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Experimental Setup For Study Of Drop Deformation In Air Flow

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Abstract. Experimental study for study of deformation of drops in air flow is considered. Experimental setup includes a module for obtaining the drops, an air flow system and measuring system. Module for formation of drops is in the form of vertically arranged dropper with capillary with the possibility of formation of fixed drops. Air flow supply system comprises an air pump coupled conduit through a regulating valve with a cylindrical pipe, installed coaxially with dropper. The measuring system includes the video camera located with possibility of visualization of drop and the Pitot gage for measurement of flow rate of air located in the output section of branch pipe. This experimental setup allows to provide reliable and informative results of the investigation of deformation of drops in the air flow.

1 Introduction

Processes of loss of stability of the shape of drops in the blowing gas flow leading to their deformation and crushing play important role in hydrogasdynamics of two-phase flows [1]. These processes are of practical importance in meteorology (the formation of a spectrum of drop sizes of atmospheric precipitation [2]), in engine building (the dispersion of fuel droplets in internal combustion engines and liquid rocket engines [3, 4]), in ecology problems (evolution of a cloud of drops of toxic components liquid rocket fuels, formed during depressurization in the atmosphere of fuel tanks of carrier rockets [5]) and in a number of other branches of engineering and technology. In this paper, we consider an experimental setup for studying the deformation of a stationary droplet in an air flow.

2 Experimental facility and methods of measurement

In order in investigate the deformation of drops in air flow, the experimental setup has been developed, including a module for producing of drops, a system for supplying the air blowing into the drop, and measuring system. Module for formation of drops is in the form of vertically arranged dropper with capillary with the possibility of formation of fixed

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drops. Air flow supply system comprises an air pump coupled conduit through a regulating valve with a cylindrical pipe installed coaxially with dropper. The measuring system includes the video camera located with possibility of visualization of drop and the Pitot gage for measurement of flow rate of air located in the output section of branch pipe.

The basic criterion for determining the deformation of a drop in the gas stream is the Weber number [1]:

$$\mathrm{We} = \frac{\rho_g \left|\vec{u}_l - \vec{u}_g\right|^2 D_0}{\sigma}, \qquad (1)$$

where ρ_g is the gas density; $\vec{u}_l$ is the drop velocity vector; $\vec{u}_g$ is the velocity vector of the gas flow blowing in drop; D_0 is the diameter of initial spherical drop; σ is the coefficient of liquid tension.

Weber' number characterizes the relation of forces of dynamic pressure of gas to force of surface tension. With increase in *We* the deformation of drop increases, and at achievement of some critical value of Weber number the crushing of drop occurs due to development of instability of Kelvin-Helmholtz [1].

In an experimental study of patterns of deformation and crushing of drops in flow along with registration of the characteristic sizes of the deformed drop it is necessary to determine Weber number (1) by the values measured in experiment ρ_g, $\vec{u}_l$, $\vec{u}_g$, D_0, σ.

To improve the accuracy of measuring the degree of deformation of the drop and the parameters included in the Weber number, by providing strictly controlled blow-off conditions for the initial droplet, an installation scheme is proposed for studying droplet deformation in a flow [6]. The scheme of setup for research of deformation of drops in flow is given in fig. 1.

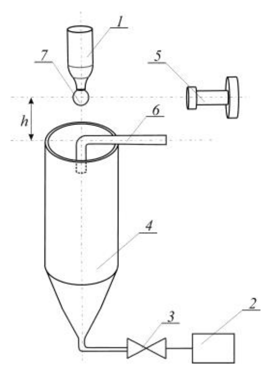


Fig. 1. The scheme of setup for studying the deformation of drops in flow.

The experimental setup includes a vertically located dropper with a capillary *1*, system of giving directed vertically up blowing in the hanging drop of flow of air and measuring system. The system of giving of flow of air contains the air pump *2* connected by the pipeline through the regulating valve *3* to the cylindrical branch pipe *4* established coaxially with dropper *1*. The measuring system includes the video camera *5* located with possibility of visualization of drop and the Pitot gage *6* for measurement of flow rate of air located in the output section of branch pipe *4*. To register the shape of the drop *7* “Citius C 100” video camera was used. Video registration was carried out with the space permission 384×790 pixels with rate of 300 frames per second and time of exposure (0.5÷2.0) of ms.

Experimental setup works as follows. By means of the air pump *2* and valve *3* the set rate of flow of u_g, air that is measured by the Pitot gage *6* is established. By means of dropper with capillary *1* the motionless drop of working fluid forms (water and glycerin solutions, silicone oil, castor oil, etc.).

After forming of initial drop *7* it is influenced by uniform flow of air from branch pipe *4* under the influence of which the drop is deformed. Dimensions of the deformed drop *7* are recorded by a video camera *5*. Then by means of the regulating valve *3* higher u_g levels are established and similar measurements are taken.

3 Measurement results

Let's consider results of measurement of deformation of drop of glycerin in air flow at the room temperature. Physical characteristics of air and glycerin, necessary for calculations, at temperature 20°C are provided in table 1.

Table 1. Physical characteristics of air and glycerin.

Parameter	Air	Glycerin
ρ, kg/m^3	1.205	1260
μ, Pa·c	$1.808\cdot10^{-5}$	–
σ, H/m	–	$63\cdot10^{-3}$

Distance between cut of dropper and output section of branch pipe of $h \le 10$ mm.

Diameter of capillary is determined by equation:

$$d_\kappa \le \frac{1}{6}\sqrt{\frac{0.8\cdot\sigma \mathrm{Bo}^3_{\kappa p}}{g\cdot\rho_l}}\ , \tag{2}$$

where d_k is the diameter of capillary of dropper; $\mathrm{Bo}_{\kappa p} = 4.5$ critical value of number of the Bond; g is the acceleration of gravity; ρ_l is the liquid density; h is the distance between cut of dropper and output section of branch pipe [7].

Thus, diameter of capillary has to be no more $d_\kappa \le 3.21$ mm. For experiments, the value $d_\kappa = 2.5$ mm was chosen.

Diameter of initial drop is calculated on equation:

$$D_0 = \sqrt[3]{\frac{0.8\cdot 6\sigma d_k}{\rho_l \cdot g}}\ . \tag{3}$$

Video frames of the initial and deformed droplets are shown in fig. 2 for different values of the blowing rate and Weber numbers calculated by equation (1). Degree of deformation is calculated by processing the results of video shooting using the equation:

$$\varepsilon = \frac{D_m}{D_0}\ , \tag{4}$$

where D_m, D_0 diameter of transverse section of the deformed and initial drop.

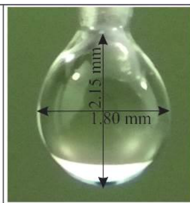
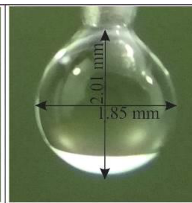
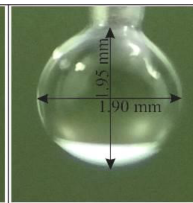
Drop shape			
ε	1	1.03	1.05
u_g,m/c	0	0.7	3.6
We	0	0.018	0.49

Fig. 2. Video frames of the initial and deformed drops.

4 Conclusion

The considered scheme of the experimental setup for the investigation of drop deformation in flow provides an increase in the accuracy of measuring the degree of deformation of the drop and the parameters included in the Weber number due to the providing the strictly controlled blow-off conditions for the initial drop with a significant simplification of the experimental equipment of the apparatus and the alignment of the measuring apparatus.

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