FTD-HT-67-274

AD 672341

FOREIGN TECHNOLOGY DIVISION

EFFECT OF FORCED OSCILLATIONS ON STREAM DECAY

by

G. S. Lazarev

Distribution of this document is unlimited. It may be released to the Clearinghouse, Department of Commerce, for sale to the general public.

13

FTD-HT- 67-274

UNEDITED ROUGH DRAFT TRANSLATION

EFFECT OF FORCED OSCILLATIONS ON STREAM DECAY

By: G. S. Lazarev

English pages: 9

SOURCE: Machinostroyeniye (Machine Building). No. 6, 1966, pp. 72-77.

Translated under: Contract AF33(657)-16408

UR/0304-66-000-006 TP7001462

FTD-HT - 67-274 Date 15 Sep 19 67

S

ITIS INDEX CONTROL FORM

01 Acc Nr	68 Translation Nr	65 X Ref Acc Nr	76 Reel/Frame Nr	
TP7001462	HT6700274	AP6027625	881	1502

97 Header Clas	63 Clas	64 Control Markings	94 Expansion	40 Ctry Info
UNCL	UNCL, 0	0		UR

02 Ctry	03 Ref	04 Yr	05 Vol	06 Iss	07 B. Pg.	45 E. Pg.	10 Date
UR	0304	66	000	006	0072	0077	NONE

Transliterated Title
VLIYANIYE VYNUZHDENNYKH KOLEBANIY NA RASPAD STRUI

09 English Title
EFFECT OF FORCED OSCILLATIONS ON STREAM DECAY

43 Source
MASHINOSTROYENIYE (RUSSIAN)

42 Author	98 Document Location
LAZAREV, G. S.	
16 Co-Author NONE	**47 Subject Codes** 20
16 Co-Author NONE	**39 Topic Tags:** nozzle design, nozzle flow, atomization, jet breakup, vibration effect, forced vibration, fluid viscosity
16 Co-Author NONE	
16 Co-Author NONE	

ABSTRACT : The effect of vibrations on the disintegration of a liquid jet was studied theoretically and experimentally. Equations were derived for the variations in a jet radius in the presence of vibrations. The experimental study was made in an assembly containing a glass nozzle 0.5 to 1.2 mm in diameter which was placed in a plastic tube mounted in a holder connected to a mechanical vibrator (up to 10,000 cps). The disintegration of the horizontal water jets was recorded photographically. When the vibrations were in resonance with the natural frequency of the jet, the non-disintegrated section of the jet was shortened by a factor of 2.5. Forced vibrations with frequencies differing from the natural frequency or its multiples had little effect on jet disintegration. It is concluded that forced nozzle vibrations with resonance frequencies can be used in praxis to intensify atomization processes. Orig. art. has: 5 figures. English Translation: 9 pages.

621.43

EFFECT OF FORCED OSCILLATIONS ON STREAM DECAY

Candidate of Technical Sciences, Docent G.S. Lazarev

(Paper presented by Candidate of Technical Sciences Ye.N. Izotov, Docent of the Voronezh Polytechnical Institute)

The paper discusses results from an investigation of the decay of a liquid stream continuously being discharged into free space under the action of forced mechanical nozzle oscillations excited by an electrodynamic vibrator. It has been established experimentally that there exists a completely defined resonance frequency of the forced oscillations which promotes intense stream decay. The problem of stream decay into drops has never previously been considered from this viewpoint.

1. THEORETICAL PREMISES OF STREAM DECAY AT LOW LIQUID DISCHARGE VELOCITIES

The decay of a stream of a liquid into drops is the subject of systematic investigation. In the theory of stream decay proposed by Rayleigh [1] and developed in the works of Weber [2], Blinov [3] and others [4-6], the formation of rotationally symmetric waves along the length of the stream has been accepted as the basic premise explaining the phenomenon of decay. The formation and development of these waves is explained both by the turbulence of the flow and by such other factors as accompany the discharge of the stream from a nozzle.

The initial perturbations that arise in a stream on exit from a nozzle exhibit a wide spectrum of frequencies and various initial amplitudes. However, the perturbations whose frequencies coincide with those of the natural oscillations of the stream exert a decisive influence on the decay of the stream and its fragmentation into drops.

The equation of stream surface defining the condition of stream disruption into drops has the form [2]

$$r = a + \delta_1^* \exp \mu_{opt} \frac{x}{u} \cos \zeta_{opt} \frac{x}{a}. \qquad (1)$$

With consideration of the viscosity of the liquid, we find the oscillation increment to be

$$\mu_{opt} = 1 : \left(\sqrt{\frac{8\rho a^3}{\alpha}} + \frac{6\eta}{\alpha} \cdot a\right). \qquad (2)$$

In this case, the wave number assumes the value

$$\zeta_{opt} = 1 : \sqrt{2\left(1 + \sqrt{\frac{9\eta^2}{2\alpha\rho a}}\right)} - \frac{2\pi a \nu^*}{u}, \qquad (3)$$

where a is the nominal radius of the stream; δ_1^* is the initial perturbation close to the nozzle; x is the instantaneous coordinate along the axis of the stream; η is the coefficient of viscosity; ρ is the density; α is the surface tension; u is the discharge velocity; ν^* is the frequency of the natural oscillations.

The disruption of the stream occurs at $r = 0$. By experiment it is easy to find x_0 – the length of the nondisintegrating part of the stream – and thus to determine the amplitude of the initial perturbations δ^*_1 causing the decay of the stream into drops

$$\delta_1^* = a : \exp \mu_{opt} \frac{x_0}{u}. \qquad (4)$$

Let us find the equation of the stream surface formed under the action of the natural oscillations

$$r = a\left[1 + \exp \frac{\mu_{opt}}{u}(x - x_0) \cos \zeta_{opt} \frac{x}{a}\right]. \qquad (5)$$

In a theoretical investigation of the influence exerted by the forced oscillations of various frequencies on the oscillations of a stream let us assume their independent superposition on the natural oscillations and let us further assume the identical quantitative relationship for the development of these forms of oscillation along the stream. In accordance with the adopted assumption, the equation of the surface of the stream with consideration of the natural and the forced oscillations can be presented as follows:

$$r = a + \delta_1 + \delta_2, \qquad (6)$$

where δ_1 and δ_2 are the deviations of the surface of the stream due, respectively, to the natural and the forced oscillations

$$\delta_1 = a \exp \frac{\mu_{opt}}{u} (x - x_0) \cos \zeta_{opt} \frac{x}{a},$$

$$\delta_2 = a \exp \frac{\mu}{u} (x - x_2) \cos \zeta \frac{x}{a}.$$

In the expression for δ_2 we find the same parameters as in the expression for δ_1, but these are here referred to the forced oscillations.

2. RESULTS OF THE EXPERIMENTAL INVESTIGATION OF THE INFLUENCE EXERTED BY FORCED OSCILLATIONS ON STREAM DECAY

The experimental investigations have been carried out on an installation whose diagram is presented in Fig. 1. Nozzle 1 was placed horizontally in chamber 2 made of plexiglas. The water head was devel-

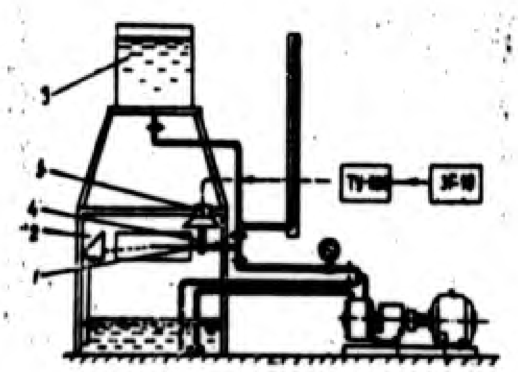

Fig. 1. Diagram of the experimental installation.

oped by tank 3 whose height setting was regulated. The experiments were conducted with glass nozzles drawn to a diameter/length ratio of 1:10 for the nozzle. The nozzle was mounted in a rubber hose and held

Fig. 2. Schlieren photographs: d = 0.84 mm; h = 1.5 m for the frequency of the forced nozzle oscillations, ν in hz.

а = a	д = e
б = b	е = f
в = c	ж = g
г = d	з = h

in place by holder 4 of the dynamic vibrator 5. The small-diameter glass nozzle developed insignificant inertia and the vibrator oscillations were transmitted to the nozzles without significant distortion. The dynamic vibrator operated on a standard ZG-10 generator with subsequent amplification with a TU600 and an expanded frequency range up to 20 khz. An electromagnetic sensor and an EO-53M oscilloscope were utilized to monitor the nozzle oscillations. The state of the liquid stream was recorded on high-contrast paper by means of Schlieren photography and a pulse light. The distance of the liquid stream from the photographic paper was set at 10-12 mm. The pulse light was positioned at a distance of 2.5 meters from the stream. The study of stream decay was carried out with nozzles whose outlet diameters ranged from 0.5 to 1.2 mm.

Figure 2 shows a photograph of a stream of water on discharge through a nozzle whose diameter is 0.84 mm. Photograph *a* corresponds to the discharge of the stream into the air in the absence of any special external exciters of oscillation ($\nu = 0$). The length of the undisturbed part of the stream is 250 mm. Although there are no external exciters of oscillation, it is not difficult to see from the photograph that the decay of the stream occurs as a result of axisymmetric oscillations which are clearly noticeable at the end of the undisturbed part of the stream. The waves formed on the surface of the stream grow intensively and lead to the decay of the stream into drops. Let us compare the form of the stream on the photograph with the theoretical shape derived from Relationship (5). The data for the calculation of stream profile $a = 0.42$ mm and $u = 450$ cm/sec have been taken from experiment. From Eqs. (2) and (3) we have found $\mu_{opt} = 356$/sec; $\zeta_{opt} = 0.707$. Comparison of the theoretical stream profile with the experimental data shows completely satisfactory coincidence (Fig. 3).

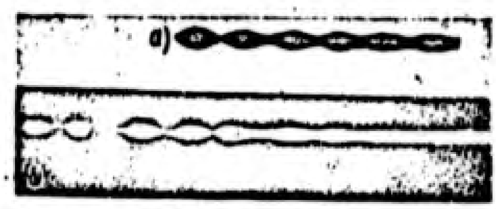

Fig. 3. Profile of stream in zone of decay into drops: *a*) theoretical stream profile; *b*) Schlieren photograph of stream, d = 0.84 mm; $\nu = 0$ hz.

According to the above-cited data for the subject stream, on the basis of Eq. (3) the frequency ν^* of the natural oscillations, corresponding to the onset of stream decay, is equal to 1205 hz. While the frequency ν^* of the natural oscillations is a decisive factor in the decay of the stream into drops, the superposition of the forced oscillations with frequency ν^* or its multiple onto the liquid stream must produce a resonance phenomenon and accelerate the decay of the stream.

Figure 2 shows the photograph of a stream for the case of superposition of forced oscillations of frequency 1200 hz onto the stream. The length of the undisturbed part of the stream is significantly reduced and amounts to 10 cm. The equation for the surface of the stream in the case of forced oscillations of frequency 1200 hz is defined by Relationship (6) in which

$$\zeta = \frac{2\pi a}{u} \nu^*.$$

The profile of the stream derived by calculation on the basis of this equation (with consideration of the experimental value $x_2 = 10$ cm) is presented in Fig. 4. Here we have a graph of the profile of the stream enlarged from the photograph of the stream and with superposition onto the stream of forced oscillations of frequency $\nu^* = 1200$ hz.

Let us examine the influence exerted on stream decay by the frequencies of the forced oscillations that are multiples of ν^*

$$\nu = \frac{\nu^*}{k},$$

where k is the coefficient of multiplicity.

The case $k = 1$ has been considered. The superposition onto the stream of forced oscillations with a frequency close to that of the natural oscillations led to a reduction in the length of the unperturbed part by a factor of 2.5. The nature of the decay was retained in this case. The photographs clearly show waves with an increasing amplitude which lead to the break-up of the stream into drops.

Let us consider the case $k = 2$; here we have $\nu = 600$ hz. The profile of the stream derived by calculation from Eq. (6) for the case $x_2 = x_0 = 14$ cm is shown in Fig. 4. The wave number for this case is $\zeta = 0.350$.

The value of the oscillation increment μ, calculated from Formula (2), is equal to $\mu = 230$. For purposes of comparison, this same graph shows the profile of the stream derived experimentally for the conditions of forced oscillations with a frequency of 600 hz. The general character of the profile confirms the capability of the stream – retaining the natural frequency of oscillations – simultaneously to take up the superposed forced oscillations of multiple frequency. On the wavelength corresponding to the forced oscillations we superpose two waves of natural oscillations; in this case, pairs of drops are formed and these are clearly seen on the photographs. It is interesting to note that the influence of the forced oscillations on the stream becomes apparent not in the zone of their superposition, but only at the point of stream decay. Apparently, the forced oscillations are propagated in the same manner as the natural oscillations – in the form of pressure oscillations inside the stream – and their amplitude gradually increases, leading to the break-up of the stream into drops in the zone of decay.

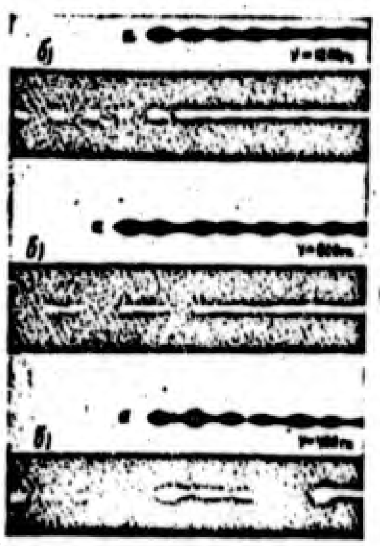

Fig. 4. Profile of stream in zone of decay into drops: *a)* theoretical stream profile; *b)* Schlieren photograph of stream, d = 0.84 mm, ν in hz.

The following frequency, a multiple of the critical frequency, corresponds to ν = 400 hz (k = 3). As we can see from the photograph, three wavelengths of the natural frequency are superposed onto the

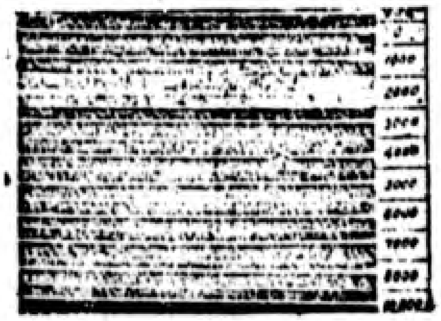

Fig. 5. Schlieren photographs of stream, d = 1.05 mm. Head 3 atm for forced nozzle-oscillation frequency of ν in hz.

wavelength of the corresponding frequency of forced oscillations of 400 hz and three drops are correspondingly formed. The frequency of the forced oscillations, not coincident with and not a multiple of the frequency of the natural oscillations, exerts no significant influence on the decay of the stream.

Figure 5 shows Schlieren photographs of the stream with d = 1.05 mm and a head of 3 atm. The resonance frequency of the forced oscillations is $\nu^* = 2000$ hz and also leads to an intensive decay of the stream.

It is interesting to follow the behavior of the forming drops in the decay of the stream under the action of forced oscillations. This can be accomplished by examining the photograph of the stream for $\nu =$ = 1200 hz (Fig. 2). The resulting drops of liquid begin to fluctuate from spherical shape to elliptical. The frequency of drop oscillation differs significantly from the frequency of stream oscillation which is, of course, associated with the change in the mass of the oscillating parts – the stream and the drops.

Thus, the experiments that have been carried out make it possible to regard as completely realistic the control of stream decay by means of superposition onto the forced oscillations of resonance frequency induced by the nozzle. This may be of significant practical interest, since it offers a real possibility of intensifying the process of fuel atomization by acting on a stream formed by spray nozzles with forced oscillations of resonance frequency.

REFERENCES

1. Rayleigh, Teoriya zvuka [The Theory of Sound], Vol. 1, GITTL [State Publishing House of Technical and Theoretical Literature], 1955.
2. Weber, K., Raspad strui zhidkosti [The Decay of a Stream of a Liquid], Collection entitled "Dvigateli vnutrennego sgoraniya" ["Internal-Combustion Engines"], ONTI [Joint Scientific and Technical Publishing House], 1936.
3. Blinov, B.I., Freynberg, Ye.L., O pul'satsii strui i razryve yeye na kapli [Stream Pulsation and Break-up into Drops], ZhTF [Journal of Theoretical Physics], 1933, Vol. III, Issue 5.
4. Kuznetsov, P.I., Tslaf, L.Ya., K voprosu o raspade zhidkoy strui na kapli [The Problem of the Decay of a Liquid Stream into Drops], ZhTF, 1958, Vol. XXVIII, Issue 6.
5. V--man [sic], L.A., Raspylivaniye vyazkoy zhidkosti forsunkami netsentrobezhnogo tipa [Atomization of a Viscous Liquid by Spray Nozzles of the Noncentrifugal Type], Collection of Scientific Projects of the Leningrad Institute for the Mechanization of Agriculture, Vol. X, 1953.
6. Kutateladze, S.S., Styrikovich, M.A., Gidravlika gazozhidkostnykh sistem [Hydraulics of Gaseous and Liquid Systems], Gosenergoizdat [State Power Engineering Press], Moscow-Leningrad, 1958.

Received 7 October 1964