INVESTIGATION OF THE FEATURES OF EXPLOSIVE FRAGMENTATION OF LIQUID METAL DROPLETS FALLING INTO COLD WATER

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The understanding of the processes underlying steam explosions [1], including those observed in large-scale facilities in nuclear power and metallurgical industries, remains insufficiently studied, primarily due to the lack of a reliable base of experimental data. The most promising and practical method for conducting experimental investigations of industrial steam explosions involves physical modeling of individual stages of this phenomenon on small-scale experimental setups (small – scale steam explosions), followed by extrapolation of the obtained results to larger scales. However, conducting such experiments presents technical challenges associated with the use of liquid corium and steel. As a result, research is often carried out using low-melting-point metals, such as tin (Sn), bismuth (Bi), lead (Pb), zinc (Zn), and their various alloys, including Wood's alloy, Rose's alloy, Field's alloy, and others, due to their availability and experimental convenience in laboratory settings.

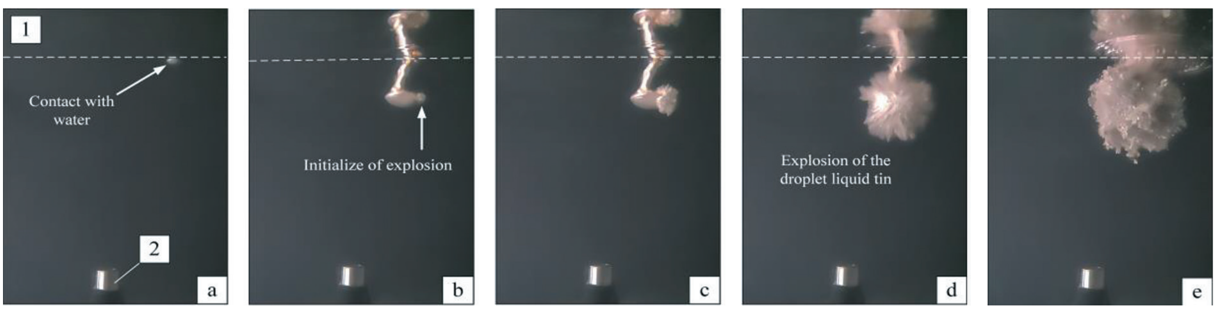

Fig. 1. Stages of the explosive fragmentation process of a single Sn droplet.
The dashed line indicates the level of the free water surface. 1 – water, 2 – pressure sensor; a – metal contact with water, b – local destabilization of the vapor film, c – propagation of the disturbance over the droplet surface, d – explosion of the tin droplet, e – expansion of fragmentation products, f – the end of the fragmentation process

This work presents experimental data obtained using liquid tin (Sn), with an initial metal temperature range of 600–800°C, in the form of small droplets impacting water at a temperature of 18°C. Original pressure fluctuation versus time dependencies were obtained using a piezoelectric pressure sensor. Combined with high-speed imaging of the process, their analysis revealed previously unobserved specific features of explosive fragmentation (Fig. 1). This allowed for the formulation of a refined scenario describing the interactions between the melt and water based on the phenomenon of explosive boiling of the cold liquid near the metal surface.

Despite the small scale of the phenomenon, it was established that pressure pulses generated by the underwater explosion of droplets can reach critical values (~10–1000 atm depending on conditions), sufficient for fragmentation to occur according to the cavitation-acoustic model. It was also found that increasing the initial temperature of the injected melt leads to an increase in the intensity of the explosion in the case of liquid tin.

The interaction of liquid lead (Pb) and bismuth (Bi) with water exhibits a fundamentally different character. For liquid bismuth, explosions occur near the surface of the coolant, whereas for lead, within the studied temperature range, no evidence of explosive fragmentation was observed. The above considerations demonstrate that experimental data obtained using low-melting-point metals are insufficiently representative and cannot be directly applied to describe the processes of corium melt interaction with water under real accident conditions at nuclear power plants. This highlights the need for additional research.

References

1. **Melikhov, V. I.** Hydrodynamics and Thermophysics of Steam Explosions [Text] / V. I. Melikhov, O. I. Melikhov, and S. E. Yakush. – M. : IPMekh RAN, 2020. [in Russian].