Engineering Practice with Oilfield and Drilling Applications

Donald W. Dareing

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To Kristin:

My wonderful companion, whose energy, integrity, support, and reliability go beyond measure.

Contents

Preface

Engineers are trained to understand the fundamental principles of mechanics and mathematics. These tools provide a background of knowledge for making professional decisions. The tools of engineering science apply across most engineering disciplines. The key to their application is visualizing a reasonable mathematical model for the problem at hand. Freebody diagrams are helpful in this regard. Mathematical solutions follow, leading to reasonable engineering results. Typically, there is only one answer, so each problem is closed-ended.

On the other hand, design and problem-solving are open-ended. There are many possible solutions and alternatives must be created. While each engineering design is different, the approach is the same. An objective of this book is to explain the engineering design process and show how to apply basic engineering tools.

The book contains three parts.

Part I	Engineering Design and Problem-Solving
Part II	Power Generation, Transmission, Consumption
Part III	Analytical Tools of Design

Part I gives a systematic process for developing an engineering design. The application of engineering tools is illustrated during the conceptual and preliminary activities of design. Concept evaluation and selection are explained. Visualizing a total device or any system in terms of its subsystems is helpful in creating a design. Key considerations in finalizing a design are implementing feedback from test results or other evaluation sources, finalizing a design and presentation of final manufacturing drawings.

Every machine has (i) a prime mover or power source, (ii) mechanisms to transmit energy and (iii) energy consumed by forming the final product, plus friction. Part II covers Power Generation, Transmission, and Consumption.

Part III contains useful tools of engineering mechanics. Each selected topic goes beyond the traditional tools of design. Mathematical modeling and methods of solution are of historical significance. Each topic is supplemented with key references for additional background information.

Physical responses of engineering systems are predictable through science and mathematics. This one thing makes it possible to design modern structures and machinery to a high degree of reliability. The first scientifically based engineered bridge is the Eads Bridge which spans the Mississippi River at St. Louis. It was designed and constructed by James Eads. Construction began in 1867. It was dedicated in 1874 and is still in use today.

My goal in writing this book was to document the essence of engineering practice. The manuscript is a condensation of lecture notes developed over years of teaching across the mechanical engineering curriculum and industrial practice in the petroleum industry. It is written for undergraduate and graduate students and as a reference for practicing engineers.

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Nomenclature

a	acceleration
BF	buoyancy factor
c	distance to outside beam surface, damping coefficient
c_{cr}	critical damping coefficient
E	modulus of elasticity
E_m	energy per pound
F	applied force, axial internal force at drill pipe-collar interface above hydrostatic
FS	safety factor
f	friction force, vibration frequency
F_B	axial force in pipe (lower end)
F_{cr}	critical buckling force
f_n	natural frequency, cps
G	modulus of rigidity, angular momentum
h	lubrication film thickness, enthalpy
h_f	friction head
H	linear momentum, elevation
I	area moment of inertia
Im	impulse
J	angular moment of inertia of a cross section, angular mass moment of inertia
k, K	local (modal) mechanical spring constant
K_0	stress intensity factor
L	length
m, M	local (modal) mass, bending moment
N	force
N_R	Reynolds number
p	pressure
P	unit force (force per area), power, diametral pitch of gears
Q	moment of area above shear surface, heat, compressive force
$Q_{eff} = Q + (p_iA_i - p_oA_o)$	plus sign means compression
q	roller bearing exponent
r	radial position, frequency ratio (ω/ω_n)

S	section modulus of a cross sectional area, Sommerfeld number, entropy
t, T	time, torque, period of oscillation
$T_{eff} = F_B + wx + (L-x)(A_0\gamma_0 - A_i\gamma_i)$	marine riser (x measured up from bottom)
$T_{eff} = F_B + wx + (L-x)w_m$	drill pipe (x measured up from bottom)
TR	transmissibility
U, V	principal axis of inertia of a cross section, V also indicated shear force
V	velocity, also total potential energy
w, W	distributed load on a beam, weight of a discrete body
x, y, z	reference frame
X, Y, Z	reference frame
$[X]$	modal matrix
$x(t)$	local response
Z	viscosity (cp)

Greek Symbols

δ	displacement, log decrement
μ	viscosity, coefficient of friction
ω	rotational speed, circular frequency
ω_n	natural circular frequency
θ	angular position
σ	normal stress
τ	shear stress
ε	normal strain
γ	shear strain
ζ	damping factor
ν	Poisson's ratio
$\eta(t)$	modal response
σ_a	allowable design stress
σ_{yld}	yield strength

$$\zeta = \frac{x}{L}$$

$$\beta = \frac{(F_B + LA_0\gamma_0 - LA_i\gamma_i)L^2}{EI}$$

$$\alpha = \frac{(w - A_0\gamma_0 + A_i\gamma_i)L^3}{EI}$$

$$\Theta = \frac{TL}{EI}$$

m

n

o

p

q

r

s

t