

Andreas Öchsner · Marco Öchsner

The Finite Element Analysis Program MSC Marc/Mentat

A First Introduction

 Springer

The Finite Element Analysis Program MSC Marc/Mentat

Andreas Öchsner · Marco Öchsner

The Finite Element Analysis Program MSC Marc/Mentat

A First Introduction

 Springer

Andreas Öchsner
Griffith School of Engineering
Griffith University
Southport, QLD
Australia

Marco Öchsner
Griffith School of Medical Sciences
Griffith University
Southport, QLD
Australia

ISBN 978-981-10-0820-7 ISBN 978-981-10-0821-4 (eBook)
DOI 10.1007/978-981-10-0821-4

Library of Congress Control Number: 2016934420

© Springer Science+Business Media Singapore 2016

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made.

Printed on acid-free paper

This Springer imprint is published by Springer Nature
The registered company is Springer Science+Business Media Singapore Pte Ltd.

*Nichtstun ist eine der größten und verhältnismäßig
leicht zu beseitigenden Dummheiten*

Franz Kafka (1883–1924)

Preface

This book is a short introduction to the general-purpose finite element program MSC Marc, which is distributed by MSC Software Corporation. It is a specialized program for nonlinear problems (implicit solver) which is common in academia and industry. The primary goal of this book is to provide a quick introduction to the software, based on simple examples. The documentation of all finite element programs nowadays contains a variety of step-by-step examples of different complexities. In addition, all software companies offer professional workshops on different topics. The intention of this book is not to compete with these professional offers and opportunities. We would rather like to focus on simple examples, often single-element problems, which can easily be related to the theory which is provided in finite element lectures. In that sense, it is rather a companion book to a classical introductory course in the finite element method.

Chapter 1 starts with some historical comments on the development of finite element software. Then, a short introduction into the steps of a finite element analysis as well as the graphical interface Mentat is provided. Chapter 2 introduces the simplest one-dimensional element, i.e., a rod which can only deform along its principal axis. The spatial arrangement is then treated to cover more practical problems. Chapter 3 covers simple beam elements which can deform perpendicular to their primary axis. These elements are then arranged as plane frame structures under the consideration of a generalized beam element which can elongate and deflect. Chapter 4 presents a higher order beam theory according to Timoshenko. This formulation considers the contribution of the shear force on the deflection. Chapter 5 extends the rod element to a two-dimensional plane elasticity problem. Chapter 6 introduces the two-dimensional equivalent of the simple beam, a classical plate. Chapter 7 covers three-dimensional elements in the form of hexahedrons. Chapter 8 introduces a nonlinear problem, i.e., the elasto-plastic deformation of rod elements. Chapter 9 summarizes a few advanced topics which are helpful for larger simulations or parametric studies.

The instructions provided in this book relate to the Marc/Mentat 2014.0.0 (64 bit) version. The graphical interface and the command structure might be

slightly different for older versions and in such case the reader is advised to adjust some of the given instructions. The same must be expected for future versions.

We look forward to receiving some comments and suggestions for the next edition of this introductory work.

Southport, QLD, Australia
December 2015

Andreas Öchsner
Marco Öchsner

Contents

1	Introduction to Marc/Mentat	1
1.1	Historical Comments on the Program Development	1
1.2	General Comments on Finite Element Analyses	1
1.3	Graphical User Interface	5
1.4	Using Units	9
1.4.1	SI Base Units	9
1.4.2	Coherent SI Derived Units	9
1.4.3	Consistent Units	9
1.4.4	Conversion of Important English Units to the Metric System	11
2	Rods and Trusses	13
2.1	Definition of Rod Elements	13
2.2	Basic Examples	13
2.2.1	1D Rod—Fixed Displacement	13
2.2.2	1D Rod—Fixed Point Load	21
2.2.3	1D Rod—Multiple Loadcases	22
2.2.4	Plane Truss—Triangle	27
2.3	Advanced Examples	30
2.3.1	Plane Bridge Structure	30
2.3.2	Transmission Tower Structure	34
3	Euler–Bernoulli Beams and Frames	39
3.1	Definition of Euler–Bernoulli Beams	39
3.2	Basic Examples	41
3.2.1	Beam with a Square Cross-Section	41
3.2.2	Beam with a Distributed Load	47
3.2.3	Portal Frame with a Distributed Load	50
3.3	Advanced Examples	54
3.3.1	Plane Bridge Structure with Beam Elements	54
3.3.2	Transmission Tower with Beam Elements	55
3.3.3	Beam Element—Generalized Strain and Stress Output	55

4	Timoshenko Beams	57
4.1	Definition of Timoshenko Beams.	57
4.2	Basic Example	59
4.2.1	Timoshenko Beam with a Square Cross-Section	59
4.3	Advanced Example	62
4.3.1	Beam Element—Generalized Strain and Stress Output	62
5	Plane Elements	67
5.1	Definition of Plane Elements.	67
5.2	Basic Examples	67
5.2.1	Plane Element Under Tensile Load	67
5.2.2	Simply Supported Beam.	71
5.3	Advanced Example	76
5.3.1	Mesh Refinement—Simply Supported Beam.	76
5.3.2	Stress Concentration	77
5.3.3	Stress Intensity/Singularity	82
6	Classical Plate Elements	87
6.1	Basic Examples	88
6.1.1	Plate Element Under Bending Load.	88
6.1.2	Simply Supported Plate Element	91
6.2	Advanced Example	94
6.2.1	Mesh Refinement—Simply Supported Plate	94
7	Three-Dimensional Elements	95
7.1	Definition of Three-Dimensional Elements	95
7.2	Basic Examples	95
7.2.1	Solid Under Tensile Load.	95
7.2.2	Simply Supported Solid	99
7.3	Advanced Example	102
7.3.1	Mesh Refinement	102
8	Elasto-Plastic Simulation	103
8.1	Fundamentals of Plastic Material Behavior	103
8.2	Basic Examples	105
8.2.1	Tensile Sample with Ideal-Plastic Material Behavior	105
8.2.2	Tensile Sample with Linear Hardening.	110
8.3	Advanced Example	113
8.3.1	Convergence of Tensile Sample with Linear Hardening	113
9	Advanced Topics	115
9.1	Procedure Files	115
9.2	Command-Line Execution.	115
9.3	Batch Processing	117

Contents	xi
Answers to Additional Questions	119
References	133
Index	135

Symbols and Abbreviations

Latin Symbols (Capital Letters)

A	Area, cross-sectional area, geometrical dimension
B	Geometrical dimension
A_s	Shear area
E	YOUNG's modulus
EI	Bending stiffness
F	Force, yield condition
G	Shear modulus
GA	Shear stiffness
GI_p	Torsional stiffness
H	Kinematic hardening modulus
I	Second moment of area,
K	Global stiffness matrix
K^e	Elemental stiffness matrix
L	Element length
M	Moment
N	Normal force
Q	Shear force
X	Global Cartesian coordinate
Y	Global Cartesian coordinate
Z	Global Cartesian coordinate

Latin Symbols (Small Letters)

a	Geometrical dimension
b	Geometrical dimension
c	Geometrical dimension
f	Column matrix of loads
h	Geometrical dimension

k	Yield stress
k_s	Shear correction factor
q	Distributed load
t	Geometrical dimension
u	Displacement
w	Specific work
x	Local Cartesian coordinate
y	Local Cartesian coordinate
z	Local Cartesian coordinate

Greek Symbols (Capital Letters)

Γ	Boundary
Ω	Domain

Greek Symbols (Small Letters)

α	Angle
β	Angle
γ	Shear strain
ε	Strain
κ	Curvature, isotropic hardening parameter
λ	Consistency parameter
ν	POISSON'S ratio
ρ	Density
σ	Stress
ϕ	Rotation
φ	Rotation

Mathematical Symbols

\times	Multiplication sign (used where essential)
$[\dots]$	Matrix
$[\dots]^T$	Transpose
$\text{sgn}(\dots)$	Signum (sign) function

Indices, Superscripted

\dots^e	Element
\dots^{el}	Elastic
\dots^{elpl}	Elasto-plastic

... ^{init}	Initial
... ^{pl}	Plastic

Indices, Subscripted

... _c	Compression
... _{eff}	Effective
... _{max}	Maximum
... _{nom}	Nominal
... _R	Reaction
... _s	Shear
... _t	Tensile

Abbreviations

1D	One-dimensional
2D	Two-dimensional
3D	Three-dimensional
BC	Boundary condition
FEM	Finite element method
SI	International system of units

Chapter 1

Introduction to Marc/Mentat

1.1 Historical Comments on the Program Development

The development of finite element software goes back to the early 60s when Richard MacNeal and Bob Schwendler in 1963 founded the MacNeal-Swendler Corporation (MSC). In 1965 MSC was awarded the original contract from NASA to commercialize the finite element analysis software known as Nastran (NASA Structural Analysis) [8]. Nastran is still today the workhorse for large *linear* simulations.

Marc was the first commercial *non-linear* general-purpose finite element program. The development of the Marc software is significantly connected with two scientists, namely i.e., Pedro V. Marcal and David Hibbitt. From the development of the Marc software, a competitive product called Abaqus emerged and Table 1.1 illustrates the common roots of both packages. Both packages have a similar core and are popular in research because the user can write user-subroutines in the programming language Fortran, which is the language of all classical finite element packages. This subroutine feature allows the user to replace certain modules of the core code and to implement new features such as constitutive laws or new elements.

1.2 General Comments on Finite Element Analyses

A finite elements analysis involves different steps and program modules. A user normally defines the computational model to be solved in a graphical interface, called the pre-processor. The geometry can either be created in the pre-processor or imported from external computer-aided design programs (CAD), see Table 1.2.

Most of the commercial finite element pre-processors have specific import filters open to third-party CAD files, e.g. a prt-file in the case of Pro/ENGINEER (Pro Creo). If there is no import filter available for a specific CAD package, the importing of a geometry file is still possible via a neutral file format such as ACIS, IGES, STL or STEP. It should be noted here that the generation of complex geometries is in

Table 1.1 Some historical steps in relation to the development of MSC Marc

Year	Comment	Ref.
1964	Pedro V. Marcal received a Ph.D. in Applied Mechanics from the Imperial College of Science and Technology, University of London	[13]
...	Pedro V. Marcal worked as Lecturer at the Imperial College of Science and Technology, University of London	[6]
~1965	A group of researchers at Brown University in Providence, Rhode Island started the development of finite element software	[20]
1967–1974	Pedro V. Marcal taught as Professor in the Division of Engineering, Brown University in Providence, Rhode Island	[6]
1971	Pedro V. Marcal founded the MARC Analysis Research Corporation in Palo Alto, California	[20]
1972	The first version of MARC was introduced	[20]
1972	David Hibbitt received a Ph.D., related to computational mechanics using the finite element method, from Brown University	[20]
1972–1977	David Hibbitt worked for the MARC Analysis Research Corporation, responsible for the development of the MARC program	[4]
1976	Dr. Bengt Karlsson who worked for the Control Data Corporation (CDC) in Sweden joined MARC	[20]
1977	Paul Sorensen received a Ph.D. from Brown University and joined General Motors. He worked previously briefly for MARC	[1, 20]
1978	David Hibbitt founded Hibbitt, Karlsson & Sorensen, Inc. (later known as ABAQUS Inc.) and began the design and development of the ABAQUS program	[4]
1999	The MacNeal-Schwendler Corporation (now MSC Software Corporation) acquired the MARC Analysis Research Corporation for about \$36 million	[15]
2005	Dassault Systèmes acquired ABAQUS Inc. for about \$413 million	[20]

Table 1.2 Some common CAD packages

Name	Company	Web page
AutoCAD	Autodesk	http://www.autodesk.com/
CATIA	Dassault Systèmes	http://www.3ds.com/
Pro/ENGINEER (PTC Creo)	Parametric Technology Corporation	http://www.ptc.com
Solid Edge	Siemens PLM	http://www.plm.automation.siemens.com
SolidWorks	Dassault Systèmes	http://www.3ds.com/