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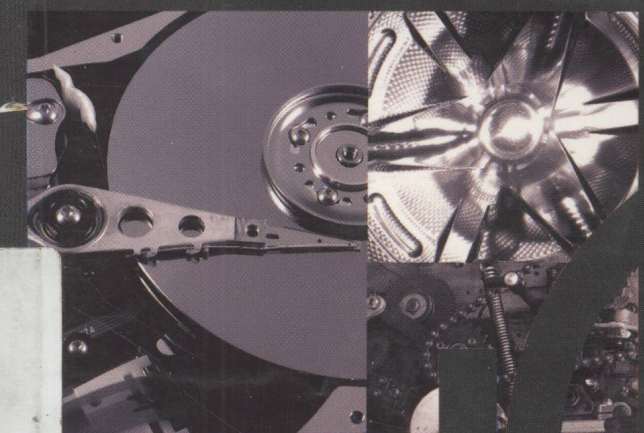
Mechanical Engineering Series

THEORY OF MACHINES

SECOND EDITION

S S RATTAN



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About the Author

S S Rattan is currently Assistant Professor in the Department of Mechanical Engineering at the National Institute of Technology, Kurukshetra. He did his postgraduation in Mechanical Engineering from Punjab Engineering College, Chandigarh in 1981. Since then he has been engaged in teaching and research. He obtained his Ph. D. degree from Kurukshetra University in 1995. He has authored several research papers, which have been published in national and international journals as well as in the proceedings of conferences in India and abroad. He is also the author of another book titled *Fluid Mechanics and Fluid Machines*. He is a member of the Indian Society of Theoretical and Applied Mechanics.

To the memory of
My Father

Preface to the Second Edition

The first edition of the book with twenty four reprints spoke volumes of its success and was certainly an index of its popularity among the teaching and student community. However, knowledge never ceases to expand and there is always scope for improvement. The first edition aimed at providing the subject matter in a concise, lucid and simple manner for easy comprehension by all. However, in order to make the book more purposeful and acceptable to a wider section of users, the revised edition includes elegant methods involving vector and complex numbers usually preferred by those who excel in mathematical skills. Such methods frequently lead to computer-aided solutions of the problems. However, those who do not wish to adopt these methods can easily skip them while reading the book.

In the present edition, apart from rewriting some of the previous sections, several new sections have been added in almost all the chapters. Many new worked examples have been incorporated. The computer programs have been rewritten in *C*, the most widely used language today. Theoretical questions have been added to the exercises. Each chapter now has a summary at the end. Also, an appendix containing objective-type questions has been added. In spite of addition of a large amount of material, care has been taken to let the book remain concise and compact. All the previous figures have been redrawn. Effort has also been made to remove errors that had arisen due to misprinting in the earlier edition.

I acknowledge the efforts of the editorial and production staff of Tata McGraw-Hill Publishing Company Ltd. for bringing out the new edition in an excellent format. I am grateful to all the teachers and students who have provided several valuable suggestions for the improvement of the book.

Further comments and suggestions on the new edition are welcome.

S S Rattan

Preface to the First Edition

Mechanisms and machines have considerable fascination for most students of mechanical engineering since the theoretical principles involved have immediate application to practical problems. The main objective of writing this book has been to present the concepts in a logical, innovative and lucid manner. The basic theory presented in the book has been evolved out of simple and readily understood principles. A sincere effort has been made to maintain physical concepts in the various derivations. The use of simple mathematical methods instead of more elegant but less obvious methods has been preferred so that those with limited mathematical skill can easily understand the exposition.

An effort has been made to give a balanced presentation of the graphical and algebraic approaches. The method chosen is that which gives a sufficiently accurate solution with the least labour. Graphical techniques have been used frequently along with the simple algebraic methods as they usually economise on effort and time. The graphical differentiation technique given in the chapter on acceleration analysis would be of considerable help to the students in their practical classes.

Computers are increasingly playing a significant role in the modern world of advanced technology. Some computer-aided problem-solving techniques have been given in the chapters on computer-aided analysis and synthesis of mechanisms.

A number of worked examples have been included to reinforce the concepts. The International System of Units (SI) has been adopted throughout the book. A bibliography at the end has been added for the convenience of students interested in additional information.

An author is always helped and influenced by many during the writing of his book. Dr N P Mehta, Dr O N Kaul and Dr B S Gill of Regional Engineering College, Kurukshetra, are only a few of many whose help I would like to acknowledge.

It is but natural that some errors creep into a work of such volume. I would appreciate if any errors and shortcomings are brought to my knowledge. Suggestions for the improvement of the book would be also welcome.

Finally, I would like to make an affectionate acknowledgement to my wife Neena, and my children Ravneet and Jasmeet, for putting up with it all so cheerfully.

S S Rattan

Symbols and Abbreviations

(Bold face letters indicate vector quantities. The same letters in italics indicate their magnitudes)

a	area, addendum
ab	velocity of B relative to A
A	area, amplitude
b	width
c	damping coefficient
C,**C**	couple
C	centre distance
d	diameter, pitch diameter, length
D	diameter, operator
e	eccentricity, maximum fluctuation of energy, piston offset
E	Young's modulus, effort, energy
f, **f**	acceleration
f	frequency, force, stress
F, **F**	force
F	degree of freedom, friction
g	acceleration due to gravity
G	gear ratio, modulus of rigidity, centre of mass
h	length, height, lift
I	mass moment of inertia, instantaneous centre
J	polar moment of inertia
k	radius of gyration
K	coefficient of fluctuation of speed, ratio
l	length
L	length, number of loops, lead
m	mass, module
M	mass
n	number, ratio, speed
N	rotational speed (rpm), number of links
p	pitch, pressure, circular pitch
P	power, pressure, diametral pitch, planet gear, number of pairs
q	torsional stiffness

r, **r**	radius
r	crank length, length
R, **R**	reaction
R	radius
s	displacement, stiffness, length
S	slip
t	title, thickness, number of teeth
T	title period, number of teeth
T, **T**	torque, tension
u	displacement
υ, **v**	velocity
w	width
w, **w**	weight
x	displacement
$\dot{x}$	velocity (derivative of x with respect to title)
$\ddot{x}$	acceleration
x, y, z	cartesian coordinates
X	displacement
y	deflection, amplitude
θ	angle, angle of lap, angle between shafts
$\dot{\theta}$	angular velocity
$\ddot{\theta}$	angular acceleration
α	angle, angle of approach
α, α	angular acceleration
β	angle, angle of recess
γ	angle, pitch angle
ψ	angle, helix angle
δ	angle, angle of dwell, angle of action, increment of a quantity, logarithmic decrement
μ	coefficient of friction
ω, ω	angular velocity (rad/ s)
π	mass density
λ	angle, lead angle of worm
ε	transmissibility
ζ	damping factor
φ	angle, pressure angle, angle of friction
π	3.1416
η	efficiency
Δ	displacement
Σ	sum of quantities

Subscripts

1, 2 etc.	number of degrees of freedom
a	ascent approach, addendum, axial arm
ab	A relative to B
A	annular gear
b	binary link, base circle

c	cam, connecting rod, centrifugal, centripetal, crossed belt, countermass, critical
d	descent, damped
e	engine
f	flank, friction
g	gear, gyroscope, gravity
h	horizontal
i	inner, input, inertia
m	mean
min	minimum
max	maximum
n	nose, normal, natural
o	initial value, output, outer, open belt, other links, without friction
p	primary, pinion, piston, crankpin, pitch line
P	planet
r	roller, recess, rack, rod, radial, resultant
s	sleeve, spring, secondary
ss	steady state
S	sum
t	tensile, ternary link, tangential
v	vertical
w	wheel
x	*x* component
y	*y* component
z	*z* component

Superscripts

c	centripetal
l	leading
t	trailing, tangential, total
s	sliding
cr	coriolis

Abbreviations

CF	complimentary function
IC	internal combustion
IDC	inner-dead centre
KE	kinetic energy
MF	magnification factor
MOI	moment of inertia
ODC	outer-dead centre
PE	potential energy
SE	strain energy
SHM	simple harmonic motion
TF	transfer function
VR	velocity ratio

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