Comparative analysis results of the homogenization of nanosuspensions using ultra-jet processing method

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Abstract. This work discusses the urgent problem of finding new highly effective dispersion methods for suspensions prepared using nanomaterials such as (boehmite, graphene, carbon nanotubes). In this research, two experiments are considered. The first experiment uses a solid target from a single crystal of diamond. The second experiment is conducted in the absence of a target. This means that ultrasound interacts with the surface of a tool for collecting the suspension at the initial time, and then with the processed suspension in the tank. Based on comparative experimental data, it has been shown that the ultra-jet processing method has several advantages.

1. Introduction
Currently, dispersion and suspension technologies have founded wide application in the national economy and underlie the production of such products as; cosmetics and medicines, paints, varnishes, inks, various technological lubricants, etc. The suspension technology can obtained in a number of technological methods: abrasive-liquid jet processing method, mechanical processing method, electro-hydraulic processing method, electron-beam processing method, “Milling” processing method, Ultrablasting method, rotary-blasting method, disc processing method and ultrasonic processing method. The dispersion technology can obtained in a number of technological methods: ultrasonic processing method, electrical dispersion method, homogenization, emulsification, “Milling” processing, ultrablasting method, rotary blasting method, disc processing method [1, 17].

2. Literature Review
Analysis of literature sources, in particular the works of Barzov, Tarasov, Galinovskiy, Abashin, Khafizov, Kobernik, Provatorov et al. showed that ultra-jet micro suspension of liquids in hydro-technologies environments [1, 4, 5, 13, 12], ultra-jet technology [6, 8, 11], and nanomaterials [7, 9] had been described. The study of the suspension of liquid using ultra-jet technology [17], under the leadership of Galinovskiy and Barzov, considered two experiments and the theoretical basis of this developed technology [16]. The first experiment used a solid target from a single crystal of diamond and has been conducted earlier in the works of the author’s team [2, 3]. In the previous experiment are studied the comparative analysis results of the distribution of the particles size of nanomaterials using ultrasonic technology and ultra-jet technology. Its advantages were noted when dispersing suspensions with carbon nanotubes, boehmite and graphene, where the minimum particle size was an order of magnitude smaller, in comparison with ultrasonic treatment. In the second work the results of particle
size with suspensions using ultra-jet technology with a target and without target are considered and discussed with the results of previous works.

3. Experiment description
This experiment has been conducted in the absence of a target, i.e. ultrasound interacted with the surface of a tool to collect the suspension at the initial time, and then with the processed suspension in the tank (tool). The purpose of this experiment is to evaluate the possibility of dispersing suspensions directly in the hydraulic installation path (figure 1).

Legend:
L1 – The distance between the hydraulic nozzle and the target surface of the tank in mm
L2 – The distance between the hydraulic nozzle and the surface of the tank-trap in mm
1 – Suction channel
2 – Jet forming tube
3 – Clamping nut
4 – Clamping sleeve
5 – Body of the integrated diamond inductor
6 – Feeding the suspension with powders (boehmite, graphene, nanotubes) in the initial state
7 – Water supply
8 – Water with processed powder (boehmite, graphene, nanotubes)
9 – High-speed cavitating jet
10 – Capacity trap
11 – Carbide target.

Figure 1. Schematic diagram of ultra-jet dispersion of nano-containing suspensions: (a) – with the target; (b) – without the target.

Suspensions based on distilled water with boehmite (produced by the Scientific Research Institute of Impulse Processes with Pilot Production “OKP NII IP with OP”, Minsk, Republic of Belarus), with graphene (OOO “Nanotech Centre” Tambov city) and with carbon nanotubes (“Arkema”, France) were processed using ultra-jet machining. In order to prepare a mixture for the initial state suspension, 3 grams of nano-powders mixed with 1 litre of distilled water in a glass beaker have been used [8].

In the next stage of this research, the possibilities of ultra-jet suspension processing method have been studied. The studies are based on the methodological base which was formed in the framework of the scientific school “Ultra-jet processing and diagnostics of materials and liquids” (NSh-3778.2018.8) at the Department of SM-12 of BMSTU [2, 3, 9].

Figure 1 shows the Flow Waterjet hydraulic system used in the experiment with jet diameter of 0.01–0.2 mm, high-pressure (pressure 100–700 MPa) and high-speed (600–700 m/s) fluid flow of the multiplier type, as well as a schematic diagram of the ultra-jet dispersion of suspensions [4, 5]. Characteristics of the studied samples of nanomaterials are presented in table 1.

Suspensions based on distilled water with boehmite, graphene and carbon nanotubes are fed into the mixing chamber of the ultra-jet unit using a special metering device. The suspension acceleration is 800 m/s, which corresponds to a maximum working pressure in the hydraulic system of 400 MPa. It has been previously found that the ultra-jet speed determines the liquid treatment efficiency [13].

As a capacity (10), specially developed technological equipment has been used (figure 2). The target is a synthetic diamond fixed in a mandrel, which, in turn, is fixed in the nozzle of the container cover using screws (4) (figure 2).
Table 1 Characteristics of the original nanomaterials samples used for preparing suspensions and their further dispersion

| Manufacturer | Composition | Technological and operational features of the powder |
|--------------|-------------|-----------------------------------------------------|
| Research Institute of Pulse Processes with Experimental Production "OCP NII IP with OP", Minsk, Belarus | Al (OOH) "Boehmite" | Mass fraction of the main substance, not less than 99[%]. A specific surface according to the BET method, up to 400 [m²/g], density, 3.06 [g/cm³], size of individual particles, 0.1-0.8 [nm]. |
| OOO "Nanotech Center" Tambov city | Graphene | Number of graphene layers is 15-25. Thickness of the nano-plates is 6-8 nm. Size of the nano-plates in the plane is 2-10 microns. The content of nano-plates is 4-7% of the mass. The oxygen content in relation to carbon is 9-13% of the mass. Sulfur content mass is ≤0.7%. Specific absorption coefficient is 30-33 lm / (g cm). |
| Arkema (France) | Carbon nanotubes | External diameter is 10-20 [nm]. Tube length is more than 2 [microns]. Specific surface according to the BET method is >300 [m²/g]. Content of impurities is not more than 1[%]. |

Figure 2. Tooling for dispersing micro and nano-suspensions: I – Upper lid of the tank; II – Bottom of the tank and tank assembly.

4. The results of the experiment
After conducting the experiment, the analysis has been performed using a Microtrac Bluewave laser particle size analyzer (Microtrac S3500). It uses the technology of three lasers technology (Tri-laser) shown in figure 3. The laser particle size analyzer (the diagnosable size range is from 0.01 to 2800 μm) allows particle size distribution in suspensions, emulsions, and powders using laser granulomere [14, 15]. Results of the analysis are average particle sizes by quantitative and volume distributions, as well as the minimum recorded particle size in the samples (see table 1).
Results of the comparative analysis of particle sizes in the composition of suspensions are presented in figures 4-6 in the initial state, after ultra-jet treatment with a target, and without a target respectively.

Figure 4. Graphs of average particle sizes values by quantitative distribution for initial samples; (a) – Boehmite, (b) – graphene, (c) – carbon nanotubes.

5. Discussion

Comparative experiments on the application of the ultra-jet method with a target with the ultrasonic dispersion method show that the proposed method allows to reduce the particle size from 2 to 10 times depending on the nanomaterial under consideration in previous articles [2, 3]. The result of ultra-jet technology without a target of this experiment are close to the obtained results of previous work using the ultrasonic treatment. Therefore, the prospect of the development of the research is the establishment of time limits for maintaining a given level of dispersion of boehmite, graphene and carbon nanotubes, which is extremely important for issuing practical recommendations on their use for the preparation of binders, the introduction of additives, paints and other materials. The comparative analysis of the obtained particle size distributions of the studied suspension samples (figure 5 and figure 6) with their
initial distributions (figure 4) show that the ultra-jet treatment method can be used practically and effectively.

**Figure 5.** Graphs of average particle sizes values by quantitative distribution for samples after ultra-jet impact without a target; (a) – boehmite, (b) – graphene, (c) – carbon nanotubes.

**Figure 6.** Graphs of average particle sizes values by quantitative distribution for samples after ultra-jet impact with a target; (a) – boehmite, (b) – graphene, (c) – carbon nanotubes.
6. Conclusion
It has been found that dispersion is carried out not only upon the impact on a solid target, but also during the passage of the hydraulic installation path, i.e. mixing chamber and focusing tube (Figure 1). Moreover; the results of this process are close to those obtained using ultrasonic treatment. It can be assumed that ensuring the circulation of the suspension according to the scheme proposed in Figure 1 b may improve the controlled indicator - particle size. The presence of a positive effect in this scheme implementation requires additional study and modernization in order to increase the efficiency and quality of suspension.

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