MECHANISM OF DECAY OF A JET INTO LARGE DROPS

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High-speed photography has shown that disintegration of a jet affects a single material cross section without reversible oscillations (contraction and expansion) in that section.

The decay of a jet into large drops is usually considered to result from transverse oscillations in the form of alternate contractions and expansions of the jet cross section [1, 2]. Resulting from chance causes, these oscillations grow in amplitude until the contractions break apart and drops are formed.

Oscillations of the jet surface, regarded as an elastic film, are damped by frictional resistance. Typical experiments [3] show that even very intense oscillations of the shape of the jet cross section, generated by a nozzle of elliptic shape, are rapidly damped and in no way promote the decay of the jet into drops. Chance pertubations of the jet cause it to break up only where they arise, without transmitting their disruptive rhythm by elastic oscillation to other parts of the jet.

The inconsistencies of the theory of decay of jets by elastic oscillations and their inevitable damping, not development, along the jet, are the result of neglecting the principal property of a liquid – its fluidity.

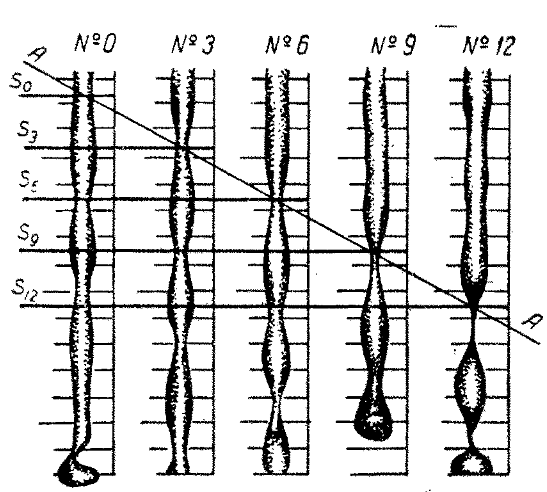
Because of this property, liquid will necessarily and irreversibly be conveyed from the nodes to the adjoining crests by Laplace forces, which simultaneously retard return flow from the crests to the nodes. Therefore the oscillations will not take the form of alternate contraction and expansion of the same part of the liquid in the jet (as they would in an elastic solid rod). The contracted parts of the liquid will go on contracting progressively right up to rupture. The crests will likewise go on expanding progressively right up to the formation of drops.

We took high-speed motion-picture photographs of the decay of water jets up to $30 \cdot 10^{-3}$ m in length. The jet discharged from a nozzle of internal diameter $0.97 \cdot 10^{-3}$ m at a velocity 1.07 m/sec, as computed from the volume of water discharged.

For a film speed of 1850 frames/sec the exposure time per frame was $\tau_f = 0.55 \cdot 10^{-3}$ sec. Taking into account gravitational acceleration and neglecting air resistance in the initial short sections of the trajectory, we may calculate the distance through which a single material section of the jet moves in 0, 3, ..., 12 frames from a chosen initial position:

$$s = v\tau + g\tau^2/2.$$

The results of calculations using this formula were: for frame No. 3, $\tau \cdot 10^3 = 1.67$ sec, $s \cdot 10^3 = 1.8$ m; for No. 6, 3.33 and 3.6 respectively; for No. 9, 5 and 5.6; for No. 12, 6.67 and 7.4.



Progressive displacement of the same material section of a jet.

In the accompanying figure these positions, magnified five times, are located on the line AA and represent the development of the contractions and expansions of the same material section of the jet with time. The figure very clearly confirms the continuous development of contractions and expansions of the same material sections of the jet.

The alternation of contraction and expansion along the jet is due to Laplace forces. Of necessity, every contraction generates an expansion by squeezing out liquid. Every expansion is accompanied by a contraction, due to the creation of a spherically symmetrical distribution of forces. In this way a train of contractions and expansions, alternating along the jet, is formed.

For short slow jets, the source of this train is primarily the end of the jet, where the drops break away.

For fast jets, disturbances at the nozzle outlet may also be the source. In both cases the amplitude of contraction and expansion increases progressively downwards, since the residence time of each material part of the liquid in the jet runs in this same direction.

NOTATION

s – the distance through which the same material section of a jet moves in 0, 3, 6, 9, 12 frames (see figure); v – initial discharge velocity; τ – time taken to travel distance s; g – acceleration of gravity; τ_f – exposure time per frame.

REFERENCES

1. Rayleigh, Proc. Lond. Math. Soc., 10, 4, 1878.
2. Rayleigh, Phil. Mag., 34, 145, 1892.
3. V. I. Blinov and E. L. Feinberg, ZhTF, no. 5, 1933.

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