Updated Technology Issues

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Document History & Change Control Record

Issue	Date	Description or Change Summary
1	September 2001	**Outline Technology Issues: D3101 – D3103** As prepared for the Network Steering Committee, 27 & 28 September 2001.
2	October 2001	**Initial Technology Issues: D3104 – D3106** As discussed and refined at the Network Steering Committee, 27 & 28 September 2001.
3	February 2002	**Updated Technology Issues: D3411 – D3413** Updated to take account of presentations and discussions at 1st Annual Industry Meeting, 13 & 14 November, Wiesbaden.
4	September 2003	**Updated Technology Issues: D3421 – D3423** Updated to take account of presentations and discussions at 1st Annual Industry Meeting, 13 & 14 November, Wiesbaden.

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Executive Summary:

FENET is a Thematic Network, funded by the European Commission, which seeks to co-ordinate activities within Europe aimed at improving both the quality of industrial applications of finite element (F.E.) technology and the level of confidence that can be placed in the computed results.

Its principal objective is to collate and structure existing information and to facilitate the efficient exchange of experience and knowledge within, and between, different industrial sectors within the European Community.

Technology issues are grouped under three broad themes, namely;

- Durability and Life Extension
- Product and System Optimisation
- Multi-physics and Analysis Technology

This document contains reports from each of the three theme areas on current topical issues. The reports are based on initial presentations made at the Network Steering Committee and have been updated to take account of the presentations and discussions at the 1st Annual Industry Requirements Seminar in Wiesbaden. The intention is that, together with the Industry Requirements reports, they provide a firm foundation for the subsequent programme of technology workshops. To that end proposals are made for a preliminary (ie 1st year) programme of activities.

This document will be reviewed and updated periodically.

Anyone wishing to attend workshops etc can obtain further details by sending an email to info@werbos.de or by visiting the network web site www.fe-net.org

Industry Sector	RTD Thematic Area	Date	Deliverable Nr
	Durability and Life Extension	Aug 2003	D3421

Deliverable D3421

Updated Technology Issues Durability & Life Extension

Prof. Adib Becker University of Nottingham UK

Summary:

A summary of the main discussion points related to Durability and Life Extension issues from the first FENET Annual Workshop is presented and a preliminary programme in response to these issues is proposed.

1 Introduction

This report summarises the main FENET activities related to RTD1 on Durability and Life Extension (DLE) in the first two years of the FENET thematic network (from 1 August 2001 to 31 July 2003).

The report covers the main points raised in the five DLE workshops launched to date:

- First DLE Workshop: "Industrial Views on Durability and Life Extension Issues" (13 November 2001, Wiesbaden, Germany)
- Second DLE Workshop: "Finite Element Simulation of Contact Problems" (27-28 February 2002, Copenhagen, Denmark)
- Third DLE Workshop: "FE issues related to Structural Integrity-Fracture, Fatigue, Creep" (13-14 June 2002, Zurich, Switzerland)
- Fourth DLE Workshop: "Finite element simulation of fracture and crack growth" (11-12 September 2002, Trieste, Italy)
- Fifth DLE Workshop: "Finite Element Simulation of Welds and Joints" (27-28 February 2003, Barcelona, Spain)

A list of presentations in each workshop and a brief analysis of the workshop discussions are presented. Based on the feedback and discussions with other FENET members, a list of future DLE workshops is proposed.

2 First DLE Workshop

"Industrial Views on Durability and Life Extension Issues"
(13 November 2001, Wiesbaden, Germany)
Chairman: Prof. Adib Becker, University of Nottingham

Overview

A Preliminary workshop on DLE was organised during the first FENET industry meeting in Wiesbaden. A number of industrial FENET members presented short presentations outlining industrial views on DLE issues, as follows:

- Advanced assessment concepts for ligh weight structures
  Alfred Comec (GKSS Research Centre, Germany)
- Design of Elastomeric Engineering Components using FEA
  Hamid Ahmadi (TARRC, UK)
- Fatigue Assessment of FPSO
  Jack Reijmers (Nevesbu, The Netherlands)
- FE based fatigue analysis
  Neil Bishop (RLD Limited, UK)
- Durability and accuracy issues
  Charles Kernthaler and Mike Bright (AWE, UK)
- Deterioration and repair of reinforced concrete structures
  Geir Horrigmoe (Norut Teknologi, Norway)
- FE simulation of laboratory tests on knee implants
  Yasar Deger (Sulzer Innotec, Switzerland)

The workshop concluded with an open discussion forum in which many DLE issues were raised, and ideas for future DLE workshops were collected.

DLE issues raised

Following the presentations of the FENET Industry Coordinators and discussions with several FENET members, a summary of the main issues related to DLE is presented below:

Generic Issues:
- Contact mechanics
- Fracture and fatigue of rubber and plastics
- Cracks in welds
- Adaptive meshing in fracture and contact problems
- Case studies on durability and life extension

Aerospace:
- Damage assessment, damage tolerance
- Crack growth
- Residual strength
- Linking FE and Boundary Element Methods
- Probabilistic analysis

Land Transport:
- Fracture, crack growth, adaptive meshing
- Residual strength
- Characterization of composites

Bio-Medical:
- Wear modelling for prostheses
- Modeling bone fracture
- Interface modeling for implants biomaterials
- Civil Construction
- Reinforced concrete deterioration
- Residual life prediction
- Durability of constructions

Consumer Goods:
- Abuse loads
- Impact analysis
- Life estimation

Marine & Offshore:
- Fatigue, stochastic loading damage
- Delamination, composites

Power & Pressure Systems:
- Residual stresses
- Crack growth
- High temperature and damage assessment
- Use of probabilistic fracture analysis
- Extreme loads

Process & Manufacturing:

- Extending product life through process optimization
- Durability and wear of tools
- Obtaining and applying failure criteria
- Effect of manufacturing defects on life

3 Second DLE Workshop

"Finite Element Simulation of Contact Problems"
(27-28 February 2002, Copenhagen, Denmark)
Chairman: Prof. Adib Becker, University of Nottingham

Overview

This workshop was concerned with contact problems, including impact, friction, sliding and case studies. The seminar addressed the following issues:

- FE contact benchmarks
- Difficulties experienced by FE users in modelling contact problems
- Current limitations of commercial FE software
- Desirable contact features that are not currently being offered by FE software
- The need for further research in the application of FE to contact problems

List of Presentations

- Finite Element Modelling of contact phenomena in structural analysis
  Albert Konter (Netherlands Institute for Metals Research, Netherlands)

- Overview of current NAFEMS contact benchmarks
  Dr. Nawal Prinja (NNC, Limited, UK)

- Evaluation of the current contact benchmarks by software vendors and FE users
  Adrie Bout (MSC Software Benelux B.V., The Netherlands)
  Dr.-Ing. Reinhard Helfrich (INTES, Germany)
  David Ellis (IDAC, UK)

- More challenging contact benchmarks
  Dr. Alan Prior (HKS (UK) Limited, UK)

- Coupling FE contact and heat transfer analysis in investment casting simulations
  Gottfried Laschet and L. Haas (Access e.V., Germany)

- Solving contact problems using an augmented Lagrangian method
  Dr. Philippe Jetteur (Samtech, Belgium)

- Alternative Technology: Boundary Element Contact Analysis
  Prof. Adib Becker (University of Nottingham, UK)

- Paper Calendering: FE Simulation As an Optimisation Tool
  Dr Yasar Deger (Sulzer Markets & Technology Ltd, Switzerland)

Analysis of the workshop

(i) Comments on the current NAFEMS contact benchmarks

- Limited in scope, but important as the first step in establishing contact benchmarks
- Limited to 2D contact only
- Limited to continuum elements
- Can be improved by a clearer definition of data input
- Would benefit from showing solutions from two or more FE codes
- Useful to add a detailed “educational” description of the ‘difficult’ benchmarks.
- Should also consider the curved patch test
- Should show all FE mesh details (all nodal coordinates)

(ii) The need for more challenging contact benchmarks

- 3D contact
- Self-contact
- Multi-body contact
- Stick-slip in contact area
- Rotating shaft with no friction
- Compression of rubber
- Shell on shell contact
- Beam contact
- Explicit/Implicit comparison
- 2D/3D Linear vs. quadratic elements
- 3D tetrahedron vs. hex elements
- 3D 27 node brick elements
- Impact (high velocity)
- Dynamic contact (low velocity)
- Large strain contact
- Metal forming

(iii) Challenges in FE modelling of industrial contact problems

- Loaded rigid surfaces
- Identification of unknown or unexpected contact regions
- Automation of contact analysis
- Re-meshing during contact analysis
- Visualisation of contact elements
- Informative post-processing diagnostic display
- Improved quadratic elements
- Better friction models
- Experimental verification of FE contact solutions
- Coupled thermo-mechanical contact
- Heat conduction across interfaces
- Cemented joints
- Thin lubricating films

Concluding Remarks

The contact workshop has been successful in stimulating many discussions regarding the need for further contact benchmarks and case studies. It was acknowledged that although the current published NAFEMS benchmarks are limited in scope, they are important as the first step in establishing contact benchmarks.

Most delegates agreed that there is genuine need for more complex contact benchmarks. This will be addressed by the Non-linear working Group of NAFEMS with a view to commissioning further contact

benchmarks and launching further contact workshops.

In view of the interest generated by this workshop, a second FENET contact workshop will be planned for the Durability and Life Extension series of workshops. The objectives of the second workshop will be to define a new set of more advanced benchmarks and to invite feedback from FE analysts.

4 Third DLE Workshop

"FE issues related to Structural Integrity - Fracture, Fatigue, Creep"
(13-14 June 2002, Zurich, Switzerland)
Chairman: Prof. Adib Becker, University of Nottingham

Overview

This workshop was launched as part of the FENET programme of technology workshops in Zurich, which were attended by 76 delegates. The workshop was focussed on the FE analysis of fracture, fatigue and creep problems in order to identify further workshop topics on the theme of structural integrity. The workshop addressed the difficulties experienced by FE users in structural integrity analysis, current limitations of commercial FE software, desirable features that are not currently being offered by FE software.

The main objectives of this workshop were:

- To provide an overview of the current state of FE technology in applications related to structural integrity, particularly in fracture, fatigue and creep.
- To provide a discussion forum to identify the need for FE benchmarks in structural integrity
- To identify specialist workshop topics in structural integrity

List of Presentations

- Fatigue life improvement of an innovative suspension system
  Dr Nawal Prinja (NNC Ltd, UK)

- Defect assessment of a pressure vessel nozzle
  Keith Wright (Structural Integrity Assessments Ltd, UK)
  Janak Patel (Robust Solutions Ltd, UK)

- Commercial FEM codes customisations for creep-fatigue damage assessment
  Dr. Mauro Fontana (University of Naples "Federico II", Italy)

- Generalised computational analysis of contact fatigue initiation
  Dr Miran Ulbin (University of Maribor, Slovenia)

- Integrated FEM based package for fatigue and damage tolerance - SAFE
  Emmanuelle Alios (Airbus, France)
  Jean-Pascal Kleinermann (SAMTECH, France)

- Fatigue problems in floating production storage and offloading vessels
  Mirek Kaminski (MARIN, The Netherlands)

- Predicting stress intensity factors for cracked structural components using the fractal-like FEM
  Dr. S. O. Oyadiji (University of Manchester, UK)

- Comparison between numerical and simplified analytical models for the evaluation of residual stresses in welded plates
  Dr. Paolo Ferro (University of Padova, Italy)

- 3D analysis of reinforced concrete structures
  Prof. Z. Bittnar (Czech Technical University, Prague)

- Industrial application of fatigue damage analysis and FEM
  Omar Salomon (CIMNE, Spain)

- Crack propagation simulation with MSC.Marc
  Dr Christophe Noiret (MSC Software, France)

- Analysis of aircraft impact on containment of NPP
  Prof. Z. Bittnar (Czech Technical University, Prague)

- Shape optimisation based on fatigue life estimation results
  Peter Allinger (FE-DESIGN GmbH, Germany)

- Pretest analysis of 1:4 Scale Prestressed Concrete Containment Vessel
  Jose Sanvi-Cente (Principia, Spain)

Analysis of Workshop

The discussions during this workshop have identified a number of issues related to structural integrity that require further development. The following is a list of the main topics.

(i) Fracture
- Modelling crack closure
- 3D crack models
- 2D and 3D crack propagation laws
- Interaction of two or more cracks
- Crack propagation and re-meshing in commercial FE packages

(ii) Fatigue
- Modelling variable fatigue loads
- Choosing multi-axial fatigue criteria
- Specialist Fatigue software

(iii) Creep
- Creep damage laws
- Implementing damage in “user-subroutines”
- Changing internal variables in FE software
- Damage benchmarks
- User-friendliness of “user-subroutines”
- Creep-fatigue interaction

(iv) Weld analysis
- Development of weld benchmarks
- Development of “Guidelines” and “Best Practice” on using FEA in welds
- Modelling residual stresses and comparison with experiments
- Modelling weld interfaces (heat affected zones)
- Modelling cracks in welds
- Implementing FE solutions in weld design codes

Concluding Remarks

This workshop has been successful in stimulating discussions regarding structural integrity from a wide range of FE users covering many industry sectors in several European countries. The use of FE technology in structural integrity assessments is widespread and well established in many industries. However, the workshop has highlighted many of the difficulties currently faced by FE analysts, and has identified several areas for future development of FE technology.

Four main areas of structural integrity have been identified as the topics for future FENET-DLE workshops, namely fracture, fatigue, creep and welds. The next DLE workshop will address the use of FE technology in the analysis of fracture and crack growth.

5 Fourth DLE Workshop

"Finite element simulation of fracture and crack growth"
(11-12 September 2002, Trieste, Italy)
Chairman: Dr. Nicola Petrone (University of Padova, Italy)

Overview

This workshop was conceived as the natural continuation of the previous FENET Technology Workshop held in Zurich on 13-14 June 2002, since more reliable tools and procedures are still needed to use FE methods for the numerical simulation of fracture and crack growth. Therefore, the main purpose of this workshop was to give, when possible, a solution to the several difficulties experienced by FE users in industrial topics related to components' collapse or to specific crack features.

The main objectives of this workshop were:

- To identify the potential and the limitations of current FE methods and tools in FE fracture and crack growth simulations.
- To create the opportunity for a mutual sharing of experiences, either successful or unsuccessful, for increasing the degree of competence and awareness on the topics.
- To propose a set of actions to be adopted by the users and the software developers to solve the problems and spread the adoption of FE simulations.

List of presentations

Four contributions were delivered, and an open forum was held at the end of each presentation. The chairman invited the audience to interact with the speakers, resulting in discussions regarding benchmarks and robust approaches for the numerical simulation of cracks.

- Three dimensional crack modelling: techniques and considerations from the analysis of pin-loaded tubular joints
  Dr. Richard Grant (NEWI, University of Wales, UK)
  Dr. John Smart (University of Manchester, UK)

- Evaluation of stress intensity factors using finite elements
  B. Zafošnik, Z. Ren, M.Ulbin and J. Flašker (University of Maribor, Slovenia)

- Evaluation of fatigue life by means of the crack tip stress method after finite element

evaluation
G. Meneghetti (University of Padova, Italy)

- Crack propagation and life prediction with a parametrized model with SAMCEF
  Albert Gonze (SONACA)
  J.P. Delsemme (Samtech Liegi)

Analysis of Workshop

Amongst the four presentations delivered, two focused on 2D crack modelling applications highlighting methods for simplified SIF evaluation based on Virtual Crack Extension (VCE) and Crack Tip Stress Method (CTSM); the former allows mixed mode analysis and crack linking predictions by means of special crack tip elements, the latter allows linear elastic analysis (mode I) with coarse mesh after calibration using well-known case studies.

One presentation focused on 3D crack modelling emphasizing the possibility to predict, for a given crack trajectory, the crack twist and tilt on a particular pin-loaded tubular joint. Application to other load conditions and more complicated components may be considered, but further analyses have to be performed. The last presentation dealt with crack path prediction in aerospace components by means of a customized tool; for a given rivet line, the crack is simulated by progressive release of special elements. Such an approach enables an assessment of the durability of the components by means of life to failure considerations.

The forum showed that 2D and 3D crack modelling can be properly performed as the state of the art is available in many research centres in universities and industry, but the state of practice is still out of reach of many FE users. With respect to numerical simulation of crack initiation, propagation and merging, the audience raised the need for tools able to estimate crack direction during propagation as well the growth rate.

Regarding the simulation of final fracture events and behaviour, there is a wide interest of several industry sectors in developing robust and reliable software tools dedicated to the simulation of crash, brittle collapse, etc. In spite of the level of software efficiency in Multi Physics applications, the FE codes for structural problems require suitable meshing and re-meshing tools specialized for crack propagation and related topics. Moreover it is not completely clear at which level the improvement should be developed; within CAD software or during the meshing step. A large number of the audience suggested that it is more convenient for FE users to have a re-meshing tool within the pre-processor instead of a CAD code. Another question dealt with the identification of who should start up the development of such tools; researchers, software houses or users. A common conviction was that FE users should join the researchers to spur software developers on to agree to their needs for simplification of the analyses related to crack simulation (initiation, growth and prediction of path propagation) and to liaise with them in a design oriented synergic action.

Considering the ongoing planning of Framework VI, there has been a common interest in the definition of a research project that aims to transfer experiences from the component scale to the micro and nano scales, justifying the research and the participation of software developers.

Concluding Remarks

This workshop has demonstrated how the FE simulation of fracture and crack growth is still a challenge in many industry sectors. In addition, when tools are available, users are not very confident in adopting them for their own analyses. This may be due to a mismatch between the need for a routine use and the lack of suitable benchmarks. The open forum held at the end of each presentation provided a deeper insight into the current state of the art on the topics related to final fracture and crack features simulation, highlighting SIF evaluation methods (Virtual Crack Extension) and Crack Tip

Stress Method (CTSM) and prediction of crack path propagation on pin-loaded tubular joint and on an airfoil.

6 Fifth DLE Workshop

"Finite Element Simulation of Welds and Joints"
(27-28 February 2003, Barcelona, Spain)
Chairman: Prof. Adib Becker, University of Nottingham

Overview

Discussions in the previous DLE workshops have identified the analysis of welds and joints as challenging across many industry sectors, and have highlighted several difficulties in modelling the real-life behaviour of welds and joints.

The main objectives of this workshop were:

- To provide an overview of current practice in modelling welds and joints using FE analysis
- To identify current limitations and difficulties in modelling welds and joints
- To provide a forum for discussion on "Guidelines" and "Best Practice" on using FE in weld and joints
- To present current techniques for modelling residual stresses and cracks in welds and joints
- To discuss the need for benchmarks for welds and joints

List of Presentations

- Finite Element Modelling of Features Common in Fabricated Plate/Shell Construction
  Dr. Jim Wood (Strathclyde University, UK)
- Simulation of welding processes and modeling of welded joints using ABAQUS Frans Peeters (ABAQUS Europe, The Netherlands)
- "SYSWELD – Complete Finite Element Solutions for Simulation of Welding Processes"
  Josef Tejc (MECAS ESI Plzen, Czech Republic)
- A numerical simplified model to predict the thermal load and residual stresses of welded joints
  P. Ferro, F. Bonollo, and A. Tiziani (University of Padova, Italy)
- Comparison of Predicted and Measured Residual Stresses In a Pipeline Girth Weld
  Keith Wright (Structural Integrity Assessments Ltd, UK)
  Vinod Chauhan (Advantica Technologies Ltd, UK)
- FE Analysis of Creep of Welds and Weld Repairs - Strategies and Difficulties
  A.A. Becker, T.H. Hyde and W. Sun (University of Nottingham, UK)
- Joints modelling by means of FEA for evaluation of influence of surrounding structure
  Radek Doubrava (Aeronautical Research and Test Institute, Prague, Czech Republic)
- Numerical and experimental analysis of the electron beam welding of a Nickel based superalloy
  P. Ferro, A. Zambon and F. Bonollo (University of Padova, Italy)

Analysis of Workshop

- There are many difficulties/challenges in modelling weld processes and analysing weld behaviour.
- Obtaining accurate material parameters for use in FE models of welds is often difficult. The material properties of narrow Heat-Affected Zones are particularly difficult to obtain in laboratory tests.
- FE models of large 3D welded structures require very fine meshes and can be impractical for structures containing welds.
- Residual stresses are difficult to calculate and difficult to implement in FE analysis.
- General-purpose FE codes are capable of analysing heat transfer and thermal stresses caused by the weld process, but require specialist subroutines and user interaction to simulate the welding process.
- Specialist FE weld simulation software incorporate built-in complex phase transformation data which enable users to simulate the welding process.

Concluding Remarks

This workshop has stimulated many discussions on the latest advances in the simulation of the welding process and the structural integrity of welds. There is a need for further research to incorporate the effects of residual stresses and crack propagation. Guidelines, best practice and benchmarks for modelling structures containing welds are also needed.

The next DLE workshop (Modelling Fatigue of Metals) will be held in Noordwijk, The Netherlands, on 9 - 10 Oct. 2003. The workshop will address the use of FE technology in the analysis of fatigue of metals, current limitations and difficulties and will provide a forum for discussion on “Best Practice” and benchmarks.

7 Future DLE workshops

Next two DLE Workshops

- Modeling fatigue of metals
- FE analysis of Creep Behavior

Other Possible Future DLE Workshops

- FE simulation of Contact problems – 2
- FE simulation of damage
- Modeling fatigue of rubber and plastics
- Modeling wear and deterioration
- FE simulation of residual stresses

Cross-RTD Possible Future workshop topics

- Implementing FE solutions in Design codes
- Uncertainties in material properties
- Alternative techniques: Boundary Element Technology

Industry Sector	RTD Thematic Area	Date	Deliverable Nr
	Product and System Optimization	Dec 2001	D3422

Deliverable D3412

Updated Technology Issues Product and System Optimisation

Prof. Grant Steven - University of Durham, UK

Summary:

A summary of the main discussion points related to Product and System Optimisation (PSO) issues from the first FENET Annual Workshop is presented and a preliminary programme in response to these issues is proposed.

1 Introduction

This report summarises the main discussions points related to RTD2 on Product and System Optimisation (PSO) raised at the First FENET Annual Workshop (13-14 November 2001, Wiesbaden)

The first preliminary workshop on PSO was launched on 13 November 2001. Following this workshop and other discussions with FENET Industry Coordinators, a preliminary workshop programme on PSO issues is proposed, starting with a workshop on Design of Experiment (DOE) and Response Surface Analysis (RSA) methodologies for PSO to be held in February 2002.

2 First PSO Preliminary Workshop (13 November 2001, Wiesbaden)

A half-day workshop on DLE was organised and chaired by Professor Steven on 13 November 2001. A number of industrial FENET members made short presentations outlining industrial views on DLE issues, as follows:

Robustness Measures in System Engineering
Rainer Hoffmann, Jacek Marczyk, EASi Engineering GmbH, Alzenau, Germany
What is robustness / Measures of robustness / Sources of non-robustness

Issues in Product Optimisation at Samtech
P. Morelle, Samtech, Liège, Belgium, Samtech Deutschland (c/o TSE), Reutlingen, Germany
Summary
Presentation of state of the art Samtech's technology for automatic MDO and Design Automation, and more particularly, BOSS/Quattro MDO task Manager and Topology Optimisation using pure discrete variables

BOSS and discrete variables
P. Morelle, Samtech, Liège, Belgium, Samtech Deutschland (c/o TSE), Reutlingen, Germany
Nearby classical gradient methods, genetic algorithms allow to find solutions of combinatory problems involving :a high number of variables/constraints / discrete variables, even integer or non numerical design variables / discontinuous functions

Forging Simulation for Aeroengine Components
Hengan Ou, Cecil Armstrong and Mark Price, Queen's University, Belfast, Northern Ireland, UK
Forging Criteria/Requirements:
Alloy forgeability / Forging Quality: microstructure, mechanical properties, dimensional tolerances / Cost: material utilisation/rejection rate, production rate, post-forge machining

Need for Survey of European Activity In the PSO area

Grant Steven, University of Durham
There is a great gulf between the classical mathematics of structural optimization and the needs of industry in the area of PSO. A survey is suggested which can identify usage and awareness of the mathematics and techniques that are available. The draft of this is in the following section.

Other Organizations involved in PSO

Dr Osvaldo Querin, University of Leeds
There are several global groups that have the topic of the RTD as their main activity. The principle one is the International Association for Structural and Multi-disciplinary Optimization. An overview of this organization and its activities was presented

The workshop concluded with an open discussion forum in which many PSO issues were raised, and ideas for future PSO workshops were collected.

2.1 Preamble

FENET has been running for several months now and a crucial ingredient of the activity is to establish issues and requirements in each Tech Area. From these can come definitions of research and guidance to members on current and best-practice. In joining FENET we have acknowledged that our contributions are pre-competitive in our industry areas and that as far as possible we will share our wisdom. It is hoped to get a 100% response to this survey thereby ensuring that the EU funding body feel their funds have been wisely spent and also will make any messages coming from the survey much more authoritative. The survey results can also form the genesis for future research and development activity for FENET members funded by the EU.

We plan a survey every year on this topic. Through this it is hoped to see how the various activities of FENET have diffused across the network.

As some sort of background to the PSO Technical Area there is at the end of this survey for you to tear off the background paragraphs that were in the original FENET submission to the EU.

PLEASE FILL IN AS APPROPRIATE, YOU DO NOT NEED TO RESPOND TO EVERY POINT. YOU'RE CONTRIBUTION IS VALUABLE TO THE GOALS OF FENET.

IF YOU FORGET MAIL/FAX TO

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Fax 44 (0) 191 374 2550

- Name_____
- Organization_____
- Response Nature (circle which applies) Personal Organization
- Nature of FEA Technologies used (FEA, BEM, CFD others)?_____
- How dependant are you/your organization on FEA _____
- What analysis type do you use Lin Static/Non Lin Dynamic etc. _____

_____

- What engineering software do you/org use_____

_____

- Do you/org actively pursue PSO _____
- How do you do this (analysis/trial and error/laboratory/software)_____
- What software if any do you/org use for PSO _____

_____

- How important is PSO to you/org _____
- Can you/org identify financial benefits from PSO_____

- Which is more important to you/org Product Opt System Opt
- What tools do you have for your decisions in PSO

  Experience

  Consultants

  Commercial Software

  In-House Software

  Others(name)_____
- If you had endless money to spend in this area what would you spend it on ?

  _____
- If you were able to direct research and development in this area what would you do?

  _____
- Circle any of the following areas do you feel lacking in the area of PSO

  Education/Training/Software that is appropriate/Software yet to be developed/Access to technical resources/Some organization that you can go to for support
- Do you feel the Software developers in this Technical Area are aware of your needs

  _____
- If you could get software to do one (or more) thing in this area what would it be(Extra line for more things)

  _____

  _____
- Are you/org **aware** of the following optimization methodologies (put Y or N) or **use** any of them (put Y or N)

  Genetic Algorithms_____Aware_____Use_____

  Genetic Programming____Aware_____Use_____

  Design of Experiments____Aware_____Use_____

  Response Surface Analysis__Aware____Use_____

  Simulated Annealing_____Aware___Use____

  Mathematical Programming____Aware___Use___

  Sensitivity Analysis_____Aware___Use___

  Evolutionary Structural/Design Optimization___Aware___Use___

  Linear or Quadratric Programming_____Aware___Use____
- Are there PSO methods you use that are not mentioned above_____
- What are ISSUES in the Tech Area of PSO that you/org feel are important

  1._____

  2._____

  More

  ??_____

- Are there are REQUIREMENTS in the TECH AREA of PSO that you/org feel are important
  1._____
  2._____

  More??_____

- Are there things you/org feel that FENET could do to help you/org in the area of Product and System Optimization_____

Thank you for your time-----Please hand in or return to Grant Steven

3 PSO issues raised in the First FENET Annual Workshop

Following the presentations of the FENET Industry Coordinators and discussions with several FENET members, a summary of the main issues related to PSO is presented in Table 1.

<table>
<tr><th>Industry Sector</th><th>Topics relevant to Product and System Optimization</th></tr>
<tr><td>(Generic)</td><td>● Terminology/glossary
● Available methodologies
● Which is best!!!
● Which method to use for which situation
● User training and understanding
● Case studies on Product and System Optimisation
● Benchmarking for PSO</td></tr>
<tr><td>Aerospace</td><td>3.1 Product & System Optimisation
<table>
<tr><th>ID</th><th>Modelling / analysis requirement</th><th>TRL</th><th>Remark(s)</th></tr>
<tr><td>1.1.1</td><td>Multi-level process integration</td><td>5</td><td></td></tr>
<tr><td>1.1.2</td><td>Integration of engineering analysis into design and development processes</td><td>5</td><td>Objectives are:
More effective, shorter engineering analysis cycles.
Support collaborative, concurrent, multi-disciplinary engineering</td></tr>
<tr><td>1.1.3</td><td>Model data management and configuration control</td><td>5</td><td>Provided by some PDM tools, but integration with CAE tools need to be improved</td></tr>
<tr><td>1.1.4</td><td>Automation of the structural analysis process</td><td>5</td><td></td></tr>
<tr><td>1.1.5</td><td>Extended enterprise interoperability</td><td>5</td><td></td></tr>
<tr><td>1.1.6</td><td>Simulation of manufacturing processes: cold working, interference fits, sheet metal forming</td><td>7</td><td></td></tr>
<tr><td>1.1.7</td><td>Non-linear dynamic analysis for impact, crash, bird-strike, etc.</td><td>8</td><td></td></tr>
<tr><td>1.1.8</td><td>Non-linear static analysis of metallic structures with accurate failure prediction</td><td>6</td><td></td></tr>
<tr><td>1.1.9</td><td>Widespread industrial application of structural optimisation</td><td>5</td><td></td></tr>
<tr><td>1.1.10</td><td>Use of legacy models and data</td><td>5</td><td>Need for better data integrity, open standards, configuration control, meta-data</td></tr>
<tr><td>1.1.11</td><td>CAD-to-CAE model idealisation</td><td>5</td><td>Need for idealisation benchmarks?</td></tr>
<tr><td>1.1.12</td><td>CAE-to-CAD modification feedback</td><td>2</td><td></td></tr>
<tr><td>1.1.13</td><td>Support heterogeneous mix of tools / computing platforms</td><td>5</td><td>Need for more open standards</td></tr>
<tr><td>1.1.14</td><td>Use of open standards: e.g. ISO/STEP (AP209, ...), W3C/XML, OMG, NCSA/HDF5, …</td><td>4-8</td><td>Maturity level depends on used standard and application domain</td></tr>
<tr><td>1.1.15</td><td>Catalogues of parts/components with FEM representation</td><td>3</td><td>Applied in pilot projects
Needs further development</td></tr>
<tr><td>1.1.16</td><td>Capture design/analysis experience</td><td>4</td><td>Large documented corpus of experience available at ESA and aircraft industry. Some courses given</td></tr>
<tr><td>1.1.17</td><td>Enable access to captured design/analysis experience</td><td>3</td><td>Link with knowledge management.</td></tr>
</table></td></tr>
<tr><td>Process & Manufacture</td><td>●To incorporate empirical knowledge in analytical (FEA) tools
●How to obtain reliable validation and verification data
●Multi scale modelling
●How to couple various commercial and/or proprietary programs
●How to extend product life through process optimisation
●How to obtain and apply failure criteria (forming limit diagrams)
●Fundamentals of material models
●How to obtain material data in strain, temperature, strain rate range of process
●How to obtain process data (friction, heat transfer coefficients..)
●How to analyse multi (2) phase systems with commercial codes
●How to translate material properties that are generated during the process into final product performance</td></tr>
</table>

Civil and Construction Issues with PSO implications

•Design rules are based on analytical models
  –Translation from FEM results to design rules sometimes elaborate
•In Europe Contractors in construction industry are often relatively small companies
  –Contractors do not do very much research by themselves
•General lack of knowledge on model parameters for loadings, materials, groundlayers etc.
•Relative simple and limited analyses are done by design department of constructors
  –Nonlinear failure analyses are primarily done by experts
•Special purpose application programs gain popularity
•Nonlinear analyses still requires expert users, the models are too complicated for use as a black box
•Structural behaviour is sometimes so complex that behaviour can not be modelled appropriately.

Consumer Goods Technology Needs with PSO Implications

- More accurate modelling of materials, mainly plastics
- Costs for Analysis
  - Need to have a measure for gain from performing simulations
- Risk Reduction
  - Probabalistic Design Analysis
  - Design and Analysis for Product Liability
  -
- Multiphysics Analysis
  - Coupling of Moldflow Analyses and Stress Analyses
- Fatigue & Life Predictions
  - Most metals used are OK
  - Plastics used are a real problem, data not available
- People to use the Technology
  - Analysts are comfortable in Linear Analysis & Mid-range Non-Linear Analysis
  - Design Engineers can perform Linear Analysis using CAD Integrated FEA Tools
  - Typical Ratio of 1 Design Engineer/Analyst vs. 5 Designers
  - EMC – Better to employ specialist in the physics then teach the FEA Tools
  - Injection Moulding – Better to employ a Toolmaker/Moulder then teach the FEA Tools
  - Need to conduct In-House training on company specific problems, must include both successful project as well as failures!
  - Teach Analysis vs. Physical Testing – Sometimes Physical Testing can be wrong!! – Yes, Really!!
- Expense of High-End Analysis Software
  - Multiphysics
  - Impact Analysis and Drop Tests
- Reporting Results
  - To whom?
  - Design Teams – what does this mean?
  - ISO 9000
  - Automated reporting – is this feasible?

- Needs to be flexible (with templates?) for ISO, etc
- What should be included in an automatically generated report? Potentially Huge Cost Savings here!!

Analysis Issues

- Material Modelling (Plasticity & Strain Rate Dependencies)
- Impact & Drop Test Analysis
- Manufacturing Simulation (Moulding followed by stress analysis but including residual stresses)
- CAD Integration
- Multiphysics
- Life Predictions
- EMC (Television Interference & Health Issues)

Business Drivers

- Time to Market
  - Virtual Prototyping & Physical Prototyping
- Cost of Simulation
- Quality Control (Analysis versus Testing)
- People with skills in the physics as well as simulation
- CAD Integration

Future Work

- CAD Integration!!!
- Non-linear & fatigue life Material Data for non Metals
- Durablility & Life Predictions for non-metallic components

4 Recommendations for FENET-PSO Workshops (Month 7-Month 16)

The first PSO workshop (PSO-Workshop 1) at Wiesbaden has been very useful in collecting feedback from FENET members and identifying future workshop topics. The following table presents a recommendation for future PSO workshops in the next year.

Table 2

Proposed PSO Workshop Programme for Month 7 – Month 16

RTD Workshop	FENET Month	Provisional date	Title	Topics covered
PSO-Workshop 2	M7	Feb 2002	The use of Design of Experiments (DOE) and Response Surface Analysis(RSA) in PSO	Features of DOE Features of RSA Case studies from industry Benchmarks Performance indicators
PSO-Workshop 3	M10	May 2002	The use of Evolutionary Algorithms for Process and System Optimization (PSO)	Discussion topics *Training in Optimization methods *model reduction problems Technical presentations *Evolutionary Algorithms for PSO *More Benchmarks for Structural and Design Optimization *More case studies of PSO in industry
PSO-Workshop 4	M13	Aug 2002	The use of gradient based methods for PSO	Further survey of FENET members Educational needs for PSO. More on benchmarks for PSO. Production of “How to” material for design engineers.
PSO-Workshop 5	M16	Nov 2002	Desigh optimization for production	TBA
PSO-Workshop 6	M19	Mar 2003	“What’s best“ guide to design optimization	TBA

Industry Sector	RTD Thematic Area	Date	Deliverable Nr
	Multi Physics & Analysis	May 2003	D3423

Deliverable D3423

Updated Technology Issues Multi-Physics and Analysis

Prof. Mark Cross and Dr. Avril Slone - University of Greenwich UK

Prof. E Oñate and Dr. M Chiumenti - CIMNE, Spain

Summary:

A summary of the main discussion points related to Multi-Physics and Analysis issues from the FENET MPA Workshops held during 2002 is presented

1 Introduction

This report summarises the workshops related to RTD1 on Multi-Physics and Analysis (MPA) held during 2002. Starting with the first MPA workshop in February 2002, where the complex nature of MPA was discussed and it was proposed to separate the study of MPA problems into two workshops to study loosely couples and strongly coupled problems in more focused manner.

Subsequently it was proposed to study MPA in the light of industry specific problems in future workshops in 2003.

2 First MPA Workshop on the Computational Modelling of Multi-Physics

Processes

It was concluded by the Steering Committee during the Wiesbaden meeting that the first MPA workshop should be on the overview of multi-physics modelling, as shown in the following table.

Table 3

FENET-MPA Workshop

Workshop Title:	Computational Modelling of Multiphysics Processes
Date:	27-28th February 2002
Venue:	Copenhagen
Organiser:	Prof. M. Cross, University of Greenwich
Description:	This is the first workshop in the FENET EU Thematic Network on issues related to Multi-Physics and Analysis. The objective of this workshop is to focus on the status and challenges of multi-physics simulation technology. The workshop will address the following: ● Overview of challenges of MPA – contemporary applications – levels of coupling – survey of commercial CEA analysis technology ● Multi-physics case studies – formulation and routes to solution ● Road-map for the future- key problems – characterisation of problems – physics vs. levels of coupling – software capabilities- gaps and limitations.

Structure of the workshop

The workshop was divided into three sessions.

- In the first session an overview of the challenges of MPA was given and the six multi-physics problems were considered in a general discussion. The audience comprised of developers of FEM, engineers and also experimentalists working in multidisciplinary problems.
- In the second session the audience was divided into six groups and time was allowed for each group to consider the problems and to identify whether there was a viable route to solution using existing CAE tools and gaps in the existing technology.
- In the third session, each group brought forward their solution and there was a round table discussion of the perceived limitations and strengths in current technology, with a view to identify possible developments in MPA

Conclusion

The format of this workshop, where there was a significant level of audience participation was highly successful. The workshop identified three broad strategies to solve the different problems, i.e. de-coupled, loosely coupled and strongly coupled. Two main fields of study in the field of MPA were identified, namely, fluid-structure interaction and thermo-mechanics. The continuing need for good solution algorithms and computing strategies was discussed, as was the lack of benchmarks and existence of only a small number of validated software tools.

These topics render Multi-Physics problems too complex and wide ranging to study as a single phenomenon, such that it was proposed to separate the study of MPA problems into two workshops and study one single topic in each, namely:

- Loosely coupled analysis.
- Strongly coupled analysis.

This strategy will enable a highly focused area for discussion.

3 Second MPA Workshop on the Computational Modelling of Loosely Coupled Multi-Physics Problems

In previous workshops several topics have been identified in the area of Multi-Physics and Analysis (MPA), including the strategies used to solve the different problems, i.e. de-coupled, loosely coupled, strongly coupled. This workshop was the first of a pair addressing the level of coupling require for practical simulation of Multi-Physics problems and focused on loosely coupled or de-coupled problems, thus enabling a highly focused area for discussion. Accordingly the workshop is described by the following table

Table 5

FENET-MPA Workshop

Workshop Title:	Computational Modelling of Loosely Coupled Interaction in Multi-physics Problems
Date:	13 14th June 2002
Venue:	Zurich
Organiser:	Prof. M. Cross, University of Greenwich and Pere-Andreu Ubach, CIME
Description:	The aim of the workshop is to identify and discuss recent advances in loosely coupled problems. Accordingly, the specific objectives of the

	workshop are: • To define a validation and verification strategy for loosely coupled simulation methods and software. • To identify and select benchmark problems incorporating experimental results for validation of loosely coupled numerical simulation codes. • To select existing and new numerical solution procedures for loosely coupled analysis using FEM. • To identify industrial problems where loosely coupled analysis is needed. Candidate contributors to the Workshop are: • Developers of FEM software for coupled problems and also developers of tools for coupling together specific existing software tools for each of the phenomena. • Engineers working in multidisciplinary problems. • Experimentalists contributing examples and data for validation of multidisciplinary analysis codes.

Conclusion

In this workshop there was an important contribution by the software companies. Two main topics of discussion arose, namely, the concern for supplying software tools that were easily operated by the end user, and the difficulty for performing multi-physics without a single and shared database
At the end of the workshop there was an open discussion and although the number of participants was low, their contributions were significant. The question was posed
How far can we arrive using the strategy of exchanging data between different applications, versus the option of making a shared database?

The following conclusions were drawn

- Data exchange strategies could be sufficient for loosely coupled problems but that this strategy was not sufficient for fully coupled, complex, problems.
- These difficulties may be avoided by the use of common (shared) databases...
- The participants would like to point out a recommendation for software companies. This is the possibility of setting up a committee in charge of defining standards for the structure of the database, in order that all the companies use this common standard for their upcoming programmes, thus allowing the user to take advantage of the features of many software vendors without having a lack of performance due of the multiplication of data storage.

4 Third MPA Workshop on the Computational Modelling of Strongly Coupled Multi-Physics Problems

Previous workshops have identified several generic topics in the area of Multi-Physics and Analysis (MPA) which render Multi-Physics a too much complex and wide ranging to study as a single phenomenon, such that it was decided to separate the study of MPA into two workshops. Thus this workshop is the second in the series and follows on from the successful workshop on loosely coupled analysis held in Zurich, June 2002 and is described by the following table.

Table 6 **FENET-MPA Workshop**	
Workshop Title:	Computational Modelling of Strongly Coupled Interaction in Multi-physics Problems
Date:	11-12th September 2002
Venue:	Trieste
Organiser:	Prof. M. Cross, University of Greenwich
Description:	The aim of the workshop is to identify and discuss recent advances in strongly coupled problems. Accordingly, the specific objectives of the workshop are: • To define a validation and verification strategy for strongly coupled simulation methods and software. • To identify and select benchmark problems incorporating experimental results for validation of strongly coupled numerical simulation codes. • To select existing and new numerical solution procedures for strongly coupled analysis using FEM. • To identify industrial problems where strongly coupled analysis is needed. Candidate contributors to the Workshop are: • Developers of FEM software for coupled problems. • Engineers working in multidisciplinary problems. • Experimentalists contributing with examples and data for validation of multidisciplinary analysis codes.

Structure of the workshop

The workshop was held over one day. It was opened by Professor Cross who gave an overview of closely coupled MPA, which was followed by four presentations in various fields of complex applications. These applications included overviews of the state-of-the-art in a number of commercial CAE tools, and instigated some short presentations by other software vendors with a range of multi-physics applications. The day was concluded by a master class in closely coupled MPA.

Conclusion

It is evident that, even in the time from the start of FENET, the commercial CAE analysis sector has been busy developing capabilities in multi-physics and specifically addressing some classes of closely coupled problems. However, it is clear that though these technologies have genuine capability, they are often very phenomena specific and cannot be easily coupled into other physics modules without considerable re-engineering. The problems of running on high performance parallel systems present yet another level of challenge in this context. Although it may be straightforward to generate high scalabilities on single physics codes, such as CFD, it is much harder to achieve high levels of performance for multi-physics simulation. It was also clear from the master class that there is much work to be done in enabling analysis engineers to obtain both the expertise and confidence to go

beyond their base 'phenomena' expertise to address the full complexities of multi-physics, even though raw software capabilities may be available.

5 Fourth MPA Workshop on the Computational Modelling of Fluid Structure Interaction Problems

During the first year of FENET project several workshops where organized to study the different typologies of coupling in MPA: one-way coupling, weak and strong coupling algorithms. Many different problems as well as possible alternative solutions have been presented and discussed among all the partners. The main idea for this fourth MPA session of the FENET workshop was to focus on a more specific area within the MP. According to this idea, the current MPA session has been based on *Fluid-Structure Interaction.*

Table 7

FENET-MPA Workshop

Workshop Title:	Fluid Structure Interaction
Date:	27-28th February 2003
Venue:	Barcelona
Organiser:	Prof. E Oñate & Dr. M Chiumenti, CIMNE
Description:	The main idea for this MPA session of the FENET workshop is to focus on a more specific area within the MP. According to this idea, the current MPA session is based on FLUID-STRUCTURE INTERACTION, including the following items: •Aero-elasticity •Aero-acoustic problems •MP in Aerospace •MP in Marine •MP in Offshore structure

Structure of the workshop

The workshop was held over two half-days. The meeting was opened by Professor Oñate, who gave an overview of most significant applications in MP related with fluid-structure interaction. This overview was followed by six presentations during the first day and by four further presentations the following day. The session was concluded by a round-table discussion to summarize the main aspects concerning fluid structure interaction, the associated problems and possible solutions from both the academic and the industrial point of view.

Conclusion

The format of this workshop was highly appreciated by an extremely interested and knowledgeable audience due to the variety of issues addressed:

- Coupling topology. Multi-Physics solution strategy depends on the level of coupling, which may be increasingly sophisticated, ranging through uncoupled, weakly-coupled and strongly-coupled problems. Most real-life problems are MP problems, but in the past there has been a tendency to either ignore one of the phenomena, or to treat the problem as weakly or totally un-coupled, as this was both simpler and cheaper. With increasingly sophisticated MP software becoming available it is possible to analyse these problems in a more realistic manner, so that in the future we should move to truly MP software. So that as computer power increases, the standard could be MP analysis, which would give the community more accurate knowledge of MP problems. The question is "*What are the barriers to the uptake of MPA?* Multi-physics
  Analysis requires **expertise** and **knowledge** of different fields, for example CSM, CFD, to name but a few, from the point of view of both *developers* and *users*.
- Numerical tools to be used.
  1. *Use different codes* for each one of the physical phenomena involved:
     - Specific software focused on the solution of specific problem
     - Developers and user have separated knowledge and work on separated physics
     - Less efficient (i.e. DB exchange)
     - It could be the solution for weakly-coupled problems
  2. *Use one code*:
     - Only one integrated environment (starting developments from scratch)
     - No inertia coming from the use of traditional codes difficult to modify
     - Knowledge of different physics
     - Highly efficient (only one DB)
     - Adequate for strongly-coupled problems
- New methodology. Recent challenges to solve MP problems: extension of FE method to *FE-particles method*. This means a **new methodology** to solve in an *alternative* manner complex problems
- Discretisation. Multi-Physics analysis may require different **time** and **space discretisation** (i.e. aero-acoustic problems)
  1. *Mesh* depends on the physics (i.e. temperature gradients, stress concentrations, turbulence,…)
  2. *Time integration scheme* depends on the physics (i.e. frequencies, dynamics, …) Sub-cycling can aid speed.
- Validation. Multi-Physics solutions need both numerical and experimental **validation,** as found in other fields, e.g. in sheet-metal-forming or casting. It is crucial to know whether the simulation is close to real-life behaviour or are the simulation results just *pretty picture*. Also it is difficult to define test cases.