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ACKNOWLEDGEMENT

Many thanks to the SolidWorks corporation for granting permission to use images, created with an educational software version in this book. All FEM-result-plots and all of the graphic images that are used to explain the experiments in this book are created with help of the SolidWorks Educational software.

ABSTRACT

This book contains 21 experiments with FEM which will help students in understanding various result-plots that are available in Finite Element Methods. This book is written for students who are beginning to work with Finite Element Methods. Mechanical Engineering students will be able to increase their understanding of stress-situations in parts that are loaded with forces and moments. Students are given tasks to perform. These tasks, including running the FEM-experiments and studying the theory are estimated to cost the student 100 hours of work in total. The amount of hours varies depending on previous experience with FEM-software. If more experienced students use the tasks in this book, it could be advisable to give the students similar tasks with more complex geometries and request students to report and explain the resulting stresses.

PREFACE

FEM (Finite Element Method) is probably the most powerful tool that can help in understanding stresses and deformations in parts or constructions that are loaded with forces. This book contains 21 experiments with discussion. These experiments and discussions are presented to improve the understanding of FEM-results.

FEM can however also be a frustrating tool because it delivers many results which means that some of all those results will be hard to explain.

When used correctly, Finite Element Analyses will give the same results as real life constructions under loading, but it gives possibilities to show a lot more results. This is very useful but also overwhelming for starters. Interpreting all available results is difficult for a beginner just because of the sheer amount of results that can be displayed. The 21 experiments in this book are meant to help the beginning engineer in understanding all of the relevant results.

This book contains 4 sections.

The first section consists of chapter 1 to 7. In this section the most relevant results that can be displayed with help of FEM are discussed.

The second section consists of chapter 8 to 13. In this section, general engineering principles that are commonly used in combination with FEM-analyses are discussed.

The third section consists of chapter 14 to 19. In this section, various reasonably standard engineering problems are calculated with help of basic equations and verified with help of FEM.

The fourth and last section consists of chapter 20 and 21. In this section, more advanced studies are discussed. This is especially done to warn FEM-users for the fact that just result-plots of various stresses and strains are certainly not always enough to assess the stress-situation of a construction under load. Other phenomena, like nonlinearities, buckling and fatigue should be considered when analysing constructions under stress.

Performing experiments is a powerful way of acquiring new skills. That is why students are advised to actually perform the experiments in FEM that are described in this book. Tasks are provided in every chapter for this purpose, making this book well-suited for use in class.

Much effort went in to creating, calculating and simulating the examples with care. The author does not take responsibility for any possible errors in this book.

TABLE OF CONTENTS

LIST OF SYMBOLS

Symbol	*Stands for*	*units*
φ	Angle	radians
v	Deflection	mm
r	Radius	mm
A	Area	mm^2
q	Distributed load	N/mm
M	Moment	N*mm
E	Modulus of elasticity	N/mm^2
σ	Normal stress	N/mm^2
τ	Shear stress	N/mm^2
ε	Strain	[-]
I	Area moment of inertia	mm^4
J	Area moment of inertia	mm^4

Besides the standard units, this book uses variables to stimulate individual tasks for every student in an engineering class. This is done by a student-task at the end of each chapter. These tasks are introduced with a plot that has letters for dimensions, stresses or forces. These values are recommended to be specified for students:

Dimension-value *a*:
    ranging roughly between 20 and 70 mm
Dimension-value *b*:
    ranging roughly between 100 and 300 mm
Stress-value *c*:
    ranging roughly between 5 and 50 N/mm^2
Stress-value *d*
    ranging roughly between 5 and 50 N/mm^2
Stress-value *e*:
    ranging roughly between 5 and 50 N/mm^2
Force-value *f*:
    ranging roughly between 100 and 500 N

It can be convenient to couple these variable values to for example the student-number of each student in a class. It is also recommended to request the students to submit their software-files.

Example student number: 123456

Example for coupling student number to student tasks:

a = (first two numbers of student-number +40)/2 = (12+40)/2 =	26 mm
b = (number 3 and 4 of student-number +50)*2 = (34+50)*2=	168 mm
c = (number 5 of student-number +1)*5 = (5+1)*5=	30 N/mm^2
d = (number 6 of student-number +1)*5 = (6+1)*5=	35 N/mm^2
e= (number 1 of student-number +1)*5 = (1+1)*5=	10 N/mm^2
f = (number 2 and 3 of student-number +1)*5 = (23+1)*5=	120 N

CHAPTER 1: INTRODUCTION

Uniformity of material-properties is assumed in all experiments in this book if not mentioned otherwise. This means that the mode of elasticity and all other material-properties are the same throughout the objects that are calculated.

Various ways of restraining parts from moving will be used in this book. These ways of restraining are shown in Figure 1.1.

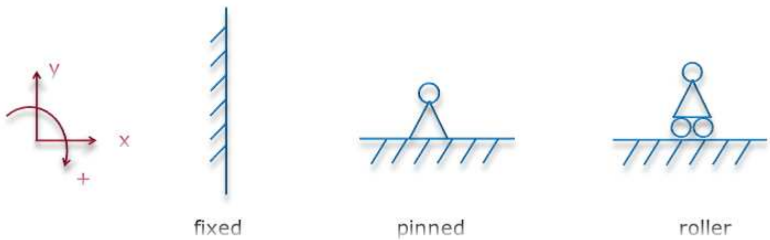

Figure 1.1 Symbols for restraining parts from moving, commonly called "fixtures" or "boundary conditions"

The symbols in Figure 1.1 are commonly used in engineering internationally. The fixed symbol indicates that a point or surface of a part can not move and also not rotate in all directions (x, y and z). The pinned symbol indicates that