DYNAMICS, ENERGETICS AND FINE STRUCTURE OF A DROP IMPACT FLOW

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Abstract

Optical measurements of a drop impact flow analysed basing on the on fundamental equations system. Several types of flow structures that are intrusive, as well as cavity formation regimes, identified. The important role of energy transport processes, both fast – local atomic-molecular and conventional slow that are translational and dissipative, in the formation of flow patterns is marked. Conversion of available surface potential energy as a physical factor and critical condition definition of the flow changes are defined. Ligaments i.e. the finest jets (trickles) with transverse sizes from atomic-molecular clusters to macroscopic scales are identified in flow patterns. Ligaments are manifested themselves as fine ejecta and spikes with splashes in patterns of the fluid contact, thin filaments on the surface of the cavity with accompanied crown, and fine fibre loops inside the fluid volume.

Keywords: drop, impact, experiment, cavity, crown, splash, ligament

1 Introduction

Public interest in the flows accompanying the coalescence of a free-falling drop with a target fluid, mentioned in literature from ancient times and having a noticeable impact on the development of music, sculpture, the creation of jewellery, began to support by systematic scientific research starting from the second half of the 19th century only. Rare first publications of hydrodynamics [1] and acoustics of drop impact studies [2] in the second half of the last century changed by systematic studies, the number of which continues to progressively increase.

The formation of the structure of the drop impact flows is actively influenced by all mechanisms of energy transport that includes slow dissipative (diffusion), well-known with the velocity of flows and the group velocity of waves, and the fastest one which are results of the direct atomic-molecular interaction action when fluids coalesce and the free surface is disappeared. The transformed surface energy, an extensive quantity, is initially enclosed in a thin interface around the domain of the existence of the ASPE where large perturbations of all thermodynamic and mechanical quantities arise.

The released energy then slowly spreads under the influence of molecular (diffusion) processes and forms a set of ligaments that are fine jets and loops (trickles) in the bulk and on the surface the fluid, spikes, and sets of the ejected secondary small droplet (sprays). Some of the spikes are directed outside, a few oriented inside the flow and small droplets from their tips fell on the surface of coalesce drop [5]. The ligaments manifest themselves in the form of fine vortex loops of a coloured liquid when the ink drop coalesces with the target fluid as well [6]. Mathematical images of ligaments that are high-gradient filaments and interfaces are a rich family of singularly perturbed solutions of the system of fundamental equations [7]. Accordingly, the experimental technique was developed taking into account the condition of registration both slow large-scale, in the size of a drop, components that are a cavity, a crown, capillary or acoustic waves, and thin ligaments.

2 Physical and spatio-temporal process parameters

The determining parameters of the problems of formation and coalescence of a free-falling drops with a fluid at rest, which were studied in experiments, are the density of air \( \rho_a \) and water \( \rho_d \) (hereinafter \( \rho_{a,d} \)).
kinematic $\nu_{d,d}$ and dynamic $\mu_{d,d}$ viscosity of media; full $\sigma^2_d$ and normalized to the density of the liquid surface tension coefficient $\gamma = \sigma^2_d/\rho_d$ $\text{cm}^3/\text{s}^2$, acceleration of gravity $g$, equivalent diameter $D$, surface area $S_d$, volume $V$, mass $M$, height $H$ and droplet velocity $U$ at the time of initial contact; available potential surface energy $E_\sigma = \sigma S_d$ and kinetic energy $E_d = MU^2/2$ [6].

The fraction of energy $E_\sigma$, stored in a near-surface spherical layer with a thickness of the order of the size of the molecular cluster $\delta_0 \sim 10^{-6}$ cm and mass $M_0$, under the experimental conditions is about 1% of the kinetic energy of the droplet, but its density is much higher: $R_\sigma = E_\sigma M / E_d M_0 \sim 1000$. The processes of converting surface energy into other forms play a decisive role in the formation of thin trickles.

Physical processes determine length scales, including the capillary-gravitational parameter $\delta^2_c = \sqrt{\gamma / g}$ included in the dispersion equation of short surface waves, dissipative-capillary $\delta^2_g = v^2 / \gamma$, capillary $\delta^2_c = \gamma / U^2$ and Prandtl’s scales $\delta_{U}^2 = \nu / U$ and $\delta_{U}^6 = \kappa / U$.

Groups of time scales include environmental parameters $- \tau^2_c = \frac{\sqrt{\gamma / g}}{\gamma}$, capillary $\tau^2_c = \gamma / U^2$, and its velocity $- \tau^2_U = D / U$, $\tau^2_U = U / g$.

The characteristic time of conversion of the available potential energy into other forms is determined by the duration of the fusion of the near-surface layers $\tau_e \sim \delta_0 / U \approx 10^{-8}$ s.

The frequencies of capillary $\omega_c$ and acoustic waves $\omega_a$ are associated with wave vectors $k_c, k_s$, and the corresponding wavelengths $\lambda_c = 2\pi / k_c, \lambda_s = 2\pi / k_s$, dispersion relations $\omega^2_c = g k_c + \gamma k_c^3$ and $\omega^2_s = c_s^2 k_s^2$, where $c_s$ is the velocity of sound. The drop size, lengths of different waves and the flow components (cavity and crown), presented spatial and temporal scales define demands to experiment and metrology of instruments.

Ratios of corresponding length scales define conventional non-dimensional parameters, i.e. Reynolds number $Re = \frac{UD}{\nu}$, Froude $Fr = \frac{U^2}{gD}$, Bond number $Bo = \frac{gD^3}{\gamma}$, Ohnezorge $Oh = \frac{\nu}{\sqrt{\gamma D}}$.

Weber number $We = \frac{U^2 D}{\gamma}$.

### 3 Technique of experiment

Experiments with photo and video recording of flows performed at the Stands of the USF “HPC IPMech RAS” with transparent water pools of different sizes $30 \times 30 \times 5$ cm and $10 \times 10 \times 7$ cm [4]. The observation area was illuminated by sloping light rays of two multi-element sources of constant light MultiLED. The flow pattern was recorded with an Optronis CR3000×2 high-speed video camera (shooting frequency is up to 20 000 frames per second, shutter speed is 1/10000 s). Description of facilities and experimental procedure is described in detail in [6].

In these experiments, drops of water or an aqueous solution of alizarin ink, $D = 0.42$ cm in diameter, freely fell from a height of $0.6 < H < 200.0$ cm. The contact velocity of $0.34 < U < 4.3$ m / s was determined from video films. The surface energy of the droplet was $E_\sigma = 4 \mu J$, and the kinetic energy was in the range of $2.24 < E_k < 360 \mu J$. Experimental parameters: Reynolds number $1450 < Re < 18000$, Froude number $2.8 < Fr < 450$, Bond number $Bo = 2.39$, Ohnezorge $Oh = 0.0018$, Weber number $6.7 < We < 1100$.

### 4 Observation of the flow patterns drop impact

Methodological consistency of spatial and temporal resolution of the applied experimental technique that is the brightness of “multipoint” light sources, shooting frequency, a shutter speed of video recording, careful tuning of lenses helped to visualize and register fine short-lived but stably reproduced structural components of flow, which were not previously studied.
The primary contact of the drop with the target liquid is accompanied by the emergence of a shroud with thin spikes (thorns) and series of droplets (sprays) from their tips (in Fig. 1, \( t = 0.2 \) ms, five spikes \( l_s = 0.4 \) mm long and \( d_s = 0.05 \) mm thick are visible in the angle range from 2 to 4 o’clock). Traces of the ejecta \( \Delta\tau \approx 0.14 \) mm wide are visible at the base of the spikes. The first fast small droplets \( l_d = 0.03 \) mm in diameter flying at a velocity of \( \approx 10 \) m/s are ahead of the main group (\( d_{b}^{2} = 0.1 \) mm) by 0.3–5.5 mm. Droplets flying out in the radial directions synchronously are collected in separated annular layers. Groups of droplets are sequentially emitted at an interval of \( \Delta\tau \approx 0.05 \) ms [8].

![Figure 1: Ejecta, spikes and spray of the primary contact of a drop with the target liquid](image)

When a drop of ink solution merges with water against the background of ejecta (\( \Delta\tau = 0.4 \) cm), spikes of length \( 0.4 < l_s < 1.0 \) mm are visible (Fig. 1, \( t = 0.32 \) ms). Here, primary fast sprays and larger droplets escaping with a \( \Delta\tau \approx 50 \) μs delay are also distinguished. Their velocities differ by 4 times.

At the end of the immersion phase, the rest of the drop, with a distorted image of the mask lying on the bottom, surrounds a light ring - the bottom of the cavity and a dark shell - the crown wall (Fig. 1, \( t = 0.45 \) ms). On a thin ejecta, inclined outward, two groups of spikes \( 0.8 < l_s < 1.2 \) mm long (at 4 o’clock) are visible. Another group of spikes is turned inward towards the drop (at 3, 6, 9 o’clock). The multidirectionality of the spikes indicates the complex structure of the crown, consisting of several fine layers. The fast inner layer is pulled into the dome by surface tension forces and crumpled. At the ends of the folds, short, inward-directed spines appear, from the tops of which droplets fly out. Towards 6 o’clock, a cavity with a group of capillary waves is visible on the falling drop, as in [5]. The outer layer is turned towards the water surface. Over time, all layers merge and form a single crown edge.

When registering the flow pattern in the vertical plane, the light source was installed behind the droplet trajectory on an inclined line of sight (2°). Below the undisturbed liquid surface (marked with a white line) is a mirror image of the flow pattern. The primary contact of the drop is accompanied by three groups of small splashes (width of lines \( d_d < 0.03 \) mm) flying at angles of 3°, 8°, and 11° (Fig. 2, \( t < 0.03 \) ms). The velocity of the first group, consisting of two clots (outer thin \( l_d = 2.0 \) mm and inner \( l_{d}^{2} = 1.14 \) mm) is \( u_r = 20 \) m/s, the second is \( u_r = 1 \) m/s. Spikes thickness is \( 0.1 < d_s < 0.2 \) mm.

During the time \( \Delta\tau = 0.1 \) s, the first group of splashes (\( 6^\circ < \varphi < 13^\circ \)) shifted from the source by 1.0 mm, and the second (\( 16^\circ < \varphi < 45^\circ \)) – by 0.45 mm. A new group of splashes appeared in the frame, as well as a chevron of the crown, tilted at an angle of 46°. Over time, the zonal structure of the splashes appears: at \( t = 0.3 \) ms, streaks of length \( l_d = 0.7 \) mm are separated by a 0.5 mm empty intervals. The pinch-off directions of the main droplet groups are preserved.

At \( t = 0.5 \) ms, splashes fly out radially at an angle to the horizon and obliquely downward from the tops of two teeth at a velocity of \( u_r = 7.8 \) and 6.0 m/s, respectively. All sources operate intermittently; the pause duration is \( \Delta\tau \approx 50 \) μs. The immersion of the drop and the growth of the crown is accompanied by a smooth rise in the liquid level. The number and speed of splashes gradually decreased with decreasing droplet speed in the range of \( 2.4 < U < 3.4 \) m/s.
Figure 2: Groups of drop impact splashes (\( D = 0.42 \text{ cm}, \ U = 3.4 \text{ m/c}, \ Re = 14300, \ Fr = 290, \ We = 700, \ Bo = 2.4, \ 0.42, \) mark length 1.5 mm, speed 10000 fps): a–d) – \( t = 0.02, 0.2, 0.3, 0.5 \text{ ms}\)

In the photograph, liquid-stained trickle coloured by the drop fluid are traced in the crown and in the split ejecta with spikes \( 2 < l_s < 3.5 \text{ mm} \) long and \( 0.07 < d_s < 0.16 \text{ mm} \) thick (Fig. 3, 1 ms). The layers gradually merge into a single crown (\( t = 2.3 \text{ ms}\)). The thickness of the ejecta increases, its angular position changes. Droplet trajectories are presented by strokes, the slope of which increases as they approach the crown. Strokes indicate a change in the position and inclination of the spikes, which are the source of all splashes of one group. Drops from the different spikes fly out synchronously and are collected in rings separated by circular empty rings.

Figure 3: Evolution of the crown and the field of splashes (\( D = 0.42 \text{ cm}, \ U = 3.9 \text{ m/c}, \ Re = 16800, \ Fr = 390, \ We = 930, \ Bo = 2.4, \ Oh = 0.0018, \) mark length - 0.5 cm): a–d) – \( t = 1.0, 2.3, 3.7, 10.0 \text{ ms}\)

With time, the number of spikes decreases, their thickness (Fig. 3, \( d_s \approx 0.1 \text{ cm} \) at \( t = 3.7 \text{ ms}\)), and the size of droplets grow. Six echelons of droplets indicate that the process remains cyclical. The chevron spikes are \( 0.07 < h_c < 0.26 \text{ cm} \) high and include both contacting liquids. In the distribution pattern of fibers (thin - \( d_f < 0.08 \text{ mm} \) and thicker \( d_f \approx 0.3 \text{ mm}\)), the zonal structure created by waves appears. At the bottom of the cavity, the fibers converge, intersect and form a network with triangular, quadrangular, and pentagonal cells.

Two echelons of large droplets (\( d_b \approx 0.1 \text{ cm}\), emerging with an interval of \( \Delta t \approx 2 \text{ ms} \) and separated by the distance \( \Delta r = 0.36 \text{ cm} \), are observed at \( t = 10 \text{ ms} \). The thickness of the crown with a height of \( h_c = 0.47 \text{ cm} \) is variable (from 0.6 to 0.9 mm), the height of the teeth’s on the chevron is from 1.2 to 2.6 mm. The distance between the fibers (with a thickness of 0.1 to 0.3 mm) increases to 1.3 mm. The ring structures visualize \( 0.31 < \lambda < 0.36 \text{ mm} \) long capillary waves traveling from the chevron to the base of the crown. The substance of the drop is distributed on the surface of cavity and crown in filaments separated by bands of target fluid [9].

The dynamics and geometry of the flow at the coalescence of a droplet with the target liquid depend on the ratio of the ASPE \( E_\alpha \) to the kinetic energy of impacting drop \( E_k \). At low contact velocities (\( E_k < E_\alpha \)), the coalescent drop forms an intrusion that is a continuous volume of colored liquid; the formation of a cavity begins with a delay. At high impacting drop contact velocities, a cavity and a crown, which uniformly or discretely colored by the substance of the drop, are started to form immediately.

Samples from the videogram of the flow pattern in the intrusive mode are shown in Fig. 4 (here, near the surface of the liquid, there is a “blind zone” with a height of about 1.5 mm, caused by the capillary rise of the target liquid near the wall). On a short trajectory, the drop does not collapse into a sphere and consists of a central cylindrical section and two heads. The lower head is spherical and the upper head is flat. When the velocity of a drop with a diameter of \( D = 0.42 \text{ cm} \) is equal to \( U = 0.34 \text{ m/c} \), ASPE \( E_\alpha = 4 \mu J \) is greater than the kinetic \( E_k = 2.24 \mu J \), dimensionless numbers are \( Re = 1450, \ Fr = 2.8, \)
Bo = 2.39, Oh = 0.0018, We = 6.7. An approaching drop oscillates and is covered with short capillary waves with the lengths $\lambda_c = 0.46$ and 0.54 mm (Fig. 4, $t = 0.0$ ms).

![Figure 4: Formation of intrusion and cavity during slow coalescence of a drop of diluted ink solution (1: 1000) with water: a–f) – $t = 0.0, 6.4, 11.5, 19.1, 24.7, 34.0$ (frame width - 1 cm)](image)

When the bottom of the droplet sinks, the coalescence line contracts to the center of the flow, the contact spot area decreases, and simultaneously with the annihilation of the droplet surface, a new free surface is formed. Now the ligaments transfer part of the transfer energy and momentum of the drop to the contact patch. In this case, the growth rate of the cavity width decreases: from $v_i = 2.13$ m/s at $t = 5.3$ ms) to $v_r = 0.44$ m/s at $t = 6.2$ ms.

Part of the intrusion breaks off from the free surface and folds into an annular vortex with a core diameter of $d_i = 1.93$ mm and a shell of $D_i = 6.63$ mm, part remains in the near-surface layer ($t = 11.5$ ms, Fig. 4). In this case, the surface of the liquid bends smoothly, and a cavity with a conical base and a cylindrical central part is formed in its center (not visible in this projection). The dimensions of the cavity increase rapidly, and at $t = 19.1$ ms its depth is $h_c = 3.1$ mm, the diameters of the cylindrical part are $d_c = 3.2$ mm, and the base on the free surface is $d_p = 6.6$ mm.

The growing cavity "pushes" the central part of the vortex, the toroidal core of which lags by a height of $h_l = 1.73$ mm from the lower edge of the intrusion, from the top of which a small vortex ring $d_l = 0.58$ mm and a new toroidal vortex $d_v = 0.8$ mm in diameter on a $d_p = 0.64$ mm stem and $h_p = 0.1$ mm in height are ejected.

Under the action of buoyancy forces, the cavity collapses (Fig. 4, $t = 24.7$ ms) and breaks away from a uniformly submerging intrusion, which has restored its toroidal shape. Vortex sizes under the intrusion slowly grow. After the collapse of the cavity, a toroidal vortex with a tip 5.7 mm in diameter remains in the liquid, from which a colored veil peels off, connected by a stem $d = 2$ mm in diameter with a near-surface lens of a colored liquid droplet with a diameter of $D_c = 9.4$ mm at $t = 34$ ms. Further, the near-surface part of the intrusion continues to expand and become thinner, the vortex, slowing down, plunges into the liquid.

Of great scientific and practical interest is the study of the distribution of the droplet substance in the receiving liquid in the case of both miscible and immiscible contacting media. Detailed experiments have shown that in the case of mixing liquids, the droplet substance is discretely distributed over the cavity and crown surfaces, and even partially gets into the outgoing spray [10]. The nature of the propagation of the droplet substance in the thickness of the receiving liquid is illustrated by a series of photographs shown in Fig. 5. In the phase of contact, it is difficult to distinguish the features of the distribution of the substance in the used registration technique (Fig. 5 a), however, even in the phase of formation of the crown one can
see separate areas with a high concentration of the dye (Fig. 5 b). With the beginning of the collapse of
the cavity, a part of the colored substance remains in the receiving liquid in the form of elongated oblique
stripes (Fig. 5c).

Figure 5: Vortex loops at the bottom of the cavity arising during the collapse of the cavity caused a
drop of an aqueous solution of alizarin ink impact into water $D = 0.42 \text{ cm}$, $U = 3.1 \text{ m/s}$:

- $t = 0.5, 2.0, 26.0, 30.0, 37.0, 50.0 \text{ ms}$

Over time, ligaments i.e. thin near-surface flows in form of the filaments colored with the drop fluid
are observed on the cavity boundary. They located under a small positive angle with the horizon. Their
sizes monotonically increase with time (Fig. 5d). Simultaneously, the filaments rotate, and the rate of
angular rotation is maximum at the flow periphery (Fig. 5e). The filaments are stretched and transformed
into fine loops (Fig. 5f). Other manifestations of fine flows components were studied in [11].

The inhomogeneity of the color of the cavity wall indicates a discrete distribution of the drop
substance in the target fluid [9]. The contour of the cavity is colored unevenly; its shape is disturbed by a
small growing vortex ring in the center and protruding colored loops on the sides. With time, the cavity
flattens and begins to contract to the surface, the vortex loops go beyond their boundary and propagate
inside the fluid volume (Fig. 5, e).

As the capillary wave disturbances grow, the shape of the cavity is distorted, and the loops become
thinner. The collapsed cavity leaves the droplet substance in the liquid volume in the form of separate
vortex loops lying almost horizontally (Fig. 5, f). As lengths of the loops increases, they become more
pronounced and turn to the vertical in the mode of the beginning of the formation of the ascending
pedestal (Fig. 5, d). The filament structure of flow observed long time [6].

5 Mechanisms of energy transport in drop impact flows

Calculations of the flows accompanying the impact of a droplet into the target fluid, as well as the
planning of the experiment, are usually carried out on the basis of the Navier-Stokes equations in the
approximation of the axial symmetry of the flow [12]. In reality, drop impact flows in a target liquid at all
stages have a fine structure, which includes waves visible on the free surface and thin fast jets, i.e.
ligaments (trickles) inside the fluid [9, 11]. The sharpness of the fluid boundaries and the smoothness of
the surface of the basic structural components indicated in many publications [2,12], starting with the
articles of Worthington [1], are often caused by the difficulty of photographing transparent objects and
the inconsistency of spatial and temporal resolution during registration. Carefully prepared experiments
show the existence of thin and hyperfine flow components [9]. Their transverse dimensions are
comparable to the size of a molecular cluster in a liquid $\delta_\ell \sim 10^{-6} \text{ cm}$. On such scales, the internal
energy is unevenly distributed in the liquid, in particular, its large gradients are caused by the localization
of ASPE in thin layers in the vicinity of contact surfaces or interfaces with large gradients of thermodynamic quantities [6,7].

To describe fine processes, the description of the medium is expanded, the equation of state of which now includes the distributions of thermodynamic quantities, exactly Gibbs potential $G$ (free enthalpy) [13]. Thermodynamic potentials in an inhomogeneous liquid with a free surface are unevenly distributed.

The anisotropic atomic-molecular interactions in areas with large gradients of thermodynamic quantities (in particular, high-gradient concentration layers and near the free surface) manifests itself in the existence of ASPE and chemical types of energy. This energy can be transformed into thermal or mechanical energy of fluid flow, and also produced work on creating a new free surface.

When the incoming drop coalesces with the target fluid liquid at a speed of $U \sim 1 \text{ m/s}$, the free surfaces are annihilated in a time of the order of $\tau_s \sim 10^{-10} \text{s}$, and the subsurface layers at $\tau_\sigma \sim 10^{-8} \text{s}$. When the free surface is disappeared, the ASPE $G_s - G_f$ and $G_\sigma - G_f$ converted into perturbations of temperature, pressure, and the energy of mechanical motion. The converted energy remains in a thin double energy-saturated layer (DESL) with a thickness of about $\delta_\sigma \text{ cm}$. In this domain, there are no two last terms $-\sigma_i d\sigma + \mu dN$ in the expression for the thermodynamic potential. The thickness of DESL is slowly growing under the influence of processes of molecular diffusion of matter and momentum. The primary contact of the drop initiates the process of formation and degradation of a thin DESL in the target fluid, in which the liquid fibers of the drop and the target medium alternate [9].

The dyed fibers approach the spikes that are thin jets, from the tips of which small droplets are ejected. Further, the drop core begins to merge with the receiving liquid. In this case, in a time of the order of $\tau_d \sim 10^{-3} \text{s}$, the kinetic energy of the drop $E_k$ is transferred to the target fluid, and the cavity, the crown with a system of spikes, a splash (cumulative jet), the new cavity, thin streamer, gas bubbles, capillary waves, and sound packets are sequentially formed [1-3, 5]. After the decay of fast processes in the fluid, a cascade of vortex rings is formed, slowly disappearing out under the action of molecular diffusion.

From the analysis performed, it follows that in the course of the evolution of droplet flows, several mechanisms of energy transfer operate: first, the fastest atomic-molecular one during the merging of near-surface layers, then the slower one with fluid flows and the group velocity of propagating capillary or acoustic waves, and at the last stages, the slowest diffusion mechanism.

To describe such processes, it is useful to introduce additional dimensional parameters, including the thickness of the internal energy localization layer $\delta_E^i$ (in the case of ASPE $\delta_E^i \sim 10^{-6} \text{cm}$), the time of coalescence of such a layer, and the ASPE conversion $\delta_U^i = \delta_i / U_1^i$, which is determined by the ratio of its thickness $\delta_E^i$ to the normal component of the flow velocity $U_1^i$. Natural dimensionless parameters complementing the set of traditional numbers of Reynolds, Froude, Weber, Bond, Ohnesorge in the problem of drop coalescence are the ratio of the ASPE $E^i_k$ to the kinetic energy of the drop $E^k_k = E^k_d / E^k_D$, the thickness of the internal energy localization layer $\delta_E^i$ to the characteristic length scale $\delta = \delta_i^E / D$ (in studied problem, the scale is the diameter of the drop $D$), and the ratio of the conversion time of the ASPE $\tau^i_U = \delta_i / U_1^i$ to the intrinsic time of the problem $\tau_p = \delta / \tau_s$. In the case of the destruction of the ASPE of the merging drop and target fluid the shortest time, composed of the parameters of the molecular processes of the medium is $\tau_s = c_1^v = c_0^v / c_0^k \sim 10^{-10} \text{cm/s}$. The temporal ratio $\tau = \tau_p / \tau_s$ characterizes the thermodynamics of the energy transformation process where the fastest one is isochoric, the slower is isobaric, and the longest is isothermal. The efficiency of acceleration of the liquid layer increases with decreasing energy conversion time $\tau_p$, when the process is isobaric and a large portion of the converted energy is converted into pressure perturbations. The converted energy is dissipated by dissipative processes (thermal conductivity and viscosity in isobaric and isothermal processes).
6 Conclusion

Detailed high-resolution observations give room to identify new groups of stably reproducible drop impact processes with accompanying spatial structures including impact capillary waves of secondary droplets on the surface of an coalesce drop, fibrous patterns of the distribution of the drop matter inside and on the surface of the target fluid, complex shapes and texture of the surface of flows.

An important role in shaping the flow pattern is played by all energy transfer processes: both local fast that is atomic-molecular on ligaments, and slow that include translational and dissipative mechanisms, forming thin fibers and interfaces, vortices, capillary, and acoustic waves.

The analysis is based on results of complete solutions of the fundamental equations of fluid mechanics system including the empirical equations of state for the Gibbs potential and density, performed taking explicitly into account the compatibility condition, which gives room to systematize and characterize the observed phenomena in a unified way in a wide range of process parameters.

The experiments carried out far from cover all the structural features of impact drop processes, which substantially depend on all physical parameters, which in real conditions change in a wide range.

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