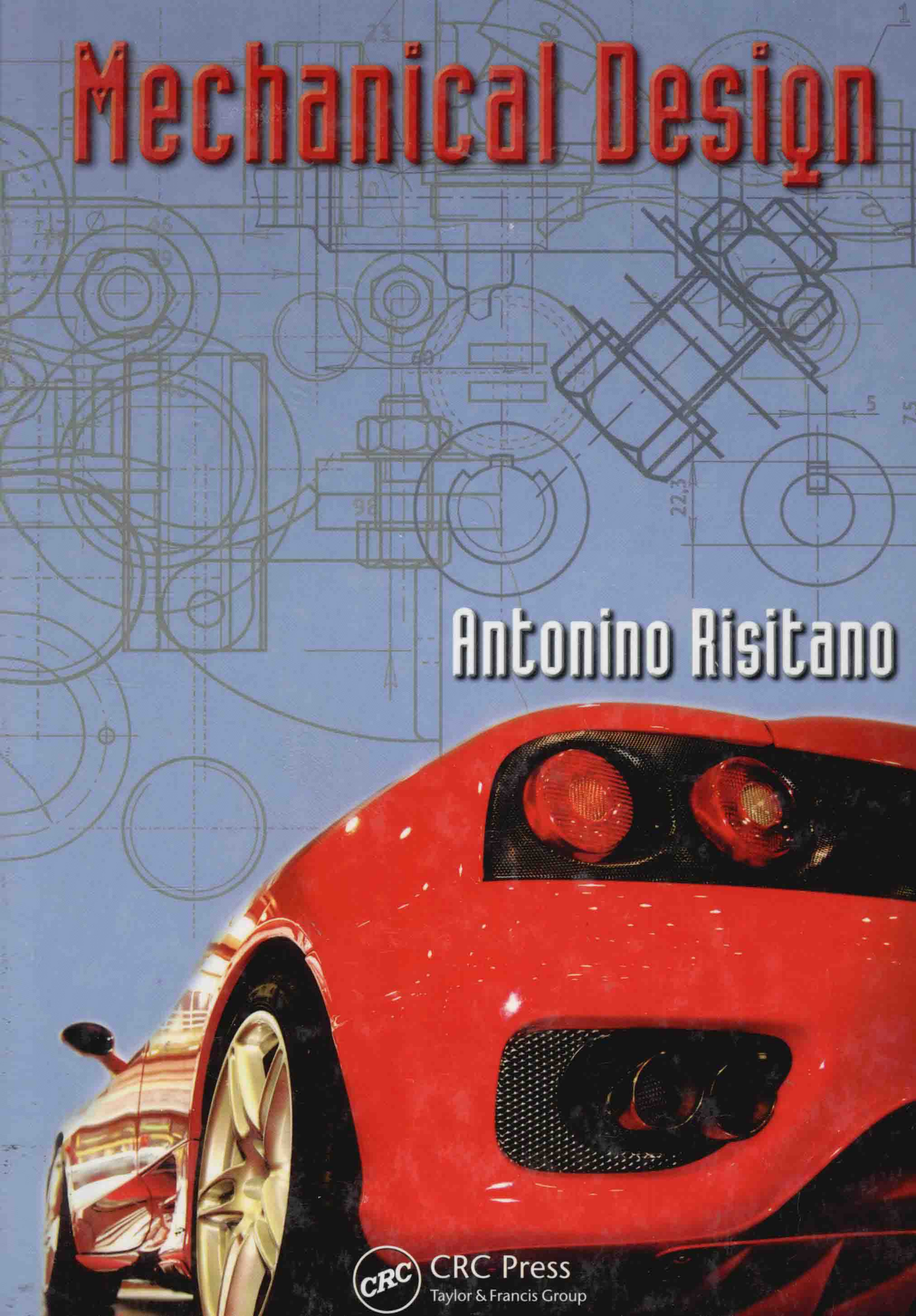
Mechanical Design

Antonino Risitano



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Preface

This collection is the result of a decade of continual elaboration and revision of teaching notes at the earnest request of students of the machine construction course that has been run for several years now at the Faculty of Engineering of the University of Catania for mechanical engineering students.

Beginning with current training needs, the various parts of the book's arguments are dealt with in such a way as to be accessible to all students of courses in industrial engineering. The goal and the hope are that this collection of notes can be used not only by students of the mechanical engineering course but by all those whose training requires them to acquire the fundamentals of the design of mechanical components.

For this course, the textbooks have always been written by Prof. R. Giovannozzi, (the "maestro"), and the review of notes served mainly to help students get the most out of the texts, supporting them above all in those areas where, by experience, they have the most difficulty. Furthermore, the notes have also served to shorten study time, an important contribution given the requirements of the new teaching regulations.

I have always used Prof. Giovannozzi's texts for reference, because of all the sources consulted, although some inspired me (particularly those by American authors), his proved the most complete in dealing with these subjects; they remain excellent texts, and are certainly stimulating for students. The approach and methodology continue to be extremely valid, and in my opinion cannot be replaced by those proposed in other texts.

The analytical approach to the subjects is still based on algorithms from traditional calculus without reference to more current methodologies, which, however, students do come across in other courses. This choice was made so as not to deprive students of the ability to use simple models and calculations that are reliably effective and helpful at times when more complicated algorithms or well-known commercial programs need to be used.

The aim is still to induce students to be logical, starting by analyzing the physical problem with the most appropriate schematic, and ending with a constructional definition of the component in need of planning.

To guarantee due completeness of subject requirements, it was considered essential on occasion to add references to current norms, or more advanced approaches to calculation (e.g., cogwheel resistance tests, lubrication theory, brake measuring) wherever necessary, compared to the text references. In such cases, however, the calculations suggested in Giovannozzi's text are side-by-side with those obtained by the most recent methods so that students can compare. Often, construction details in the maestro's texts are still quite rightly valid references today.

To comply with the requirements of the new teaching regulations, the principal materials tests and simple stress states are outlined prior to the study of fatigue, which refers to fine-tuning methods developed at Catania's Faculty of Engineering. The hope is that other industrial engineering students—not just the mechanical engineers—can thus benefit from the teachings and procedures of the maestro.

Typical machine construction course subjects/modules occupy the greater part of this book (mechanical system component planning), but two preliminary sections enhance its appeal: the methodological set-up of the project (traditional or more recent), and the project criteria that take into account the environment. These two parts are echoed in a work published in the U.S. authored by myself, together with Prof. G. La Rosa and Ing. F. Giudice, who have collaborated in editing that work.

Finally, as mentioned above, this work should be seen as a collection of notes on lessons conducted by the author and inspired by Giovannozzi's book, without which the notes are inadequate.

"The intelligence of the reader" in using the collection, as the maestro often said, might allow all that is contained in the Giovannozzi manual to conform to current—above all professional—needs.

A case study in which theoretical methods and tools are applied to the planning of real mechanical systems is reported.

Since there is always room for improvement, we welcome suggestions from our readership. Please address these to the author at arisitan@diim.unict.it

Symbols

Symbols

A	Area
a	Distance
B	Coefficient, life
b	Distance, Weibull shape parameter
C	Basic load rating, bolted-joint constant, center distance, coefficient of variation, column end condition, constant, correction factor, heating coefficient, specific heat, spring index
c	Distance
d	Diameter
D	Diameter
E	Energy, error quantity, modulus of elasticity
e	Eccentricity
F	Force
f	Coefficient of friction, deflection, frequency
G	Modulus of rigidity
g	Acceleration due to gravity
H	Heat, power
HB	Brinell hardness
H	Distance, film thickness
I	Integral, mass moment of inertia, second moment of area
J	Mechanical equivalent of heat, polar second moment of area
J_p	Polar second moment of area
K	Stress-concentration factor, stress-correction factor, torque coefficient
k	Endurance-limit modifying factor
L	Length, life
l	Length
M	Moment, bending moment
M_t	Torsional moment
m	Mass, slope, strain-strengthening exponent, factor of safety
N	Normal force, number, rotational speed
n	Factor of safety–load factor, rotational speed
P	Force, unit-bearing load
p	Pitch, pressure, probability
Q	First moment of area, imaginary force, volume
q	Distributed load, notch sensitivity
R	Radius, reaction force, reliability, Rockwell hardness, stress ratio
r	Correlation coefficient, radius
S	Sommerfeld number, strength
s	Distance, sample standard deviation
T	Temperature, tolerance, torque
t	Distance, time
U	Strain energy
u	Unit strain energy
V	Linear velocity, shear force
v	Linear velocity
W	Cold-work factor, load, weight
w	Distance, unit load

X	Coordinate
x	Variate of x
c_1	Surface factor
c_2	Size factor
P_{crit}	Euler critical load
i	Interference
W	Section modulus
α_i	Stress concentration factor
β_i	Fatigue stress concentration factor
σ	Normal stress
τ	Shear stress
τ_{am}	Allowable shear
σ_{am}	Allowable stress
σ_r	Ultimate stress
σ_s	Yield stress
σ_0^I	Fatigue limit for $R =$
η	Notch sensitivity
λ	Slenderness ratio
E_l	Energy required for fatigue fracture
σ_0	Fatigue limit for $R = -1$ (limit stress above which some crystal is plasticized)
σ_i	Minimum stress
σ_s	Maximum stress
σ_m	Mean stress
σ_p	Plastic stress
$\sigma_{0,2}$	Yield stress
ε_p	Plastic strain
R	Tress ratio
N	Current number of cycles
N_f	Numbers of cycles to failure
ε	Strain
ε_0	Strain corresponding to σ_0
α	Coefficient of linear thermal expansion
T	Surface temperature
T_a	Ambient temperature
T_0	"Limit temperature" (corresponding to end of thermo-elastic phase)
ΔT	Temperature increment of the hottest area
E	Modulus of elasticity
υ	Modulus of Poisson
ρ	Density
c_ε	Specific heat for constant strain
c_σ	Specific heat for constant stress
k_c	Thermal convention coefficient
K_m	Thermo-elastic constant
ΔQ_p	Plastic energy liberated as heat
dQ_e	Energy liberated as heat
V	Land volume
V_p	Plastic volume
t_0	Thermo-elastic time (corresponding to T_0)
t_r	Time between thermo-elastic time t_0 and complete test time t_f
$t_f = t_0 + t_r$	Complete test time

Recurrent Symbols for Chapter 15

a	Addendum
u	Dedendum
g	Clearance
m	Diameter pitch
m_0	Diametral tool pitch, base pitch
n	Number of teeth
p	Pitch
pf	Pitch on the base circle
r	Current radius
R	Pitch radius
D	Pitch diameter
ρ	Base radius
θ	Angle of action
δ	Pressure segment
d	Distance center to center
s	Tooth thickness
τ	Gear ratio
φ	Current angle
λ	Addendum tool factor
v	Velocity
x, x'	*Correction factors*

AGMA Symbols
(by J. E. Shigley and C. R Mischke, *Mechanical Engineering Design*, Fifth Edition)

C_a	Application factor
C_f	Surface-condition factor
C_H	Hardness-ratio factor
C_L	Life factor
C_m	Load-distribution factor
C_p	Elastic coefficient
C_R	Reliability factor
C_s	Size factor
C_T	Temperature factor
C_V	Velocity factor (for use in Equation 14.14)
C_v	AGMA dynamic factor
E	Modulus of elasticity
F	Face width
H	Power
H_{BG}	Brinell hardness of gear tooth
H_{BP}	Brinell hardness of pinion tooth
I	Geometry factor
J	Geometry factor
K_a	Application factor
K_f	Fatigue stress-concentration factor
K_L	Life factor
K_m	Load-distribution factor
K_R	Reliability factor
K_S	Size factor
K_T	Temperature factor
K_V	Velocity factor (for use in Lewis equation only)
K_v	AGMA dynamic factor

S_C	Endurance stress
S_c	AGMA surface fatigue strength
S_t	AGMA bending strength
T	Tooth thickness
V	Pitch-line velocity
Wt	Transmitted (tangential) load
Y	Lewis form factor
Z	Length of line of action
υ	Poisson's ratio
σ	Tooth bending stress
σ_{all}	Allowable bending stress
σ_C	Surface compressive stress
σ_c	Contact stress (AGMA formula)
$\sigma_{c,all}$	Allowable contact stress
Φ	Pressure angle

Contents

PART II The Properties of Design Materials

PART IV Design of Components and Mechanical Systems