Design Concepts and Strategies

for Precision Engineering

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Contents

List of symbols

Quantity	Unit	Description
α	$\frac{1}{\mathrm{K}}$	coefficient of thermal expansion
α	$\frac{\mathrm{rad}}{\mathrm{s}^2}$	angular acceleration
ε	–	strain
ε	–	emissivity
$\varepsilon_{\mathrm{rr}}$	–	ratio of out of roundness of elliptical contact area
δ	m	total displacement of a system
δ_{c}	m	deformation due to compliance
δ_{decr}	m	decrement of amplitude
δ_{p}	m	play
δ_{sh}	m	displacement due to shortening
δ_{st}	m	static displacement due to dynamic force amplitude F_0
δ_{th}	m	deformation due to thermal effects
δ_{vp}	m	virtual play
ζ	–	damping ratio
η	$\mathrm{Pa} \cdot \mathrm{s}$	dynamic viscosity
η	–	loss coefficient
θ	rad	angle of deflection
λ	$\frac{\mathrm{W}}{\mathrm{m} \cdot \mathrm{K}}$	thermal conductivity
μ	–	coefficient of friction
ν	–	Poisson's ratio
ξ	–	correction factor for stress in notch hinge

Quantity	Unit	Description
ρ	$\frac{\text{kg}}{\text{m}^3}$	density
σ	Pa	normal stress
τ	Pa	shear stress
ϕ	rad	phase angle
φ	rad	rotational angle
ω	$\frac{\text{rad}}{\text{s}}$	angular velocity
ω_d	$\frac{\text{rad}}{\text{s}}$	damped frequency
ω_n	$\frac{\text{rad}}{\text{s}}$	natural frequency
A	m^2	area
a	$\frac{\text{m}}{\text{s}^2}$	acceleration
a	–	ratio of distance of pole to length of flexure
a	$\frac{\text{m}^2}{\text{s}}$	thermal diffusivity
a_{AB}	m	half-width of rectangular contact for objects A and B
b	m	width of cross section
C_{w}	m^6	warping constant
C_p	$\frac{\text{J}}{\text{kg}\cdot\text{K}}$	specific heat capacity
c	$\frac{\text{N}\cdot\text{s}}{\text{m}}$	damping constant
c_{c}	$\frac{\text{N}\cdot\text{s}}{\text{m}}$	critical damping constant
D	–	specific damping capacity
d	m	diameter
d_{A}	m	depth of point of interest in cylinder A
d_{B}	m	depth of point of interest in cylinder B
E	Pa	modulus of elasticity
E^*	Pa	combined modulus of elasticity
E_{r}	Pa	reduced modulus of elasticity
F	N	force
F_0	N	amplitude of dynamic force
f	Hz	frequency
$f_2(\varepsilon_{\text{rr}})$	–	correction factor as function of out of roundness
$f_3(\varepsilon_{\text{rr}})$	–	correction factor as function of out of roundness
f_{s}	–	form factor for shear in short beams
G	Pa	shear modulus
h	m	height of cross section
h	m	width of the neck of a notch hinge
I	m^4	second moment of inertia

Quantity	**Unit**	**Description**
J	m^4	polar moment of inertia
K	m^4	torsional stiffness factor
K	–	wear coefficient
k	$\frac{\mathrm{N}}{\mathrm{m}}$	translational stiffness
k'	$\frac{\mathrm{N}}{\mathrm{m}}$	reduced translational stiffness of element at application point
k_r	$\frac{\mathrm{N \cdot m}}{\mathrm{rad}}$	rotational stiffness
k'_r	$\frac{\mathrm{N \cdot m}}{\mathrm{rad}}$	reduced rotational stiffness of element about application axis
$k_{r_{\mathrm{sys}}}$	$\frac{\mathrm{N \cdot m}}{\mathrm{rad}}$	system stiffness for rotation
k_{sys}	$\frac{\mathrm{N}}{\mathrm{m}}$	system stiffness for translation
k_{i}	$\frac{\mathrm{m}^2}{\mathrm{N}}$	specific wear rate
L	m	length
L^*	m	length of reinforced flexure between pivot points
L_{eff}	m	effective length for buckling
L_{sf}	m	length of material from end to slip-front
M	$\mathrm{N \cdot m}$	bending moment
m	kg	mass
n	–	number of elements
p	–	ratio of rigid part to length of reinforced flexure
p	Pa	contact pressure
p_{max}	Pa	highest contact pressure in rolls
Q	J	heat energy
$\dot{Q}_e$	W	heat transfer
q	$\frac{\mathrm{N}}{\mathrm{m}}$	force per length
R_{gyr}	m	radius of gyration
R_{c}	m	reduced radius for rectangular contact
R_{e}	m	effective radius for elliptical contact
Rx	rad	orientation with respect to x-axis
Ry	rad	orientation with respect to y-axis
Rz	rad	orientation with respect to z-axis
r	m	radius
T	$\mathrm{N \cdot m}$	torque
T	K	temperature
t	m	thickness
U	J	energy
u	m	axis in additional coordinate system perpendicular to v

Quantity	Unit	Description
u	$\frac{\mathrm{J}}{\mathrm{m}^3}$	energy density
V	m^3	volume
v	$\frac{\mathrm{m}}{\mathrm{s}}$	speed or velocity
v	m	axis in additional coordinate system perpendicular to u
W	J	work
X	m	amplitude of motion of dynamic system
x	m	location of x coordinate
y	m	location of y coordinate
z	m	location of z coordinate

Foreword

Mechanical design has many aspects; teaching it has many more.

The recognition of a need for a design, the translation of that need into a question, translating the question into a mechanical specification and to come up with one or more ideas that could offer a solution to a problem. It is an extensive struggle with an often unclear list of requirements that must be met. Also available space and money often play a very prominent role. The physical laws play their part and often put a damper on the celebrations.

When educating designers, it is important to teach them how to find all the boundary conditions of the design and to minimise their impact without underestimating them and to take them into account in the designs. Although making design mistakes is the most functional learning experience, it is often possible to learn by studying the mistakes of others.

As a lecturer at Fontys University of Applied Sciences, Susan van den Berg discovered that striving for good didactics is very important. With this book, she makes a successful attempt to present a collection of the important principles in mechanical engineering, in an accessible manner. It encourages the reader to think about chosen design principles and offers a guide to assess and qualify a mechanical design. The book invites you to think for yourself and take a step to explore and understand the complex work field of a mechanical engineer. It gives simple experiments that provide insights into a number of important physical effects and proposes to apply relevant strategies.

Piet van Rens, May 2020