Foundations of Engineering Mechanics

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Engineering Vibration Analysis

Worked Problems 1

Translated by G.I. Merzon and V.A. Chechin

With 312 Figures

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Preface

Theory of vibrations belongs to principal subjects needed for training mechanical engineers in technological universities. Therefore, the basic goal of the monograph "Advanced Theory of Vibrations 1" is to help students studying vibration theory for gaining experience in application of this theory for solving particular problems. Thus, while choosing the problems and methods to solve them, the close attention was paid to the applied content of vibration theory.

The monograph is devoted to systems with a single degree of freedom and systems with a finite number of degrees of freedom. In particular, problems are formulated associated with determination of frequencies and forms of vibrations, study of forced vibrations, analysis of both stable and unstable vibrations (including those caused by periodic but anharmonic forces). The problems of nonlinear vibrations and of vibration stability, and those related to seeking probabilistic characteristics for solutions to these problems in the case of random forces are also considered. Problems related to parametric vibrations and statistical dynamics of mechanical systems, as well as to determination of critical parameters and of dynamic stability are also analyzed.

As a rule, problems presented in the monograph are associated with particular mechanical systems and can be applied for current studies in vibration theory. Allowing for interests of students independently studying theory of vibrations, the majority of problems are supplied with either detailed solutions or algorithms of the solutions.

While preparing the manuscript of "Advanced Theory of Vibrations 1", lectures given by the author to students of the Applied Mechanics cathedra of Bauman Moscow State Technological University, Moscow, Russia were partly used. These lectures were published in Russian as a textbook (V. Svetlitsky, 1994) and formed a basis of the present monograph.

The monograph is intended to students, post-graduate students, and teaching staff of technological universities. It can also be useful for mechanical engineers who apply theory of vibrations in their everyday practical work.

Valery Svetlitsky
Moscow, September 2003

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BASIC NOTATION

A	vibration amplitude;
A_{11}	bending stiffness of a rod;
A_{22}	bending stiffness of a rod with respect to the y axis (or x_2 axis);
A_{33}	bending stiffness of a rod with respect to the z axis (or x_3 axis);
C	capacitance; capacitor; capacity;
C	coefficients;
c	bending stiffness; torsional stiffness; spring rate:
D	variance; diameter of a disk, cylinder, wheel;
d	internal diameter; wire diameter;
E	Young modulus;
F	cross-sectional area;
F_0	amplitude of a perturbing force;
$F(t)$	perturbing force;
G	shear modulus;
g	free fall acceleration;
H	Heaviside function
I, i	electric-current intensity;
I_0	zero-order Bessel function of the first kind;
Y_0	zero-order Bessel function of the second kind;
J	moment of inertia;
J_x, J_y, J_p, J_k	geometric characteristics of the rod cross section;
K	correlation function; Krylov function;
k	rigidity of an elastic base;
L	inductance;
l	length;
M	moment of force;
M_1, M_2, M_3	torque and bending moments;
m	mass;
$P, P(t)$	force;
P_1, P_2, P_3	components of a concentrated force in the related coordinate system;
$P_{x1}, P_{x2},, P_{x3}$	components of a concentrated force in a Cartesian coordinate system;
p_i, λ_j	eigenfrequency (natural frequency); free vibration frequency;
Q	force; generalized force;
Q_1, Q_2, Q_3	axial force and cutting forces, respectively;

q	generalized coordinate;
q_1, q_2, q_3	components of a distributed load in a related coordinate system;
q_{x1}, q_{x2}, q_{x3}	components of a distributed load in a Cartesian coordinate system;
R	dissipative Rayleigh function; electric resistance; radius of curvature;
r	radius;
S	spectral density;
T	kinetic energy; vibration period; tension; tension force;
t	time;
U	voltage;
v	velocity;
v_*	ultimate velocity; critical velocity;
W	transfer function;
w	linear acceleration;
X, Y, Z	displacements in the directions of x, y, z coordinate axes;
$Y_{(*)}$	Lalplace transform of an original;
α	coefficient of viscous friction; angle of attack;
δ	logarithmic decrement; Dirac delta-function;
δ_{ij}	displacement of a point in the direction i under the action of a unit force in the direction j;
μ	small parameter; coefficient of dynamic viscosity; coefficient of Coulomb friction;
Π	potential energy;
ρ	density of a material;
σ	normal stress; mean-square deviation;
τ	time; tangential stress;
Φ	magnetic flux;
φ	angular displacement;
$\Omega, \dot{\varphi}$	angular velocity;
ω	frequency of free vibrations; angular velocity;
ω_*	critical angular velocity;
$\mathfrak{M}_1, \mathfrak{M}_2, \mathfrak{M}_3$	components of a concentrated moment in a related coordinate system;
$\mathfrak{M}_{x1}, \mathfrak{M}_{x2}, \mathfrak{M}_{x3}$	components of a concentrated moment in a Cartesian coordinate system;