Journal of Applied Mechanics and Technical Physics, Vol. 43, No. 3, pp. 413–414, 2002

# PARAMETRIC INSTABILITY OF A SPHERE IMMERSED IN A LIQUID AND SUSPENDED FROM A STRING WITH VARYING TENSION

**V. A. Semenov**

UDC 534.11

*The regions of parametric resonance were determined for a sphere immersed in water and suspended from a string with varying tension.*

As is known [1], the resistance force acts upon a body oscillating in a viscous liquid. This force includes two components, one of which is proportional to the velocity and the other to the acceleration of the body. The contribution of these components depends on the oscillation frequency, which complicates analytical investigation of parametric oscillations of a body in a liquid largely because of the uncertainty of oscillation frequencies of the body arising on the stability threshold. Thus, to develop an adequate theoretical model of parametric oscillations of a body in a liquid, it is necessary to obtain additional experimental data.

The present paper reports results of an experimental study of the parametric instability of a sphere immersed in water and suspended from a string whose tension was varied periodically with time. Figure 1 shows a diagram of the experimental installation. A sphere of Plexiglas 8.5 mm in diameter and a mass of 0.29 g was suspended from a bronze string 0.2 mm in diameter, which was thread through the center of the sphere. One end of the string was attached to the bracket of cloth-based laminate, and its another end was connected with the core of the excitation coil through the hole in the bracket. The string length from the fixed end to the hole in the bracket was 140 mm. The sphere was placed in the middle of the string. The constant tension of the string was regulated by a spring dynamometer connected with the core by a steel wire. All elements of the installation were firmly fixed on a base consisting of a pillar and a guide along which the bracket, the excitation coil, and the dynamometer could glide. During the experiment, the bracket with the sphere was immersed in a transparent vessel with water. Voltage from a GZ-33 generator was supplied to the excitation coil, and the voltage frequency was controlled by an F-5080 frequency meter. The alternating-current value in the coil was determined by measuring the voltage across a series-connected standard R33 resistance using a V7-22 voltmeter.

At the beginning of the experiments, we studied the relation between the magnetic force $F$ acting on the core of the excitation coil and the current $I$. For this, a controlled direct current was passed through the coil and the force balancing the core was measured by the dynamometer. The measurements showed that at $I = -25$–$25$ mA, the force depends linearly on the current and can be approximated by the formula

$$F = A + BI,$$

where $A = 0.33$ and $B = 0.012$ N/mA.

In studying parametric oscillations, a preliminary analysis of natural frequencies of the system is of importance. Therefore, the dependence of the conditional period [2] of damped transverse oscillations on spring tension in air and water was studied. At a specified spring tension, we excited oscillations of the sphere illuminated with a laser beam. The shadow from the sphere was projected on the photomultiplier detector, and the period of current change was measured with an F-5080 frequency meter. Figure 2 shows an experimental curve of the conditional period of damped oscillations versus spring tension.

The regions of parametric resonance were determined by the following procedure. At specified string tension $F_0$, alternating current of constant value $I$ was passed through the excitation coil. Then, by changing the generator frequency, the frequency $1/T$ was measured at which a parametric resonance of the sphere arose. Figures 3 and 4 show results of measurements performed for various string tensions. It follows from these figures that in the case of oscillations in air, the width of the resonance region decreases with growth in the region of parametric

Perm' State University, Perm' 614600. Translated from Prikladnaya Mekhanika i Tekhnicheskaya Fizika, Vol. 43, No. 3, pp. 85–87, May–June, 2002. Original article submitted November 1, 2001.

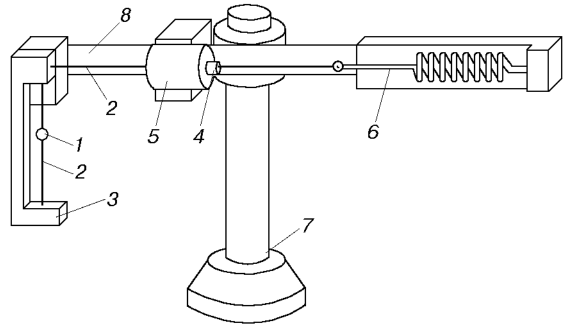


Fig. 1. Diagram of experimental installation: 1) sphere; 2) string; 3) bracket; 4) core; 5) excitation coil; 6) spring dynamometer; 7) pillar; 8) guide.

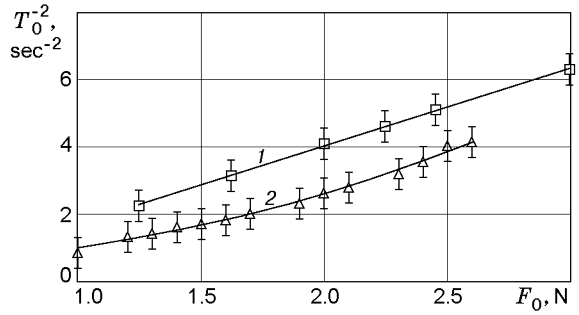


Fig. 2. Conditional period of damped oscillations of the sphere $T_0$ vs. the string tension $F_0$ in air (1) and in water (2).

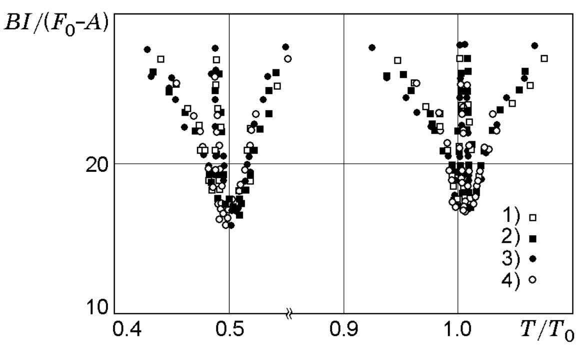


Fig. 3

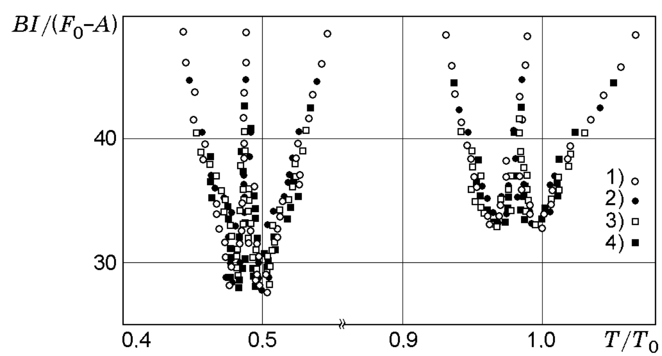


Fig. 4

Fig. 3. Regions of parametric instability in air for $F_0 = 1.5$ (1), 1.7 (2), 2 (3), and 2.3 N (4).

Fig. 4. Regions of parametric instability in water for $F_0 = 1.24$ (1), 1.5 (2), 1.7 (3), and 2.1 N (4).

instability. This result agrees with the well-known calculation data [3, 4]. However, for oscillations in water, an inverse relationship is observed. There is a narrow stability region in each resonance region. This is probably due to the presence of two close natural frequencies of transverse oscillations of the sphere, which, in turn, is due to variation of the initial shape of the sphere.

## REFERENCES

1. L. D. Landau and E. M. Lifshits, *Course of Theoretical Physics*, Vol. 6: *Fluid Mechanics*, Pergamon Press, Oxford-Elmsford, New York (1987).
2. S. P. Strelkov, *Introduction to Oscillation Theory* [in Russian], Nauka, Moscow (1964).
3. L. D. Landau and E. M. Lifshits, *Mechanics* [in Russian], Nauka, Moscow (1965).
4. M. I. Rabinovich and D. I. Trubetskov, *Introduction to Oscillation and Wave Theory* [in Russian], Nauka, Moscow (1984).