HYDRAULIC SYSTEMS ANALYSIS
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Preface

Engineering design calculations are usually based on approximations and simplifying assumptions rather than being exact and precise so as to ensure that results are obtained quickly and economically. Prerequisites of suitable calculation procedures are that they give results of sufficient accuracy for their purpose but are in no danger of being misleading. In the case of hydraulic systems and servomechanisms, one such technique for carrying out design calculations is based on the method of linear analysis. With this method the characteristics of the various components of any device are represented in the form of linear equations which are then taken together in order to predict how a completed system will behave. The actual behaviour of the practical device may be somewhat different from that predicted but the differences should be only in detail and not in essence.

This book traces the constituent features involved in applying linear methods to hydraulic mechanisms. A step-by-step approach is adopted with no attempt made to convert the text into a reference book. Involved are certain aspects of the subjects of dynamics and of fluid mechanics combined with the basic concepts of linear control theory and a few electrical ideas (for coping with electrohydraulics).

The text concentrates on this so-called 'small perturbation' or 'small excursion' or linearised analysis whose use in hydraulics has been developed in the past by various research workers. One pioneer in this field, under whose aegis the author has now worked for some years, is Professor J. K. Royle. More advanced techniques of analysis have also H. E. Merritt evolved and one book *Hydraulic Control Systems* by H. E. Merritt, dealing with both linear and other methods, is particularly recommended for further reading.

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J. D. Stringer
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Contents

Nomenclature

a	cross-sectional area of pipe (also a coefficient)
A	net area of piston
B_c	magnetic flux density
c_r	radial clearance
C	capacitance
C_1, C_2	constants
C_d	discharge coefficient
C_h	specific heat
d	diameter
D	$\equiv \mathrm{d}/\mathrm{d}t$
e	electrical potential
E	Young's modulus
f	fluid friction factor
F	force
g	gravity acceleration
g_0	force/mass conversion factor
G	an acceleration
h	a coefficient
i	$=(-1)^{1/2}$
I	electrical current
I_c	electrical control current
J	moment of inertia
k	a constant
K	a constant
K_q	valve flow coefficient
K_c	valve pressure–flow coefficient
L	leakage coefficient
m	a mass
M	a mass
n	angular speed (rad/s)
N	a magnitude
N_c	number of turns
p	complex operator
P	pressure or pressure difference (with various suffixes)
q	volume flowrate
q	rate of change of q
Q	heat transfer rate or quantity of heat
r	radius

R	electrical resistance
(Re)	Reynolds' number
s	complex operator
t	time
T	time constant
u	valve underlap
u_1, u_2	specific internal energies
v	velocity
v_s	sonic velocity
V	volume
W_x	external work
x	a displacement
y	a displacement
z	height above some datum
$\mathscr{f}$	viscous friction rate
$\mathscr{G}$	a gear ratio
$\mathscr{J}$	Joule's equivalent
ℓ	length
$\mathscr{L}$	inductance
$\mathscr{M}$	amplitude ratio
$\mathscr{r}$	a ratio
$\mathscr{t}$	temperature
α	a ratio
α_p	pump capacity
β	bulk modulus
γ	angular deflection
δ_m	motor capacity
Δ	a change or difference of
ε	eccentricity
ζ	damping ratio or factor
θ	a quantity with various suffixes (θ_i input, θ_o output, θ error)
λ	see equation C.2
μ	dynamic viscosity
ν	kinematic viscosity (also Poisson's ratio)
ρ	density
σ	$= 1/\beta$
τ	torque
ϕ	phase angle
ψ	poppet half angle
ω	a frequency (rad/s)
Ω	a constant velocity or rate of change