

**ASPECTS OF FINITE ELEMENT ANALYSIS  
IN  
PRODUCT DEVELOPMENT AND  
VERIFICATION**

**by**

**Jan Christian Anker**

**ANKER - ZEMER Engineering A/S**

**OSLO / Norway**

# Aspects of Utilization of Finite Element Analysis ("FEA") in

- ↓ Product Development
- ↓ Product Verification
- ↓ FEA technology per se is not discussed.

# Background

## ↓ FEA

↓ - method for simulating physical behavior

## ↓ utilized in Product Development and Verification

## ↓ Progress in the last decade

↓ easier to perform

↓ substantially more capabilities added to the Finite Element Systems

↓ interfaces to Computer Aided Design ("CAD") matured into (nearly) useful tools,

↓ hardware has become increasingly bigger and faster

↓ trend is expected to last

## ↓ the future looks promising

# Contents

## ↓ Basis

↓ FEA no end to itself, it is a

**Tool used in the Engineering Design Process**

## ↓ Aspects of FEA

↓ FEA in Product Development

↓ FEA in Product Verification

↓ Common aspects of FEA

↓ Product Development

↓ Product Verification

# The Engineering Design Process, FEA, and "The CAD Problem"

## ↓ Engineering Design Process by Pahl & Beitz, /1/.

↓ - 4-phase process

↓ Clarification of the Task (PD)

↓ Conceptual Design PD

↓ Embodiment Design PD (PV)

↓ Detail Design PD PV

↓ - FEA can be successfully utilized in all 4 phases, /2/.

↓ Pahl & Beitz : Emphasis on a

↓ **systematic approach in general**

↓ **the concept phase in particular**

↓ will lead to shorter development time and improved products.

# The Engineering Design Process, FEA, and "The CAD Problem"

## ↓ CAD Problem

- ↓ "How can you design or give shape to a Product you do not know will function or fail?"
- ↓ Use FEA to study/analyze functionality
- ↓ CAD systems are lacking features for functionality studies and concept variations, /3/
- ↓ "CAD is bureaucracy"
- ↓ CAD is documentation

← PROBLEM

# Aspects of FEA

## ↓ Ease of Use and Ease of Verification

### ↓ Geometry import from CAD

↓ Better interfaces

↓ More details → (Much) Bigger Models

↓ Much more powerful Hardware

↓ Much more powerful Finite Element Software

# Aspects of FEA

- ↓ No systematic Evaluation of Design Concepts
  - ↓ Increased ease of use counterproductive
    - ↓ Has to some extent obscured the usefulness of FE programs for evaluating functionality and features of design Concepts
  - ↓ Historically, the utilization of FEA has mainly been to answer one of two (equivalent) questions
    - ↓ "Will it ...?" or
    - ↓ "Why did it ...?"
    - ↓ This is still true today, most companies have not implemented design procedures that include the systematic evaluation of design concepts by FEA.

# Aspects of FEA

## ↓ Design Optimization (“DO”)

↓ Powerful, little used Tool

↓ Examples of Possible utilization

↓ Minimize weight while maintaining acceptable stress levels

↓ Minimize cost of design of 3 different materials

↓ Freedom to chose volume

↓ Production cost can be tied in

↓ Evaluate Material Damping Value

↓ Do experiment (excite a beam)

↓ Do DO with Min. Difference between measurements  
and analysis as object function,  
Material Damping as Design Variable.

# Aspects of FEA

## ↓ Design Optimization: Topological Optimization

- ↓ Concept: "fill the universe with elements, and remove those not needed".
  - ↓ Use: To generate an initial geometry based on requirements to the object
- ↓ Place in the EDP: Conceptual and Embodiment design

# Aspects of FEA

## ↓ Substantial Computer Resources needed

### ↓ CPU-time

- ↓ Especially CFD

- ↓ Design Optimization

### ↓ File Sizes

- ↓ Not only Large Models and Huge files with CAD-import

- ↓ Non-Linear Materials, Geometry, and Contact

- ↓ Transient Analysis (Non-Linear and Linear)

- ↓ Limits on File-Size by 32-bit Operating Systems

# Aspects of FEA

## ↓ Multidisciplinary

- ↓ First Programs limited to few disciplines (e.g. structural and thermal analysis).
- ↓ Today Finite Element Programs cover Multiple Disciplines
  - ↓ Advantages: "Same System for Everything" (even same mesh!)
  - ↓ "Problem": Not many engineers master ...

# Aspects of FEA in Product Development

## ↓ - Product Development

- ↓ from scratch and
- ↓ modifications

are really the same in terms of design methodology

- ↓ Concept Phase emphasized

# Aspects of FEA in Product Development

## ↓ Ease of parameter variation

- ↓ helps Understanding

  - ↓ Functioning

  - ↓ Features

- ↓ Leads to "optimum design"

- ↓ Program Controlled Parameter Variation is "Design Optimization"

# Aspects of FEA in Product Development

## ↓ Abstraction Levels

↓ Geometrically Complicated Object  
can be introduced to the FE System as

- ↓ geometry
- ↓ a set of solid elements
- ↓ a set of shell elements
- ↓ a set of beam elements
- ↓ a single matrix



increasing level of abstraction

# Aspects of FEA in Product Development

## ↓ Significance of Abstraction Levels

### ↓ Conceptual Design

- ↓ simplify the modeling to  
reduce computer time and ease interpretation
- ↓ at an early design stage, there is no geometry
  - ↓ Utilize FEA to evaluate functionality (“what if ...?”)

### ↓ Embodiment Design deals (among other things) with geometry → lower level of abstraction

# Aspects of FEA in Product Development

## ↓ Finding Engineers for FEA

- ↓ FEA very important tool (not used to its full potential)

- ↓ Ease of use

  - ↓ Meshing Technologies

  - ↓ etc etc

but

- ↓ Difficulty of Keeping Pace with Technology

  - ↓ New Commands

  - ↓ New Theory

  - ↓ New Operating Systems (Win95 ---> Win98, WinNT ---> LINUX)

# Aspects of FEA in Product Development

## ↓ Finding Engineers for FEA

- ↓ Understanding the Physics

  - ↓ Biggest problem in FEA?

- ↓ Design Engineer has the Need, Analyst has the Capability

  - ↓ Communication Problem

  - ↓ Education

# Aspects of FEA in Product Verification

## ↓ Verification

↓ Takes place in Embodiment Design and Detail Design

↓ Two types

- (i) verification of functionality and integrity according to established engineering practice - short "Engineering Verification"; and
- (ii) verification according to Standards, Codes, and Norms - short "Codechecking"

# Aspects of FEA in Product Verification

## ↓ Engineering Verification

- ↓ FE System utilized must have been verified by
  - ↓ Program Vendor
  - ↓ User / User's Organization
- ↓ Must be well documented
- ↓ The analyst must document his analysis and  
Demonstrate that the results are reasonable  
(Through comparisons with analytical solutions and simplified models)

# Aspects of FEA in Product Verification

## ↓ Codechecking

- ↯ Codechecking means extracting selected data from a FE Analysis and manipulating them according to certain rules to verify the design's performance and integrity
- ↯ The extracted data has to be correct if the Codechecking shall make any sense at all
- ↯ Data transfer into Code Checking System
  - ↯ Manually (at a high risk of introducing errors)
  - ↯ Electronically (preferably with a minimum of user intervention)
  - ↯ Correct Data Transfer into the Codechecking System important

# Aspects of FEA in Product Verification

## ↓ Duplicate Efforts

↓ "n" ( $n \gg 1$ ) Systems for Eurocode 3 found on Internet

↓ Silly Question:

"Why is the source code for FE Postprocessing not delivered as a part of Eurocode 3

(or as a part of any other code for that matter)?"

↓ Scope of Norms and Standards is to give a "best and unified solution to repetitive tasks"

# Aspects of FEA in Product Verification

## ↓ Contradictory Findings

### ↓ Matrix of Findings

FEA:	OK	OK	Failure	Failure
CC:	OK	Failure	OK	Failure
	1	2	3	4

Cases 1 and 4 are obvious,

Case 2 will be accepted by the Engineer,

Case 3 by the Lawyer

# Other Aspects

## ↓ Amount of information

- ↓ Extracting essential information
  - ↓ What is / Who decides on "Essential Information"
- ↓ Communicating essential information
  - ↓ Report writing important (hints in /4/)

## ↓ Storing Information

- ↓ Amount prohibitive for on-line storage over time
- ↓ Input files should be kept and safe-kept
- ↓ "Essential Information" should be kept on-line
  - ↓ Store information needed to visualize selected items only, see /5/.

# Other Aspects

## ↓ Communication

- ↓ Designer # Analyst → Communication
  - ↓ During and after Analysis
- ↓ Electronic communication
  - ↓ Physical Distance
    - ↓ WEB, e-mail
  - ↓ Receiver needs to use the data
- ↓ Freeware with some systems
- ↓ Interactive sessions

# Other Aspects

- ↓ Understanding / Knowledge needed of
  - ↓ the Design Process
  - ↓ the tools (here FEA)
  - ↓ behavior of the product to be.
  - ↓ Engineering Design in general and Product Development in particular
  - ↓ Steadily increasing functionality and features of today's Finite Element Systems (and the increased ease of use) put demands on
    - ↓ Learning new theory
    - ↓ Learning to utilize new features

# Other Aspects

## ↓ QA Aspects of Many Program Revisions

- ↓ One needs to have verified
  - ↓ Procedures for Modeling
  - ↓ Procedures for assessing Accuracy
  - ↓ Utility Programs and Macros
- ↓ It might be a problem if a systems comes in new Revisions too often (whatever that may be)

# Summary and Outlook

- ↓ Some aspects of FEA touched
- ↓ FEA is not utilized to its full potential
- ↓ Design Codes could be better adopted to FEA
- ↓ Education is a critical issue due to
  - ↓ Speed of development of
    - ↓ FEA Methods
    - ↓ CAD and other tools
    - ↓ Hardware and System Software
- ↓ More utilization of FEA in the future (?)
- ↓ Special tools for product development based on FEA (ref /6/) coming?
- ↓ The limits with 32-bit operating systems disappearing

## Summary and Outlook

↓ The cost of RAM-memory and disk storage is constantly decreasing.

This, together with faster CPUs, will remove many of the limits on model size encountered today.

↓ Proper Education challenge for

↓ Educational Institutions

↓ Program Vendors

↓ Companies using FEA.

↓ Standards, Norms, and Codes will include well defined interfaces for software systems like FE programs ?

↓ Some Institution will provide code checking (via WEB) on centralized computer ?

# References

/1/ "Konstruktionslehre"

(Authors: Gerhard Pahl and Wolfgang Beitz)

ISBN-3-540-56194-3, 3. Auflage

Springer Verlag, Berlin, Heidelberg, New York 1993

/2/ "F.E.A. in the Engineering Design Process"

(Authors: Robert Björnemo, Åke Burman, and Jan Christian Anker)

in: Computer-Aided Design/Engineering (CAD/CAE): Techniques and Their Applications, Vol. 58, Part 1, Chapter 4, (C. Leondes, ed.),

Academic Press, San Diego, CA, 1993, pp 119-170.

/3/ "Shortcomings of CAD Systems in Conceptual Design"

(Authors: Robert Björnemo, Åke Burman, and Jan Christian Anker)

in: PVP-Vol. 305, Current Topics in Computational Mechanics

P. 227 - 232, ASME, New York, 1995

# References

/4/ "Finite Element Analysis and CFD: The Structure of a Report and Modern Tools for Reporting"

A seminar on Report Writing (Author: Jan Christian Anker)

ANKER - ZEMER Engineering A/S, Oslo, January 2000.

/5/ "3D Visualization and animation of large FE-models"

(Author: Ketil Aamnes)

NAFEMS World Congress '99, Newport, Rhode Island, April 1999.

/6/ "Konzept für ein Finite-Element-basiertes Konstruktionssystem"

(Authors: Åke Burman and Jan Christian Anker)

Konstruktion 47 (1995) P. 401 - 408

Springer-Verlag