OPTICOPHYSICAL MEASUREMENTS

OPTICAL METHODS FOR MEASURING DISPERSION PARAMETERS
OF HETEROGENEOUS PLASMA

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The development of methods and equipment for determining the dispersion parameters of suspensions which form heterogeneous plasma and are contained in high-temperature working media of research and industrial installations helps to intensify investigation processes and apply new equipment [1-7]. The dispersed phase has a substantial effect on the properties of the working media, which require for their determination both ionization and dispersion characteristics [3, 5, 7].

The methods used for measuring the dispersed-phase parameters of heterogeneous plasma can be divided into contact and contactless methods.

Despite the fact that the contact devices have several deficiencies (kinetic errors, complicated separation of submicrometric particles), they are being widely used owing to the simplicity of their application. Thus, in order to investigate the particles condensed in a burning solid-fuel flare, metal or glass plates are used with a subsequent microscopic or photosedimentation determination of the deposited particles size [8-12]. Suspensions in the jet stream of a small reaction engine were investigated in [13] by means of the contact method for selecting samples, and the same method was used in [14] for determining the sizes and concentrations of drops in a burning pulverized-fuel flare. In order to improve the particles capture, the test plates are sometimes coated with a sticky liquid [14], and for the purpose of preventing the particles burning, the plates are blasted with a neutral gas, for instance, helium [15]. In order to eliminate nonisokinetic capture of particles, the intake is provided in [16] with an internal pressure equal to that of the incident flow. The isokinetic properties can also be improved by using receiver tanks [17, 18].

Contactless methods for analyzing the dispersed phase of heterogeneous plasma are being developed intensively. High-speed filming is used in [19] for determining the size of particles in burning flares. However, this method has substantial errors, the size of particles observable in filming differs from their true size [20].

The widely used holographic technique for determining not only the size of particles but also their distribution in space possessed similar deficiencies [21]. This method was used for investigating the dispersed parameters of a burning nitroglycerine-fuel flare with a spatial resolution of the order of 30 μm [22]. An optical scheme for recording a burning surface is shown in Fig. 1, which comprises the laser 1; the beam splitter 2; the mirrors 3, 4, 9, and 10; the collimator 5; the hologram 6; the objective 7; and the sample 8. Radiations transmitted through the tested object are recorded on a hologram in [22]. Results of a dispersed-phase holographic investigation with a resolution of the order of 5 μm are provided in [21, 23]. A magnifying optical system was placed in this case between the investigated object and the hologram. Figure 2 shows a holographic scheme for recording microparticles with low-frequency filtering, thus making it possible to raise the resolution up to 3-5 μm [23]. This scheme comprises the laser 1; the beam splitter 2; the collimators 3 and 8; the object 4; the objective 5; the mask 6; and the hologram 7. In measuring the sizes of microparticles in heterogeneous plasma by the speed of the particles propagation. It is shown in [24] that, in order to obtain a high-quality hologram, the interference-fringes shift in the course of the exposure should not exceed λ/8. The resolution of holographic methods depends on the utilized photographic materials. The problems of using various holographic techniques for measuring the spatial distribution of particles in accordance with their sizes are described in [21, 23, 25, 26] and the deficiencies and errors of these measurements are listed. The majority of authors prefer the double-beam measuring method, and this is due above all to the great depth of the reproduced-image

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definition. The potentialities of multipulse holographic recording of a burning-flare dispersed phase are noted in [27].

Side by side with individual-particle counting methods the contactless statistical methods are also being widely used (mainly optical methods); they provide information on the size-distribution-function parameters of the investigated particles aggregate.

The mean size of the absorbing particles can be determined from the spectral absorption coefficient [28, 29]. By neglecting scattering and diffraction, let us determine the emissivity

$$e_\lambda = 1 - \exp(-\gamma L),$$  \hspace{1cm} (1)

where \(L\) is the optical length of the path; \(\gamma = 4\pi M/\lambda\) is the volumetric-absorption scattering factor; \(\gamma\) is the imaginary part of the complex refractive index; \(\lambda\) is the radiation wavelength.

The value of \(L\) is determined for a known \(\gamma\) and the mean radius of particles is found for a known concentration. This method serves to determine the mean size of particles in the range of 0.1 to 2 \(\mu\)m in the burning pyrotechnical-composition flares [28]. This method has the nature of an estimate and cannot be applied if the suspensions contain particles of different compositions.

The complex refractive-index values of particles have been determined for a very small number of substances and there is even less information on such indexes at high temperatures. They have been determined with sufficient reliability up to \(3 \times 10^4\)\(\text{K}\) only for aluminum oxide [10, 30, 31].

A development of the volumetric absorption method consists of the spectral transparency method [32] in which the function of the particles distribution according to their sizes is determined from the transparency of the tested object over a wide spectral range. This method is suitable for investigating only aggregates consisting of "soft" particles whose optical characteristics differ but little from the ambient medium. The application of this method requires complicated experimental equipment, and this prevents its adoption on a wide scale. The results obtained in using a modified spectral-transparency method [34] for determining the particle sizes of the order of 0.01 \(\mu\)m in a freely burning flame are provided in [33]. The agreement of results obtained in testing suspensions in a jet flow by selecting samples and by the spectral transparency method are noted in [35].

The most effective methods consist in using the scattering of laser radiations. The mean diameter \(\bar{D}\) of dispersed particles in the jet of a reactive engine is determined from the ratio of the intensities of light scattered at two different angles and described in [36]. The relationship of the light intensity of \(\bar{D}\) was determined beforehand from the Airey-Kirchhoff formula [29].