	43,28254	9,391162	5,899563	9,391162	4,279038	1,019839
153	31,16343	6,928538	5,861528	6,928538	3,498094	1
154	60,59556	10,25212	7,724877	10,25212	5,362223	1,090411
155	60,59556	10,03383	7,674938	10,03383	4,721909	1
158	43,28254	8,538811	6,426601	8,538811	4,213481	1
159	67,52077	10,93157	7,884327	10,93157	5,353426	1
160	19,04432	5,794666	4,193871	5,794666	2,897333	1
161	58,86426	11,18227	6,761529	11,18227	5,337895	1,063235
162	27,70083	7,725002	4,653162	7,725002	3,866006	1
163	114,2659	13,77718	10,68614	13,22352	7,525622	1,036066
164	122,9224	13,62565	11,50612	11,24211	7,124191	1
165	19,04432	5,550591	4,610235	5,550591	2,775296	1
167	136,7728	16,15450	10,98418	14,53337	9,081165	1,231879
168	27,70083	7,212347	4,882782	7,212347	3,019335	1
169	60,59556	9,026277	8,615378	9,026277	4,850915	1
171	25,96952	7,216298	4,623457	7,216298	3,412049	1
172	90,02770	17,48079	6,648576	14,17148	8,866588	1,368089
173	29,43213	7,132915	5,243241	7,132915	3,159198	1
174	22,50692	7,328823	3,878048	7,328823	3,139293	1
176	27,70083	6,370580	5,668264	6,370580	3,103283	1
178	65,78947	11,08891	7,575889	11,08891	5,602259	1

179	138,5041	15,15866	11,68319	14,71097	8,009967	1,043234
180	46,74515	8,560534	6,946898	8,560534	4,204051	1
181	86,56509	12,17959	9,088583	11,84210	6,473715	1
184	129,8476	13,80565	12,04704	13,22352	7,314299	1,001832
186	38,08864	7,358345	6,743538	7,358345	3,887551	1
189	58,86426	9,671836	7,737107	9,671836	4,829218	1
190	50,20775	8,583139	7,467545	8,583139	4,289056	1
191	64,05817	11,29613	7,230227	11,29613	5,448395	1
192	110,8033	13,66234	10,32044	10,27664	6,937264	1
193	19,04432	7,114313	3,391616	7,114313	2,761573	1
194	25,96952	7,216299	4,623457	7,216299	3,412049	1
195	53,67036	8,452241	8,090030	8,452241	3,938254	1
196	45,01385	8,485761	6,774584	8,485761	4,168877	1
197	36,35734	7,355546	6,330103	7,355546	3,864926	1
198	38,08864	8,435800	5,795305	8,435800	4,392162	1
199	57,13296	9,304680	7,873393	9,304680	4,808696	1
202	25,96952	8,087668	4,048738	8,087668	3,860626	1
203	51,93905	8,574208	7,652808	8,574208	3,903789	1
204	122,9224	13,38529	11,78238	11,84210	7,007392	1,058274
205	20,77562	6,606789	4,182254	6,606789	3,404430	1
206	74,44598	10,33634	9,290595	10,33634	5,264062	1
207	39,81994	9,773503	5,215097	9,773503	5,345192	1,008286
208	38,08864	8,110488	5,945611	8,110488	3,583017	1

EKSPERIMENTI SA VODENIM AEROSOLOM OCENA PARAMETARA KAPLJICA

Dragan Šarković, Vukota Babović

Izradili smo dva tipa ultrazvučnih raspršivača tečnosti, jedan za rad u megahercnom, a drugi za rad u kilohercnom domenu. Ovaj rad je posvećen ocenjivanju veličina kapljica aerosola, proizvedenog obema aparaturama. Dva nezavisna fizička metoda karakterizacije su primenjena: mikroskopski metod i metod rasejanja svetlosti na malim česticama. Mi smo realizovali generator vodenog aerosola sa 1,7 MHz piezoelektričnom pločicom, koji proizvodi kapljice vrlo fine i fine klase, prečnika D < 2 μm. Od posebne važnosti je 40 kHz generator za grupu kapljica D < 20 μm, zbog potencijalne mogućnosti njegove primene u duvanskoj industriji i sličnim granama, gde su postignuti početni ohrabrujući rezulati. U ovom radu prikazani su podaci, slike i tabele za vodu kao radni fluid, ali komentar važi i za druge niskoviskozne tečnosti. Na kraju je dato kratko sagledavanje prostog teorijskog modela verovatnoće raspodele veličine kapljica aerosola.