INTEGRATED COMPUTER-AIDED DESIGN OF MECHANICAL SYSTEMS

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To Eli and

Jenna Danielle

Preface

In this book, the author has presented an introduction to the practical application of some of the essential technical topics related to computer-aided engineering (CAE). These topics include interactive computer graphics (ICG), computer-aided design (CAD), computer-aided analysis (CAA) and computer-integrated manufacturing (CIM). Unlike the few texts available, the present work attempts to bring all these seemingly specialised topics together and to demonstrate their integration in the design process through practical applications to real engineering problems and case studies.

This book is the result of the author's research and teaching activities for several years of postgraduate and undergraduate courses in mechanical design of rotating machinery, computer-aided engineering, practical applications of finite elements, solid mechanics, engineering dynamics and properties of materials at Cranfield Institute of Technology, Oxford Engineering Science and the University of Manchester Institute of Science and Technology (UMIST). It was soon realised that no books on the most powerful and versatile tools available to engineering designers existed. To satisfy this developing need, this book, on the use of computers to aid the design process and to integrate design, analysis and manufacture, was prepared.

The main text examines the detailed design principles of the various mechanical components which are not peculiar to the present case studies but common to other fields of mechanical engineering. The design parameters necessary for successful operation are also considered and the steps taken to ensure maximum life and reliability of the components are outlined. Although every attempt has been made to verify the different designs, no responsibility can be accepted for their performance in practice.

Following a brief introduction of the terminology used, Chapter 2 provides a detailed description of the techniques adopted in three-dimensional automated modelling. Chapter 3 provides a detailed account of the computer-aided design of two practical case studies involving the design of (i) a centrifugal peening equipment and (ii) a fluid coupling. Throughout this work, both 3-D solid modelling and 2-D draughting were interactively utilised to create, manipulate and retrieve the different geometries. In view of its importance to design, analysis and manufacture, emphasis was given to solid modelling representation. Chapter 4 provides a truly practical introduction to the application of the finite element method to structural stress analysis of mechanical systems. In Chapter 5, complete static stress analysis and dynamic response studies are performed on the different designs examined. In particular, it was desired to demonstrate the versatility of the techniques adopted in data-handling during model creation, mesh definition and model checking aspects. Chapter 6 deals with the computer-integrated manufacturing aspects of the work using the same data base developed during the modelling stage. Some coverage is also provided for numerically controlled machines.

The book is intended for mechanical, industrial and manufacturing engineers, design engineers and engineering managers. The work is also intended for postgraduates undertaking mechanical, industrial, manufacturing and production engineering degrees. It is also useful for technologists, academics and researchers working in the field of CAD/CAM. The material included is largely self-contained and readers are required to have some basic knowledge of design, analysis and manufacture; their awareness of computers will also be valuable.

Finally, I wish to acknowledge the following organisations for giving permission to reproduce a few relevant diagrams: Structural Dynamics Research Corporation — SDRC (USA), Tilghman Wheelabrator (UK) and Vacu-Blast International (UK).

S. A. MEGUID

Contents

Principal Notations

A	Area of cross-section; area of cross-section of one-dimensional element
$[\boldsymbol{B}]$	Matrix containing the derivatives of shape functions
$[\boldsymbol{D}]$	Elasticity matrix (relating stresses and strains)
E	Young's modulus
$E^{(e)}$	Young's modulus of the (e)th element
F	Force
$\{\boldsymbol{F}\}$	Load vector
G	Modulus of rigidity
h	Convection heat transfer coefficient
I	Moment of inertia
$[J]$	Jacobian matrix
$[\boldsymbol{K}]$	Global stiffness matrix
$[\boldsymbol{K}^{(e)}]$	Element stiffness matrix
k	Thermal conductivity
L	Total length of bar
$\mathscr{L}$	Lagrange multiplier
$l^{(e)}$	Length of one-dimensional element (e)
N	Shape function
$\{\boldsymbol{p}\}$	Load vector
r, θ, z	Cylindrical polar co-ordinates
R	Radius
T	Temperature; torque; transpose
u, v, w	Respective components of displacements in x, y and z directions
V	Volume of a body

v	Velocity
W	Work done by external forces
x, y, z	Cartesian co-ordinates; global co-ordinates
Y	Yield stress
α	Coefficient of linear thermal expansion
γ	Shear strain
$\{\delta\}$	Displacement vector
ε	Strain
$\varepsilon^{(e)}$	Strain in the (*e*)th element
$\{\varepsilon\}$	Strain vector
ν	Poisson's ratio
ξ, η, ζ	Intrinsic co-ordinates
π	Strain energy of a solid body
$\pi^{(e)}$	Strain energy of the (*e*)th element
ρ	Density
σ	Stress
$\sigma^{(e)}$	Stress in the (*e*)th element
$\{\boldsymbol{\sigma}\}$	Stress vector
τ	Shear stress
ω	Frequency of vibration; angular velocity

Superscripts

(*e*)	Identifies the element number
$[\ ]^T$	Indicates the transpose of a matrix

Subscripts

s	Shot
t	Target