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THE INTERNATIONAL MAGAZINE FOR ENGINEERING DESIGNERS & ANALYSTS FROM **NAFEMS**

Carrying a Torch for FEA

Simulating the manufacturing process for the 2012 Olympic Torch

Editorial

Editor
David Quinn
david.quinn@nafems.org

Deputy Editor
Nicola McLeish
nicola.mcleish@nafems.org

Design/Production
d2 print
info@d2print.com

Advertising
Paul Steward
paul.steward@nafems.org

Subscriptions
Christine Bell
christine.bell@nafems.org

Membership
For information on membership of NAFEMS, contact Paul Steward on paul.steward@nafems.org

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Publisher

NAFEMS
Beckford Business Centre
Beckford Street
Hamilton, Lanarkshire
ML3 0BT
UK

t +44(0)1355 225688
f +44(0)1698 823311
e info@nafems.org

from your editor

David Quinn
david.quinn@nafems.org
@benchtweet

Although there is always talk of "real-world" in simulation and analysis, and much trumpeting about how we keep planes in the sky, cars on the road, and buildings upright, it can still be difficult to raise our heads from the computer screen and truly look at how simulation and analysis is very much a real-world tool, which is used primarily to make lives better. If you want to bring this into sharp focus, you need look no further than one of the articles in this issue, 'Modelling like the Masters', which can be found a few pages in. This article, based on the paper which won the prize for 'Most Innovative Use of Simulation Technology' at the recent NAFEMS World Congress, brings the real world into stark focus. In it, we hear about how simulation is being used to more accurately plan and carry-out post-surgery breast reconstruction after surgical interventions due to breast cancer. A subject that has undoubtedly touched many of our lives through the years, and one which, thanks to techniques and studies such as those outlined in the article, is being pushed forward with the sole aim of basically making people's lives better and more comfortable. It's fascinating stuff, and we welcome your thoughts and feedback on this and any other topics you have something to say about.

Talking of NAFEMS events (who was?) – this issue sees the announcement of the NAFEMS 2014 Regional Conference programme, with events being held in the UK, USA, France, Germany and Sweden. The calls for papers are now open for these events at www.nafems.org/2014, as well as information on sponsorship, exhibition and attending. Our conferences and congress' get bigger with each run, and we're hoping that the 2014 programme will provide many of you with the chance to interact with NAFEMS, and attend a uniquely independent and technically focussed event.

You may also have noticed the fruits of some of NAFEMS' marketing department efforts coming to life over the past few weeks. Our newly-refreshed website was launched in September, offering a much more user-friendly experience, with plans in place to launch additional features and content over the coming months. Oh, and if you hadn't noticed, the very magazine you're reading has undergone a bit of a re-vamp. We're introducing our new regular columnist, Al Dean, who some of you may know from his work on DEVELOP3D, and we're looking forward to Al's insight and comment from a fresh perspective. We're always on the lookout for regular contributors, as well as technical articles, so if you have something to say, get in touch and we can discuss how you can get involved – this is your magazine after all.

Until next time..

news....

COGAN

COMPETENCY IN GEOTECHNICAL ANALYSIS

COGAN Project Launched

NAFEMS will be the co-ordinator for the recently approved COGAN – Competency in Geotechnical Analysis European project.

The main aim of this Leonardo da Vinci European Transfer of Innovation project is to follow on from the exceptional work done during the CCOPPS and EASIT2 projects, but with the focus being on the geotechnical industry.

The goal is to transfer the innovative outputs from the highly successful CCOPPS project (www.ccopps.eu) including its work-based e-Learning modules, and EASIT project (www.easit2.eu) including its competency framework, to the geotechnical sector of the construction industry. With three core partners from the EASIT project involved in COGAN, it is clear that there will be further innovations transferred.

The main outcomes from COGAN - all firsts for geotechnical analysis – will include:

- An Educational Base to direct staff development, consisting of around 1000 Statements of Competence in about 15 topic areas, adapted from the EASIT Educational Base;
- A Competence Framework utilising the EASIT generic framework, built around the Educational Base, to allow formal recording of competence achievement, with links to wider professional/company competence frameworks;
- Two E-Learning Modules for work-based learning, to achieve in depth the learning outcomes in two selected core competencies, and to promote the development of further modules by training providers.
- The valorisation strategy, which will target training providers in Europe, together with the adoption of all deliverables by NAFEMS – a leading training provider in engineering analysis in Europe – will ensure that the project will have a significant and lasting impact on training systems in the European geotechnical sector, and potentially in the wider construction industry.

Keep up to date with the project at
www.cogen.eu.com

First NAFEMS Event in Japan

NAFEMS is pleased to announce that we will host our first Japanese event, "NAFEMS Japan 2013 - An Introduction to the International Engineering Analysis Community", at the Tokyo Conference Center Shinagawa on December 9.

There are 2 parts to this conference. In the morning sessions, we will focus on the human resource development of the CAE engineers. We will be introducing EASIT^2, the recent EU project devoted to developing a competency framework specifically for simulation engineers, PSE, the new standard for simulation engineers certified by NAFEMS, and the mutual recognition project between PSE and the JSME senior analyst.

In the afternoon sessions, leaders from industry and academia in both Europe and Japan will give presentations on various topics relating to the most innovative applications and best-practice in CAE. There will also be an extended 40 minute discussion session to enable "Q&A" at the close of the conference.

We anticipate that this conference will contribute the further advancement of computational engineering and CAE in Japan, and begin NAFEMS activities in the region in a positive manner.

2014 Regional Conferences Announced

Next year, NAFEMS will again host a series of regional conferences aimed at bringing together our members with the wider simulation community to focus on latest issues and trends.

Conferences have been confirmed for the UK, DACH, Nordic, France and Americas regions for Spring/Summer 2014.

These conferences follow on from the well-attended World Congress in June and the successful 2012 regional conferences. The 2014 conferences will continue to focus on best practices as well as state-of-the-art simulation use.

As the only independent and vendor-neutral association dedicated to analysis and simulation, these unique events provide an open discussion forum unlike any other. Industry, vendors and academics will come together in a truly neutral arena to explore the future of simulation and how it will be deployed in the coming years.

Call for papers for the conferences will open in the coming weeks.

More information is available from
www.nafems.org/2014.

in this issue

regulars

what's on

Structural Optimization in FE Analysis

3 October 2013 4 week e-Learning Course

The objective of this course is show you a broad overview of the range of FEA based tools available and what the methods and specializations of each encompass. Plentiful hints and tips will demonstrate powerful ways to use these methods. The goal is to achieve meaningful structural optimization in support of the most effective products.

Practical Introduction to FEA

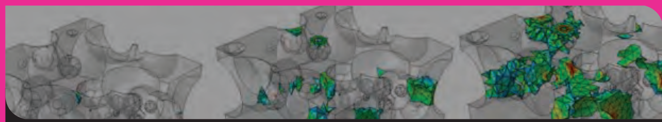
7 October 2013 Training Course | Houston, Texas, USA

This course is aimed at practicing engineers who wish to learn more about how to apply finite element techniques to their particular problems in the most effective manner. The material that is presented is independent of any particular software package, making it ideally suited to current and potential users of all commercial finite element software systems. This course is a must for all engineers aiming to use FEA as a reliable predictive tool for thermal, stiffness and stress analysis.

Practical Introduction to Non-Linear FE Analysis

8 October 2013 Training Course | Nottingham, UK

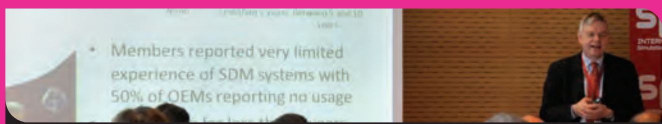
This two day non-linear FE course is intended for delegates interested in using FE to analyse advanced non-linear problems involving material non-linearities, geometric non-linearities and contact problems.The objectives of this FE course are to provide delegates with an introduction to the fundamental theory of non-linear FE analysis and to highlight the possible difficulties that may be encountered in using FE software to analyse non-linear problems.



Practical Analysis of Composite Structures

16 October 2013 Seminar | Bristol, UK

This seminar brings together experienced practitioners in composites analysis, offering insight into the best approaches for obtaining and validating composites material properties, selecting and using appropriate failure criteria, and establishing robust analysis approaches for modern composites design.



Understand Variation to Realize Robust and Optimal Design and Production

17 October 2013 Seminar | Los Angeles, CA, USA

This one-day symposium has been organized by NAFEMS Americas and the Stochastics Working Group to help attendees understand variation to realize robust optimal design and production.

Symposium participants will hear and learn about the importance of incorporating variation to reduce uncertainty in your delivered designs and products; advanced simulation and analysis methods to optimize your design and products during development; proven Robust Design processes, tools and methods used to achieve customer satisfaction

Methode des Elements Finis appliquee au dimensionnement

22 October 2013 Training Course | Paris, France

This 2-day training course is the first step of NAFEMS education for beginners in analysis. It aims to give to designers and technicians the theoretical knowledge and best practice information regarding FEM and FEA to safely and efficiently model and analyse parts and structures. While independent of any software, the course contains several exercises to ensure sound knowledge.

Improving Simulation Prediction by Using Advanced Material Models

5 November 2013 Seminar | Lund, Sweden

This seminar provides an opportunity for delegates to learn how the many modeling issues related to this topic are addressed. It also provides a rare opportunity to network with peers who are faced with similar challenges and to exchange experiences within material modeling challenges and advantages.

Non-Linear Analysis

5 November 2013 4 week e-Learning Course

The objective of this course is to break down the nonlinear problem into clearly defined steps, give an overview of the physics involved and show how to successfully implement practical solutions using Finite Element Analysis.
This course is aimed at practicing engineers who wish to learn more about how to apply finite element techniques to nonlinear analysis in the most effective manner. Ideally a student should have some experience of FEA analysis, but this is not essential. This course is a must for all engineers aiming to use FEA as a reliable predictive tool for nonlinear analysis.

Méthodologies et Bonnes Pratiques de Simulation Numérique

6 November 2013 Training Course | Paris, France

This 2-day training course is at the heart of the NAFEMS education program. It aims to give designers and analysts state of the art knowledge and best practices to perform simulation driven design and structural analysis at their best, and to include engineering simulation as a key asset in product-process design, verification and optimization.

Computational Fluid Dynamics (CFD) in Systems Simulation

12 November 2013 Seminar| Bamberg, Germany

System simulation describes the behavior and the interaction of technical devices by means of mathematical relationships. It also considers interdisciplinary coupling, which takes into account the effects of the physical behavior of the individual components of a device or the single component. In this seminar, procedures for system simulation in fluids applications will be presented and how conclusions can be achieved, ranging from the overall system behavior to single components, and vice versa.

Best Practices for the Efficient Use of CAE - Methods, Tools, Processes

18 November 2013 Seminar | Wiesbaden, Germany

The seminar will showcase "best practices" to increase the efficiency of the use of CAE in the product development process. This will include CAE workflows and the use of software tools. The seminar will describe what is feasible with the current technology and what level of development (state-of-the-art theory and software) has been reached for the different application areas.

V&V: Verification et Validation des Modèles et Analyses

19 November 2013 Training Course | Paris, France

This 2-day Master Class uniquely offers an opportunity to understand V&V concepts and requirements, improve synergy between physical and virtual tests and implement reporting to increase visibility and confidence of simulation outcomes. It is a perfect course for advanced engineers, project and program managers and any experts concerned with regulations or facing certification processes such as we have in aerospace, energy, shipbuilding, transportation industry, etc...

Computational Aeroacoustics

20 November 2013 Seminar | Gaydon, UK

This course is aimed at practising engineers who wish to learn more about how to apply CFD techniques to their particular problems in the most effective manner. The material that is presented is independent of any particular software package, making it ideally suited to current and potential users of all commercial CFD software systems. The numerous practical examples will be explained without the use of any software program. This course is a must for all engineers aiming to use CFD as a reliable predictive tool for flow analysis.

Introduction to CFD Analysis: Theory and Applications

20 November 2013 Training Course | Wiesbaden, Germany

This course is aimed at practising engineers who wish to learn more about how to apply CFD techniques to their particular problems in the most effective manner. The material that is presented is independent of any particular software package, making it ideally suited to current and potential users of all commercial CFD software systems. The numerous practical examples will be explained without the use of any software program. This course is a must for all engineers aiming to use CFD as a reliable predictive tool for flow analysis.

Engineering Simulation for Optimal Design

21 November 2013 Seminar | Paris France

This new NAFEMS France seminar is focused on state of the art methods to improve simulation driven design, part lightening and weight reduction, global optimization and validation. The goal is to cover all aspects of engineering changes, from material to shape to manufacturing processes, allowing for optimal designs complying with tighter and tighter specifications. Key academic studies and best industry cases will show up, giving the delegates the right information to enhance their own methods, processes and business.

Simulation Data Management: from Concept to Reality - Industry Experience Exchange Forum

21 November 2013 Seminar | Troy, MI, USA

Following on from the well-attended SPDM Conference as a part of our World Congress 2013, this event continues a series of SDM dedicated events from NAFEMS. This event will focus on "Realworld" SDM experiences deployment, including success cases, failure cases, lessons learned, etc providing an exchange forum for industry.

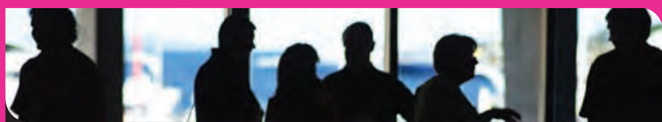
European Conference: Coupled MBS-FE Applications: A New Trend in Simulation

26 November 2013 Conference | Frankfurt, Germany

For many years, engineers have recognised the need to simulate not only components submitted to different boundary conditions, but more complex systems where different components interact with each other mechanically. Multi Body Simulation (MBS) was developed to satisfy this need, but with the goal of simulating the kinematics of multi body systems. At the same time, the classical Finite Element method was gaining further capabilities in the simulation of complex mechanical behaviours including non-linearities, both geometrical and material.

Today, those two technologies have been evolving together: MBS has gained more capabilities to introduce flexibility and even some non-linear effects in the "kinematic" description of a mechanism, whilst FE has developed the ability to take into account contact and kinematic joints. More recently, the coupling of these two methods through co-simulation has given provided solutions to another range of problems, taking advantage of both disciplines.

This conference, organized by the NAFEMS Computational Structural Mechanics and Multi Body Dynamics Working Groups, will bring together industry, academia and software vendors in order to give the attendees a clear picture of the real capabilities of these disciplines: MBS, FE, and the co-simulation of both, through the presentation of industrial applications.



An Introduction to the International Engineering Analysis Community

9 December 2013 Conference | Tokyo, Japan

The first part of this conference will focus on the human resource development of the CAE engineers. We will be introducing EASIT2, the recent EU project devoted to developing a competency framework specifically for simulation engineers, PSE, the new standard for simulation engineers certified by NAFEMS, and the mutual recognition project between PSE and the JSME senior analyst.
Later, leaders from industry and academia in both Europe and Japan will give presentations on various topics relating to the most innovative applications and best-practice in CAE. There will also be an extended 40 minute discussion session to enable "Q&A" at the close of the conference

nafems.org/events

NAFEMS TRAINING

upcoming dates

nafems.org/training

3 October 2013
Structural Optimization in FE Analysis
Online

7 October 2013
Practical Introduction to FEA
Houston, Texas, USA

8 October 2013
Practical Introduction to Non-Linear FE Analysis
Nottingham, UK

22 October 2013
Methode des Elements Finis appliquee au dimensionnement
Paris, France

23 October 2013
Practical CFD
Online

5 November 2013
Non-Linear FE Analysis - Australasia
Online

6 November 2013
Méthodologies et Bonnes Pratiques de Simulation Numérique
Paris, France

19 November 2013
V&V: Verification et Validation des Modèles et Analyses
Paris, France

20 November 2013
Introduction to CFD Analysis: Theory and Applications
Wiesbaden, Germany

invitation to tender

"How to Model Bonded Joints"

purpose

The Computational Structural Mechanics Working Group (CSM-WG) wishes to commission a new document with the suggested title "How to Model Bonded Joints". The book will form part of the existing "How to..." series of NAFEMS documents.

The successful How To series of publications is designed to guide both new and experienced analysts. The booklets are written to introduce various analysis methodologies to engineers and engineering managers, in a straightforward and informative manner. Joints are an essential part of products in all sectors of industry, Civil and Offshore, Power and Pressure, Aerospace and Land Transport, Consumer Goods and Biomechanical applications. Joints are important not only with respect to structural integrity and performance of the products themselves but in the jigs, fixtures and test hardware used throughout the product manufacture and qualification process.

Components are assembled together to maintain structural integrity and performance using a variety of methods either temporary allowing for repeated disassembly and reassembly necessary for maintenance activities or permanent attachment. Mechanically Fastened Joints, bolted and riveted are considered inherently different to bonded joints and is subject of a separate publication.

Bonded joints are considered permanent as an integral part of the product assembly. To maintain performance the joints need to survive all the loading environments experienced during the manufacture, assembly and testing and to deliver the required product performance throughout the in service life. The loads can be steady state or cyclic from vibration, shock and thermal environments.

intended readership

The document should be applicable to those familiar with or involved in design and engineering analysis and wish to learn about this subject area of simulation technology. The document should also be of value to Project Managers over seeing the use of these analyses. It should be assumed that the design engineers and analysts are familiar with basic Finite Element theory.

Booklet outline
(It should be noted that the outline provided below is that suggested by the CSM-WG but the prospective author may suggest changes based on their own experience.)

- Identification of the configuration of bonded joints covered in the document, scarf, single step single lap, multiple step single lap, single step double lap and multiple step double lap joints for example.
- The loading conditions considered, mechanical and thermo elastic and modes of failure, shear or peel for example.
- Introduction of the key features and mechanism of load transfer of the various types of joint.
- Introduction of the key parameters important to the performance of the joints, adherend stffiness, thickness of bond and adhesive material characteristics for example.
- Identification of modes of failure and assessment criteria using established sources of references where available and appropriate.
- Identify the significance of preload and/or pre-stress inherent in the joint and how to account for it in assessment of joint performance.
- Examples of idealisation of various types of joint to represent joint stiffness characteristics in larger assemblies of products.
- Examples of idealisation of various types of joint for detail analysis at component level.

guidance for proposal

Each proposal should consist of;

1. The proposed structure of the book with the titles of the examples to be developed
2. The proposed source of the data to be published
3. Work plan including milestones and interim deliveries for early review
4. Cost
5. The authors' credentials, curriculum vitae, etc. Proposals from single authors and consortiums will be considered.

Typical " How to..." documents are 60-100 pages long and the cost of preparing the document is expected to be in the low thousands of pounds.

All proposal should be sent to NAFEMS at csmwg@nafems.org to arrive no later than 31st October 2013.

Further details are available from the NAFEMS office or by contacting the Chairman of the CSM-WG csmwg@nafems.org.

NAFEMS

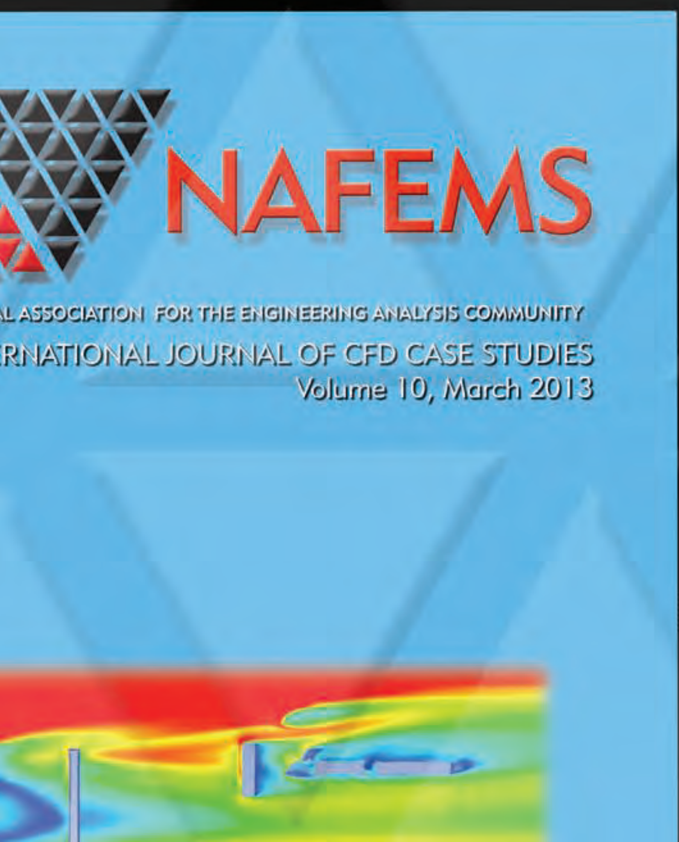
call for papers

This call for papers is for a special issue of the NAFEMS International Journal of CFD Case Studies to showcase CFD used by designers.

Numerical simulation is now firmly entrenched in the design process. Previously, simulations followed the design process to confirm the functionality. Now it is being used to kick off the design process often at the draft or concept design stage.

Engineering flow simulations are non-linear in nature and often have challenges due to modelling the flow region geometry (rather than the solid part that is modelled by CAD), turbulence (which usually must be modelled rather than directly simulated), coupled physical processes and many others. These aspects are not easy to handle and have prompted much software development to improve usability and ensure CFD is as widely used as possible. Software packages aimed at the non-CFD specialist or design engineer can, for example, automatically choose turbulence models and perform meshing for the user. Simulations performed by the designer are often used to give early understanding of relative performance of design iterations and to test out new ideas early in the design process. They may subsequently result in additional calculations by a CFD specialist, for example where a greater level of accuracy or prediction confidence is required or additional, more complex physics is present.

This special issue of the NAFEMS International Journal of CFD case studies will show how designers and other non-CFD specialists are using CFD tools and how the results are interpreted for engineering design purposes. Papers will promote the benefit of numerical simulation to and by non-CFD specialists and show how designers, by understanding further the behaviour of fluid flow and heat transfer via their simulations, can produce more effective first designs.



NAFEMS welcomes users of all CFD software products to contribute their papers. Further information about the journal can be found on the NAFEMS website at www.nafems.org/about/tech/cfd/activities/journal/

Papers for consideration should be sent to cfd.journal@nafems.org

Deadline is 31st January 2014

We thank all the authors in advance for their contribution.

2013 oct-dec

industry events

October 02
2013 ANSA & mETA North American Open Meeting
Conference | Plymouth, MI, USA

October 03
2013 LMS European Aerospace Conference
Conference | Toulouse, France

October 03
Altair Technology Conference Americas
Conference | Garden Grove, CA, USA

October 08
6th DIGIMAT USERS' MEETING by e-Xtream Engineering
Conference | Liège, Belgium

October 21
International CAE Conference
Conference | Verona, Italy

October 24
Open Source CFD International Conference 2013
Conference | Hamburg, Germany

October 29
ANSYS Automotive Simulation World Congress
Conference | Frankfurt, Germany

October 29
LMS European Vehicle Conference
Conference | Munich, Germany

November 05
ESI DACH Forum 2013
Conference | Wiesbaden, Germany

November 05
NX CAE Symposium 2013
Conference | Cincinnati, OH, USA

November 05
NACS Users Meeting 2013
Conference | Erlangen, Germany

November 06
ESTECO North America Users' Meeting 2013
Conference | Plymouth, MI, USA

November 14
The Skills Show
Conference | Birmingham, UK

December 12
Multiphysics 2013
Conference | Amsterdam, The Netherlands

nafems.org/industryevents

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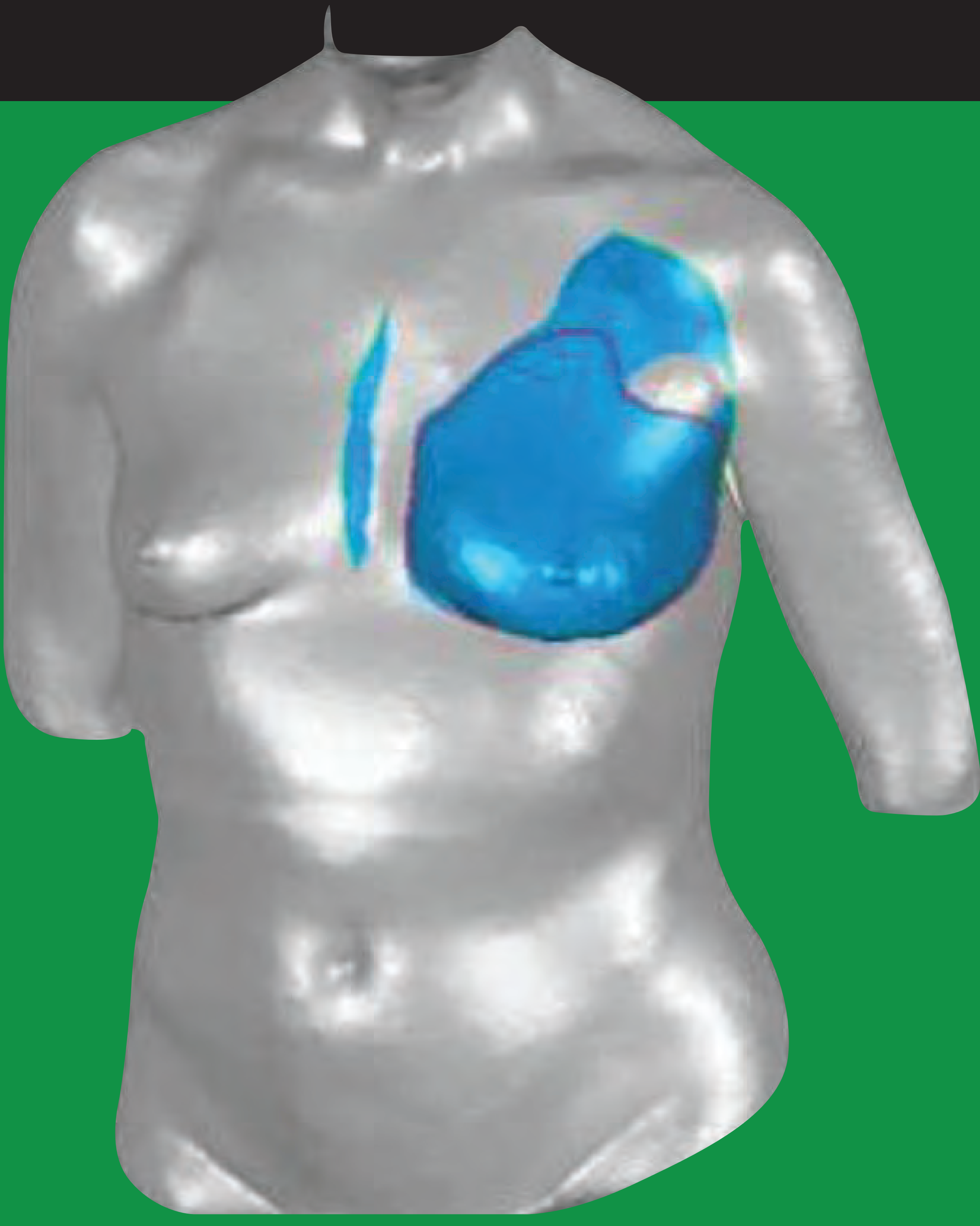

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TERS

S. Raith[1], J. Jalali[2], A. Volf[1], M. Eder[1], L. Kovacs[1]

[1] Research Group CAPS (Computer Aided Plastic Surgery) Munich, Germany.
[2] Institute of Medical Engineering at the Technische Universität München (IMETUM), Garching, Germany

Since time immemorial, artists and sculptors have attempted to capture that most elusive and imperfect form – the human body.

From The Bird Girl to Venus de Milo, the female form has been sculpted, painted and modelled by the great and the good, for the purposes of art and beauty. In the 21st century however, modelling of the human body takes on a new meaning. Computer Aided Plastic Surgery is an emerging area of CAE, and more and more is using FEA and related technologies to create accurate models of the human form which will behave in the same way as the real thing, to advance medical procedures and allow accurate planning of surgery in a non-invasive and precise manner. This article, which won the Best Paper award for Most Innovative Use of Simulation Technology at the recent NAFEMS World Congress, discusses parameter identification for the hyper-elastic material modelling of constitutive behaviour of the female breast's soft-tissues, based on MRI data, 3D surface scanning, and FEA.

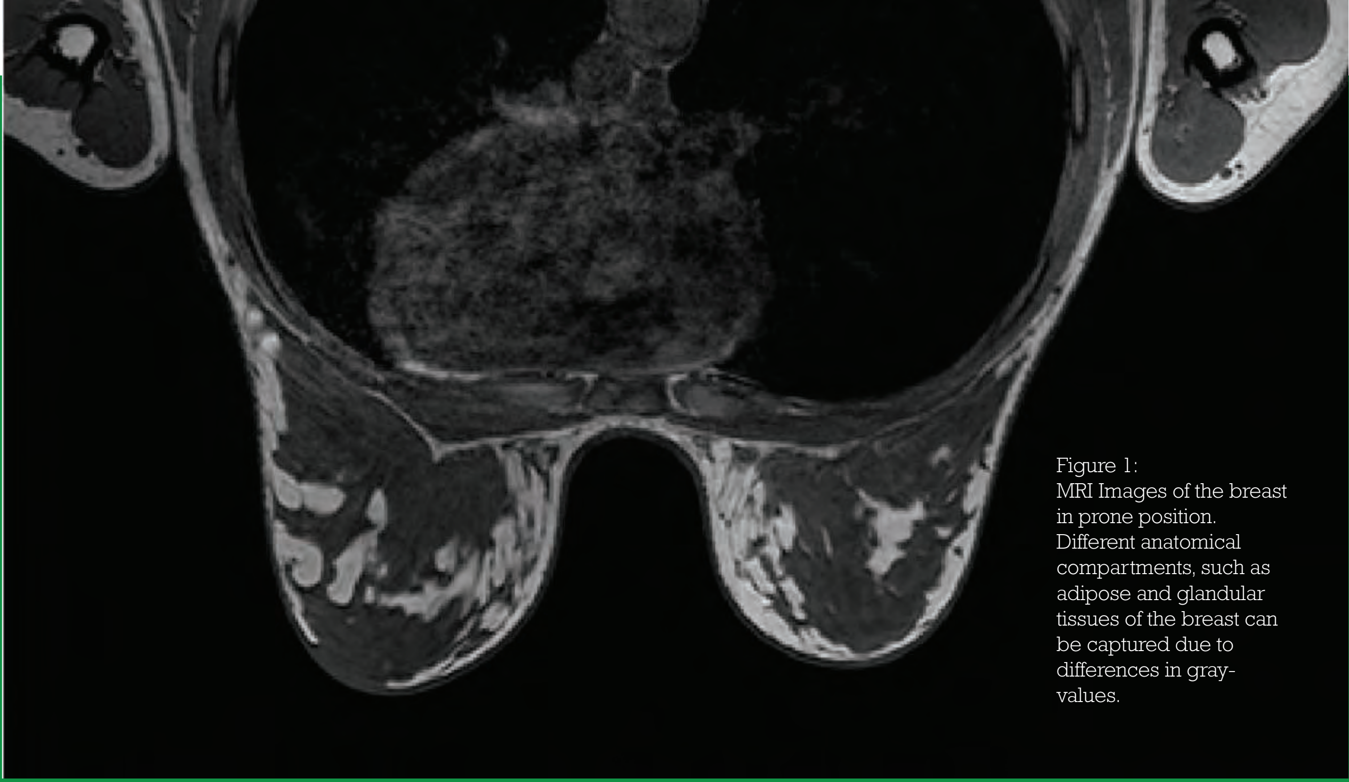


Figure 1:
MRI Images of the breast in prone position. Different anatomical compartments, such as adipose and glandular tissues of the breast can be captured due to differences in gray-values.

Surgical interventions due to breast cancer are a very common surgical procedure in women with 140,337 cases in Germany alone in 2010 [1]. After breast removal, it is often chosen to reconstruct the amputated breast in order to regain symmetry and to improve the life quality of the patients. These reconstructive surgeries are especially difficult due to the large soft tissue flaps that are necessary to reconstruct the missing breast with accurate volume and in the desired shape. Today, these operations are planned by drawing reference lines manually on the breast and the donor site. The success of the reconstruction thus mainly depends on the surgeon's skills and experience. For the improvement of breast surgeries in this scope, there is a desire to have access to planning tools that take advantage of modern measurement tools such as 3-D surface scanning and up to date simulation techniques such as FEA. For these simulations, the mechanical properties of the human soft tissues are highly relevant. It is only possible to reliably plan breast surgery operations if the physical behaviour of these structures can be modelled accurately.

Biomechanical studies of the mechanical deformations in the human body often use numerical simulations, such as the FEA. Shape changes in the female breast under varying load conditions, such as plain gravity or compression in mammography plates [2], are a current area of interest, both in the computational engineering science and in the medical sector. During radiological diagnostics, the breast is exposed to different mechanical loading conditions than at the stage of the operation planning and in the operation room. For better operation planning, a prediction of these mechanical deformations with modern imaging and simulation techniques on the computer is desirable. However, to generate realistic results that consider the physics of biological materials, it is essential to have a sufficient understanding of the theoretical constitutive models and the material parameters that describe the soft tissue of the breast. Although numerous studies have been performed to acquire material parameters, as yet, no consensus of reliable parameter sets can be generated. We think that three-dimensional body scanning can have a decisive role for the determination of soft

"The success of the reconstruction thus mainly depends on the surgeon's skills and experience. For the improvement of breast surgeries in this scope, there is a desire to have access to planning tools that take advantage of modern measurement tools such as 3-D surface scanning and up to date simulation techniques such as FEA."

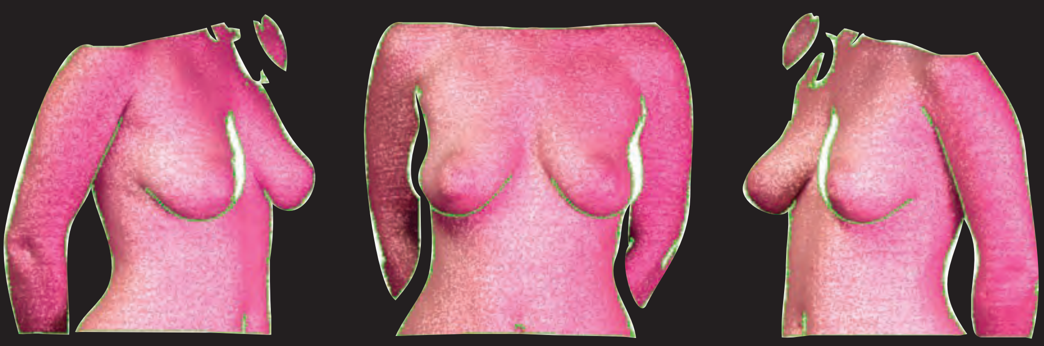


Figure 2:
Three surface scans acquired with the Konica Minolta Vivid device. The upright positions have been varied in 30 degrees to both sides in order to get the test person's side viewed surface information as well. These single shots have to be merged in a manual procedure to yield one surface representation.

tissue parameters of the breast: In the study presented here, 3-D surface scanning is used in combination with volumetric Magnetic Resonance Imaging (MRI) to capture the breast shape in different positions. Simulations with the geometrical volume models from MRI are performed and the simulation results can be validated by using a comparison to 3-D surface scans. With this workflow, it is possible to evaluate whether a certain material formulation is suitable for the simulation of the breast tissue.

Material and Methods

In the presented study, we use MRI data taken from six healthy test persons in prone position and derive volumetric finite element models out of this data. All volunteers gave their written informed consent to take part in the study and the Declaration of Helsinki protocols were strictly followed. Volunteers with a known history or hereditary risk of breast cancer, acute breast infections, known autoimmune or infectious diseases, severe breast malformations and thoracic deformations or fibrocystic mastopathy and previous breast surgeries were excluded from the study. No indications of existing breast asymmetries were observed and none of the volunteers had previously undergone any surgical interventions in the breast area, nor did they plan to do so in the future.

With the aid of FEA a force free reference state is calculated, using an iterative heuristic approach to overcome the deformations caused by unavoidable gravity loading. Starting from the obtained gravity free model, the shape of the breast in the upright position is calculated. This result is then compared to the real volunteers' breast surfaces, acquired with a 3-D surface scanner, in order to evaluate the applicability of the simulation procedure.

Volumetric Image Acquisition

Volumetric Magnetic Resonance Imaging (MRI) data of the six volunteer was captured with the aid of a Philips Achieva 1.5 Tesla MRI scanner (Philips Medical Systems DMC GmbH, Hamburg, Germany) using a T1-weitghted imaging sequence with a 512 x 512 x 179 voxel resolution and a spacing of 0.994 mm x 0.994 mm x 2 mm (imaging parameter: 4.6 ms ecco time and 9.2 ms repetition time). No intravenous contrast agent was applied. The thoracic images were obtained with the participants lying in prone position. The breasts did not touch the MRI bench. This was achieved with pillow supports located above the clavicle and in the shoulder region as well as caudal down to the lower belly area and the pelvic crest region, see Figure 1. With this support structure, all compressions of the breast due to contact with the bench could be omitted. However the breast's soft tissue is not stress free because gravity forces still act. Thus the shape of the free hanging breast can be made available for further processing and segmentation in suitable imaging software packages. The resultant models can finally be used for finite element simulations. But we have to keep in mind that these simulations do not start right away from an unloaded state, due to the gravitational forces acting on them.

3-D Surface Scanning

The post-operative outcome of breast surgery with respect to symmetry is typically evaluated in standing position. However, it is not yet common practice in clinical routine to use upright MRI systems due to their cost and the difficulties in the stable positioning of the patients when standing without further support. Usually in hospitals, there are only horizontal tube MRI devices available that permit the image acquisition for patients solely in lying position. Thus, the data for the internal anatomical structure is available either in prone or in supine positions. Three-dimensional surface scanning systems in contrast allow a variety of different positions of the patient including standing upright. Thus these techniques permit an indispensable advantage for the presented study. Due to their relatively low cost, they bear additional advantages for plastic surgeons that work as resident doctors and have no direct access to clinical MRI devices.

The imaging in upright position was performed using a surface scanner working with laser triangulation (Konica Minolta Co., Ltd., Osaka, Japan). This system has largely shown its applicability to breast shape measurements in preliminary studies [3-

7]. The 3-D surface scans of the participants were performed in standing position on predefined markers on the ground under standardized lighting conditions (light intensity 350 400 lux) with a 10 degree upward angle of the scanner facing the participants +30, 0 and -30 degrees relative to the lens in standing position [7]. During acquisition, the test persons were asked to hold their breath, while the arms had to be put down the side at the height of the pelvis and the back was supported by a wall to guarantee reproducible data by minimizing potential artefacts due to breathing and movement due to unstable standing.

These single shots from different angles (see Figure 2) of each volunteer were converted into virtual 3-D models using the appropriate software tool (Geomagic Studio 12®, Raindrop Geomagic, Inc., NC, USA) that has already proven its applicability and reliability [3-7]. All potential problems for later work with the data such as holes due to insufficiently clear scanning data or intersections between different acquisitions were fixed. For all models, the three single images (frontal, right 30° and left 30°) could be merged into one representation of the full frontal part of the breast region. No holes or overlapping surface parts are present in the prepared models. In Figure 3 an exemplary overview of different surface models derived from 3-D laser scanning is given. The obvious variance of the test persons overall build and especially the variations in breast size and shape make it a particularly difficult task from an engineer's perspective to derive comparable models out of this data. In traditional engineering, when working with technical parts, sizes and shapes are less variable and thus the geometric modelling is a less complex step.

Finite Element Modelling and Simulation

For the generation of individual specific volumetric simulation models, the underlying data for each FE model is reconstructed from the MRI scans of the six participants. The images were saved in DICOM format and loaded into the software Mimics® 14.0 (Materialise Inc., Leuven, Belgium), where the different anatomical regions of interest could be

"With the aid of FEA a force free reference state is calculated, using an iterative heuristic approach to overcome the deformations caused by unavoidable gravity loading. Starting from the obtained gravity free model, the shape of the breast in the upright position is calculated. This result is then compared to the real volunteers' breast surfaces, acquired with a 3-D surface scanner, in order to evaluate the applicability of the simulation procedure."

Figure 3: Surface scans of the breasts of eight exemplary test persons that participated in the study. The anatomical variance in breast size and shape and the overall built is obvious and leads to an especially challenging task for the engineer.

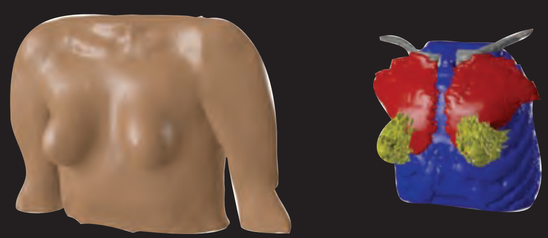


Figure 4: 3-D segmentations of the test person data coming from MRI scans taken in prone position; left: whole body of the chest region of the test person. Breathing artefacts do not disturb the accuracy of the skin segmentations. Right: inner anatomy of the test person. It is possible to segment all relevant compartments of the breast, consisting of glandular tissue, main pectoral muscles and the bony parts consisting of the clavicles and the thoracic wall.

Figure 5: 3-D surface scan (right) and comparison between FEM simulation result and scan (left) visualized as coloured deviations on the deformed finite element mesh.

automatically segmented and triangulated in different parts. Since the scope of benchmark magazine is mainly on finite element modelling and simulation, the study presented here focusses on these parts more than on the detailed anatomical modelling. The anatomical regions that are considered to be relevant for the simulation in the study are limited to a simplistic modelling of only one compartment that describes the whole soft tissue of the breast. Hence this compartment is a representation of a smeared material behaviour that summarises all tissues of that breast area, i.e. adipose and glandular tissues as well as the pectoral muscles (see also Figure 4). The skin is not considered as a separate part in this modelling. However, its effect is to a certain extent included in the identified parameter sets since the simulation results are compared to the overall mechanical behaviour of the in vivo breast that contains all anatomical parts. In consequence, the parameter configurations that are found to be optimal for the description of the constitutive behaviour of the breast are meant to represent the whole soft tissues. Comparable studies of Rajagopal et al. (2008) and Lapuebla-Ferri et al. (2010) also considered the breast tissue as homogenous material for finite element simulation, meaning that glandular and fat tissues are summarized in these works as well. Samani et al. (2007) found the mechanical properties of the two tissues to be of comparable magnitude (3.24 kPa for elasticity modulus of fat versus 3.25 kPa for glandular tissue), hence these simplifications seem appropriate.

The thoracic wall was modelled as a continuous surface, thus the intercostal muscles were considered to be one part, together with the ribs and the breast bone (see also Figure 4). The anterior part of the thoracic wall is used as a posterior demarcation of the deformable model since its deformability is considered to be negligible in comparison to the movement that the soft tissue undergoes. The other bony parts, the clavicles, were modelled in this study as well as the non-deformable, rigid bodies that are directly connected to the thoracic wall. Hence all movements of the shoulder region are locked and we have to make the assumption that shoulder positions in prone positions are comparable to the standing upright positions.

The segmented surfaces were prepared in an adequate 3-D surface processing software (Geomagic Studio 12®, Raindrop Geomagic, Inc., NC, USA and Blender®, Blender Foundation, Amsterdam, Netherlands) to improve the surface quality and reduce segmentation artefacts that

> “.... the variations in breast size and shape make it a particularly difficult task from an engineer’s perspective to derive comparable models out of this data. In traditional engineering, when working with technical parts, sizes and shapes are less variable and thus the geometric modelling is a less complex step....”

could disturb subsequent mesh generation. The triangulated surfaces treated in this manner can be utilized for the division of the complex anatomical shapes into volumetric tetrahedron meshes. For the generation of the FE model the meshing software ICEM® (Ansys Inc. Canonsburg, PA, USA) has been applied. Three surfaces containing the thoracic wall, the clavicles and the soft tissue as an entire component consisting of skin, fat, muscle and gland were imported to ICEM® in triangulated STL format. In order to eliminate the irrelevant parts of the breast model for the FE simulation, a box was defined to demarcate the model on different sides. The definition of these system boundary conditions is essential for the demand of standardizing the model generation procedure in order to maintain an inter-test-person comparability. This is the most crucial step in modelling the geometric anatomy, since the system boundary locations have a major effect on the overall performance of the FEA models. For the simulation, tetrahedron solid elements were used with u-p mixed formulation. This theoretical element formulation is suitable for general material formulations including incompressible materials, due to a hydrostatic pressure calculation. The programming language APDL (Ansys Parametric Design Language) was used for implementation and automation of the whole process.

Boundary Conditions

As boundary conditions the system boundaries as described above applied by the demarcation box have to be clearly defined in a standardized way to permit reproducibility. The system boundaries on the upper and lower boundaries, as well as at the lateral delimitations have been considered as fixed boundaries, i.e. all finite element nodes at these locations are kept initially fixed. In preliminary studies, a different variation with symmetry boundary conditions has been investigated as well, but this did not yield any significant difference in the simulations outcome. This finding stands in good accordance to literature (Tanner et al. [2]), where the influence of the boundary conditions is found to of minor importance. For the dorsal boundary conditions we considered the backward delimitation of the model to be the thoracic wall. The bony structure of the thorax can be considered as being very stiff in comparison to the soft tissues constitutive behaviour. Furthermore the clavicles are fixed and do not permit any movement. External force boundary conditions are not applied: gravity is the only loading that is put on the models.

Iterative Algorithm

Due to the soft constitution of the tissue, the breast is highly deformed even if no other forces are acting besides gravity. Therefore, in all possible spatial positions, the geometry of the breast is deformed at least due to gravity. But for mechanical simulations, an unloaded state of the geometries has to be known as the starting point of the simulation. Calculating the non-deformed reference state out of a known deformed configuration can be classified as an inverse problem. Due to the high deformation and the hyper-elastic material behaviour, a simple recalculation with inverse gravity is not satisfactorily accurate. Previous studies did not consider these effects and used a single step method instead [23]. But recently, more advanced investigations on this subject have been conducted taking these influences into account [18,19]. Rajagopal et al. presented an inverse algorithm for breast soft tissue simulation to address this topic. The study presented here uses a similar method for the iterative calculation of the unloaded reference state.

In this heuristic approach, a first approximation of the non-deformed configuration is made by a one-step backward calculation (inverse gravity). The result is then taken as the starting point to perform a forward calculation, while it is again considered to be initially stress free. It is now possible to check the error of the first inverse calculation by comparing the new result with the initial geometry that is deformed by gravity (derived from the MRI data). Since the meshing of the model does not change, the positions of all finite element nodes can be compared directly. The differences of these two models are used to make a better estimation of the unloaded configurations by adding these nodal deviations to the node positions of the first approximation of the unloaded configuration. Thereby, a better estimate may be achieved, which can be used again as an unloaded configuration for a new forward calculation. The newly calculated deformed position can again be compared to the segmented positions from MRI data and subsequently the comparison result can be used to further increase the estimate of the unloaded configuration. This procedure is performed iteratively and can be conducted in a loop where the estimate of the unknown reference state can be improved in each step. Here, a maximum repetition of 5 iterations was chosen.

Applied Material Model and Parameter Identification

Different material models are applied for the simulation of the female breast tissue by other

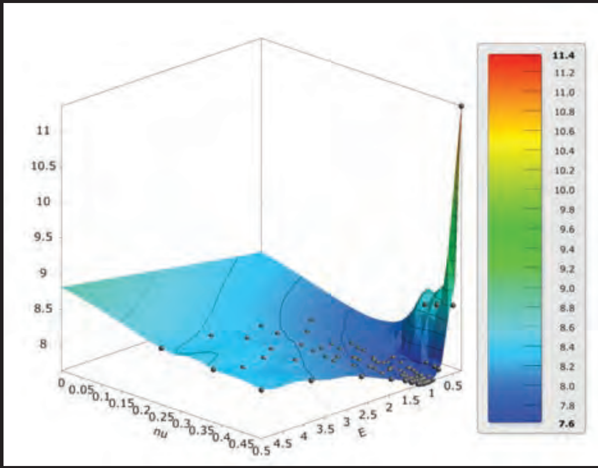


Figure 7: Typical response surface of an optimization. Young's modulus (E, factors to 0.13 kPa, as proposed in [12]) and Poisson's ratio (PR) are plotted. Mean deviation between 3-D surface scan in standing position and FEA result in mm is shown as the height of the response surface as it is objective value that is to be minimized.

research groups: Starting from linear elastic to piecewise-linear elastic, exponential elastic and hyper-elastic constitutive models that have been proposed by several authors. Different methods of deriving the relevant parameters that describe the stiffness of the materials have been used: Krouskop et al. [8], Wellman et al. [9] and Samani et al. [10] obtained the necessary material parameters based on ex vivo indentation tests. Tanner et al. [2] used different material models in one publication including linear elastic, Neo-Hookean and Mooney-Rivlin hyper-elastic models according to different earlier publications [8], [10] and [11].

Linear elastic material models, as used by Tanner et al. in [12] do not permit enough deformation to describe the movement of the breast tissue due to gravity, thus these constitutive models have not been used in this study. Even if only gravity loading is applied, the strains exceed the Hookean domain of linear stress–strain relationship. Thus, it is inevitable to use hyper-elastic material formulations to describe the deformations of the breast with finite element simulations. In the scope of the presented work, for the soft tissue modelling, hyper-elastic material behaviour was assumed and the Neo Hookean model was used as the theoretical model. This model bears the advantage of having only two input parameters (initial shear modulus and initial bulk modulus that can be transferred into Young's modulus and Poisson's ratio as commonly used in linear material modelling). Hence the material formulation is well suited for parameter identifications and optimizations, as the number of design variables can be limited to only two and thus even full samplings of the parameter spaces can be performed within reasonable calculation times. For the automatic variation of material properties as well as the results visualization, the software package optiSlang® was used (Dynardo, Weimar, Germany). Within the work presented here, full design space sampling was performed (Young's modulus ranging from 0.065 kPa to 0.195 kPa and Poisson's ratio ranging from 0.3 to 0.5, divided into eleven and three steps, respectively).

Comparison of Simulations and 3-D Surface Scans

The finite element simulation provides the breast geometry in upright position. To determine the usability of a certain material parameter set for this type of calculation, a comparison with the real world has to be made for the purpose of validation. Thus, the result surface of the calculation as it is meshed in the finite element model is exported as a triangulated surface. This result can be compared to the 3-D laser scans of the breast shape. For accurate positioning of both models, bony landmarks close to the shoulders, the clavicles and the sternum have been used.

For the 3-D comparisons, a specially developed algorithm has been used that calculates the node to node root mean square integration of the 3-D distance between the two models (in mm), according to the method described in [14]. Figure 5 shows a coloured visualization of a comparison between finite element result and 3-D surface scan. The whole workflow is automated and can be run in batch mode to allow fast processing of data with minimal efforts.

Results

The applicability of the presented workflow for the simulation of the breast was demonstrated. The whole process is automated and thus permits an easy to use interface for the comparison of different material parameters.

> "Due to the softness of the breast tissue, it undergoes high deformations even at moderate loading conditions. Even gravity load alone is enough to exceed the linear Hookean domain."

Due to the softness of the breast tissue, it undergoes high deformations even at moderate loading conditions. Even gravity load alone is enough to exceed the linear Hookean domain (Figure 6). Thus, the representation of the breast's soft tissue with purely linear elastic material models is insufficient. The finite element simulations did show a numerically instable behaviour (divergence) when these material models have been applied. Thus, hyper-elastic material modelling (Neo-Hookean) was used for all presented results. Convergence cannot be guaranteed however: in 182 out of the 198 performed simulations, a converged solution could be returned (91.9 %), but convergence were solely in regions of very soft parameter sets that were far away from the corresponding optima. Hence the convergence problems do not interfere with out parameter identifications in this particular case.

In Figure 7, a typical result of the simulations is shown. It is evident that there is a clearly defined optimum, i.e. the set of material parameters that is best suited to describe the real mechanical behaviour of the correspondent test person's breast.

Looking first at the variations in Poisson's ratio, there is a decrease towards higher values, meaning less compressibility. Thus, the often used modelling of biological soft tissues as incompressible or at least nearly incompressible can be confirmed by our findings. Since this is true for all tested models, in future work it seems unnecessary to deal with compressible material models, resulting in the reduction of unknown material parameters.

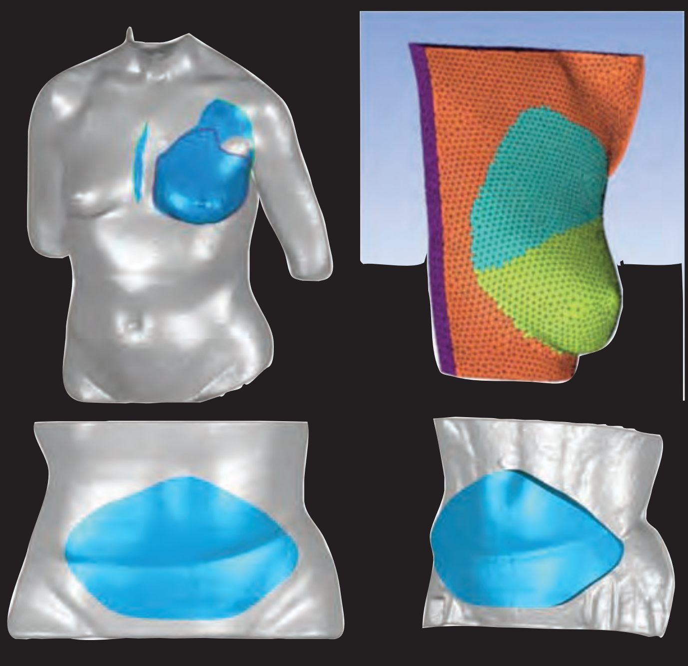
When we take a look at the material stiffness, as described by the Young's modulus, a clearly defined optimal position can be found. The model behaviour is described by a shallow slope when coming from high Young's moduli and a relatively steep increase when the material parameters become too soft. For all optimizations performed in the presented study, defined global optima could be found. The optimal Young's modulus as mean value of the six test persons was found to be 0.121 kPa with a standard deviation of 0.028 kPa.

Conclusion

The advantage of the method presented here is its non-invasive character as a combination of volume imaging (MRI) and 3-D surface scanning (Laser triangulation), and the involvement of the computer for the actual simulation. Since the whole workflow of simulation and data evaluation is automated, multitudes of simulations can be performed with little additional effort.

However, the models have certain limitations. Firstly, the level of detail in these models is relatively low, since we are summarizing all soft tissue compartments as one material with homogeneous mechanical properties. In future work, it is intended to augment the modelling in order to derive models that are better suited to represent the real physiology of the breast by dividing the soft tissue into different parts of adipose tissue, glandular tissue and the relevant muscles. Furthermore, consideration of the skin's impact on the simulation results should be evaluated. Here in particular, the question of how to model the skin as shells or volumetric finite elements arises. Any direction dependency of the material properties is neglected in our modelling. Anisotropy of the biological tissues could also be taken into account, however it is a challenging task to find physiological directions that can be applied to individual anatomical models.

Figure 6:
Simulation results of the standing position with different material parameter sets. From stiff (left) to soft (right)



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Nevertheless, the material parameters derived with the method presented here for the breast tissue can deliver patient specific material parameter sets with the advantage of circumventing any invasive tissue damage, as would be inevitable for ex vivo mechanical testing with experimental devices. The data acquired might be helpful in oncology for tumour tracking by integrating comparison of multimodality images into the simulation model, and could improve plastic and reconstructive breast surgery planning in the future.

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THE THIRD WAVE OF CFD – PART 2

Dr Ivo Weinhold, Mentor Graphics Corp., Germany
Dr John Parry, Mentor Graphics Corp., United Kingdom

The final instalment of this two part article from Ivo Weinhold and John Parry at Mentor Graphics, looks at 'what's next' for CFD. Part 1 of the article was published in the July 2013 edition of Benchmark.

What's Next - A Vision

Hanna & Parry (2011) described their vision for the future as follows: "In the author's opinion the 'Holy Grail' of CFD, that is: real-time, push-button, automated, easy-to-use, CAD-embedded, bi-directional, multi-physics enabled CFD is still to be reached. Some CFD codes come closer to these ideals than others today, and many factors will feed into creating this nirvana in the next 20 years, not least, hardware, algorithmic, physical modeling and coupling advances in the industry". Such a long-term goal, however, can only be achieved gradually. Along the way, many challenges remain, as the authors themselves note. Perhaps this ultimate goal may need to be adjusted from time to time, because design environments may also evolve along this way – CFD is after all iterative! In the following sections, a few selected milestones on this road to the 'Holy Grail', are discussed from today's perspective.

Multiphysics

An important aspect of the 'Holy Grail' of CFD is more realistic representation of complex physical reality, without the artificial 'boundaries' that exist today arising from the historical development of CFD, computational structural mechanics, multibody dynamics, kinematics, etc. as separate disciplines using different numerical techniques. The first signs of this are already visible, in what has become commonly known as 'multiphysics' simulation. However this often means little more than taking the results of one simulation (e.g. a thermal analysis) as an initial condition or boundary condition for another simulation (e.g. thermo-mechanical stress).

Some software vendors like ANSYS and COMSOL have chosen multiphysics to be a central aspect of their product philosophy and offer a respectably wide range of simulation capabilities. However, today the focus of multiphysics applications is still on mastering the functions and the technical challenges of having the individual components working together properly, because each component may have its own historical and technical background, which may be not compatible with others. Help with this problem comes from software frameworks that provide the necessary infrastructure for collaboration. These frameworks can be the result of the internal development efforts of a multiphysics software vendor, or supplied by independent third-party developers as middleware. One example for this is the Fraunhofer MpCCI Framework.

Another limiting factor of today's multiphysics approaches is providing the correct representation of an actual complex physical situation for the individual solver modules required for a given simulation project. In order to ensure that the results of one simulation can be used as input to the next, it frequently becomes necessary to have a 'white box' model that captures the geometry without simplification and requires all relevant physical effects to be simulated in complete detail, with the attendant simulation overheads. 'Black box' models that may provide considerable simulation efficiency but are limited to just one aspect of the problem (e.g. a thermal model of an electronic component) do not fit this paradigm.

Today, the selection of appropriate modules, the configuration and arrangement of the simulation workflow is the sole responsibility of the user, and the actual workflow is determined by the combined requirements of the solver modules and not on the physics of the actual engineering task. 'Multinumerics' may therefore be a more descriptive term.

A prerequisite for future success of such an approach will be not just to link, but rather to merge the separate solvers into a single, consistent solution methodology that allows the user to focus on the physics (albeit complex, there is only one physics) and have the simulation environment bring to bear whatever numerical techniques are required in a self-consistent way. It must be complemented by a UX-based design approach which shifts attention from simple feasibility to efficient solution of the engineering task as the most important criterion.

Simulation Methods

If the idea of a general physics solver is pursued in terms of a possible realization, one is inevitably faced with unifying several very different and incompatible numerical methods. This variety of methods is of course useful, because the nature of the various physical aspects of the product's behavior are very different, and for each one or more favored

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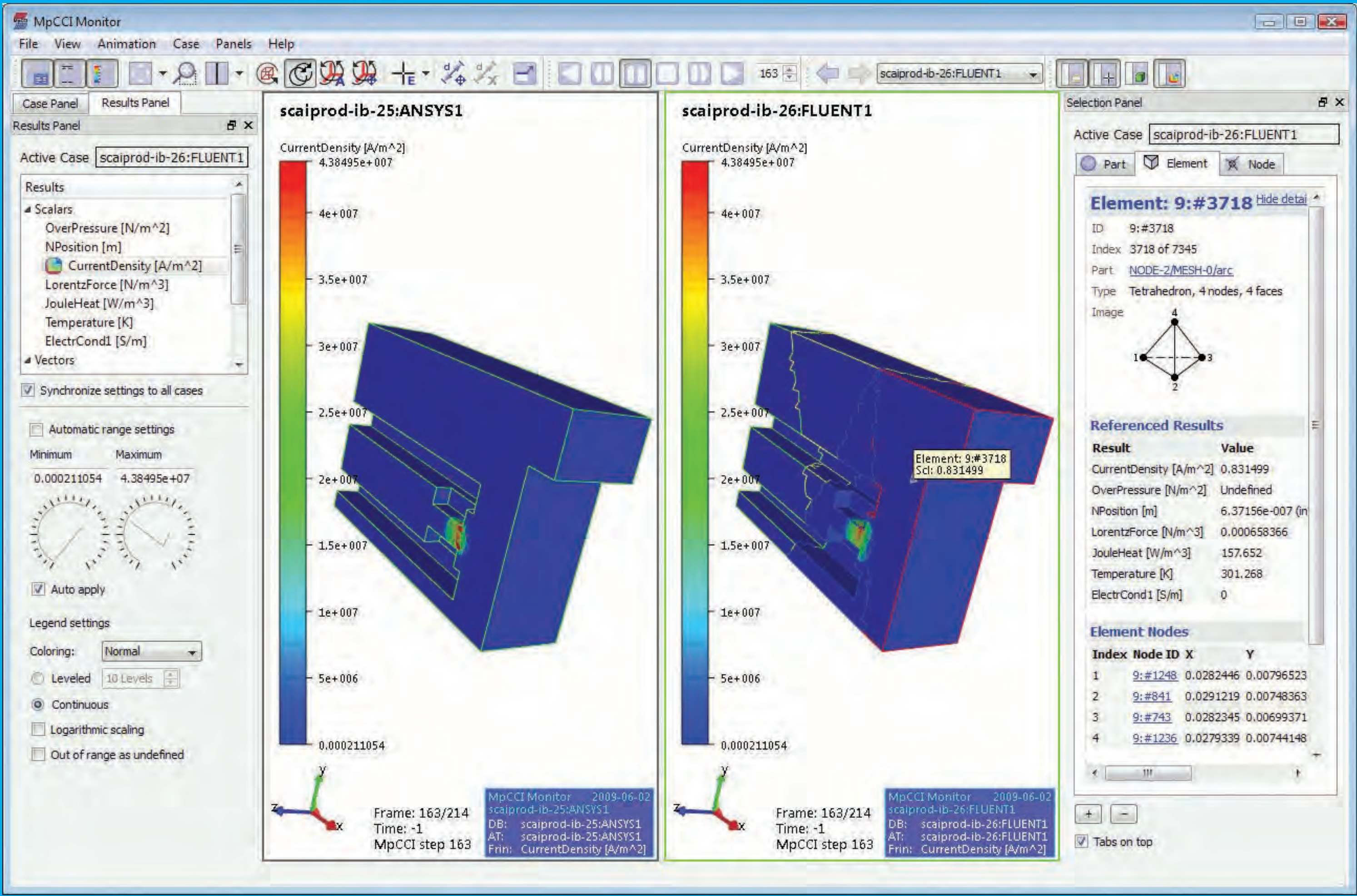

Figure 9: MpCCI Visualizer by Fraunhofer SCAI (Fraunhofer SCAI, 2012)

numerical methods exist, that provide desirable combinations of result accuracy, computational resource requirement and solution efficiency.

It is certainly not a desirable objective to sacrifice this great advantage and to try to develop a single process for all possible physical applications that will work in many areas but might be considerably less efficient than each of the best individual solutions. Rather, the aim should be to develop a solver infrastructure that uses the currently available best methods for each situation automatically, combined and bi-directionally coupled within the same simulation model and across model boundaries. This means that very different methods will need to be integrated: discretization methods such as Finite Volume for internal flows, coupled with particle methods such as Smoothed Particle Hydraulics for areas with multiple phases and phase change, and 1D methods for large flow systems, to mention just fluid dynamics. Many elements of such an approach are already available as mature, reliable components. The task is to overcome the historically-based segregation of solver modules in favor of a single simulation engine that combines the best available methods based on the simulation task. The great advantage of such an approach is that it provides the opportunity to completely remove from the engineer the burden of defining the entire numerical workflow by offering a workflow that is exclusively focused on the engineering task and its solution. In this respect we see as a real possibility to go a long way towards this 'Holy Grail' of CFD.

User Experience (UX) and Usability

Undoubtedly, the needs of the engineer as user will drive future developments of simulation software. The software will need to adapt to the working environment of the user, his needs and his individual intellectual capacity, and not vice versa. This affects the overall concept as well as every single detail of the software. This also relates to the process of product specification and code implementation employed by the software vendor. Already today, many software companies have introduced modern development processes such as Agile Development. This supports in a natural way the process required to employ user-centric design principles and is a prerequisite for the effective implementation of usability requirements with the sole objective to create and maintain an outstanding UX. Smart investments in this area will undoubtedly lead to attractive unique selling points in the CFD software market.

The working environment of development engineers and designers will also continue to change. New input techniques that better reflect the natural human movements are in development and others are already making their way into the workplace. As examples, augmented reality or touch screen operation should be mentioned. Likewise, new visualization technologies will be available for an ergonomic, exact presentation of the simulated physical situation. For example, just the age-old communication between engineers, technicians and workers based on 2D sketches and print has

of complex physical reality, without the artificial
l development of CFD, computational structural
parate disciplines using different numerical techniques."

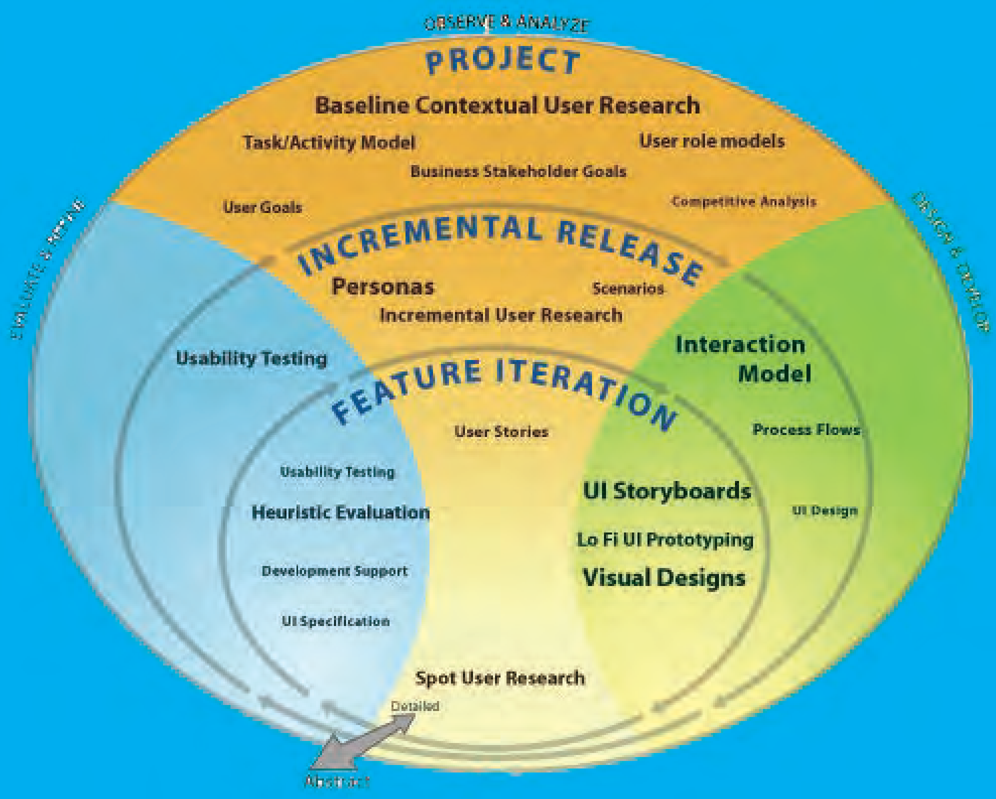

Figure 10: User Centered Design activities seamlessly employed at any given level of the Agile development methodology (Limina Application Office, 2012)

"...to ensure that the results of one simulation can be used as input to the next, it frequently becomes necessary to have a 'white box' model that captures the geometry without simplification and requires all relevant physical effects to be simulated in complete detail..."

already been complemented by communication on the basis of solid 3D prints. This will continue, as the engineer will, for the foreseeable future, continue to play the central the role as final decision maker in the development process. This trend, also picked-up and actively supported by simulation software, will gain in importance. Visualization and communication of simulated results in the context of an ever-growing reliance on virtual prototyping for cost-effective product development is tightly connected to the increasing responsibility of simulation engineers for their conclusions.

However, it is not only on the abstract, conceptual level that UX and usability will play a much more important role as a decision criterion for tool selection. Every detail of the user interface will require attention. Many user interface elements of today's CFD software date back to the early days of software development, even if they have been replaced by new, visually-appealing surfaces. The problem is not just with the surface detail, but is often located deeper in the software and its behavior. Beginning in 1990, Jakob Nielsen developed what has become quite a popular list of general principles for the design of user interfaces – the so-called "10 Usability Heuristics" (Nielsen et al., 1993). Here is an attempt to briefly comment on the application of these rules in the context of future requirements for simulation software, both in concept and practical detail:

Visibility of system status: The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.

- **Concept:** Real-time simulations are the ultimate goal, so this is also a very important aspect of the 'Holy Grail' of CFD.
- **Detail:** Particularly during long-duration activities such as solver run, geometry checks, data transfers, a real-time feedback of the current status to the user is essential. This aspect becomes especially important when remote activities are carried out. The emerging cloud computing trend has particular implications for developers and special attention will be needed to ensure compliance with this rule.

Match between system and the real world: The system should speak the user's language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.

- **Concept:** This rule applies directly to complex workflows such as considering multiple coupled physical phenomena within one simulation. As already outlined elsewhere, the software must fit to the workflow, the work context and the individual's capability, and not vice-versa.
- **Detail:** Many CFD user interfaces still use terminology only familiar to CFD experts. Focus should be on terms from the particular engineering area, and not only in the user interface but also in all documentation, online help and tutorial material.

User control and freedom: Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.

- **Concept:** The emerging cloud computing brings the danger that such an emergency exit may not be quick enough, be very expensive, or is simply unreliable due to user control being one level removed. Developers will also need to pay special attention to this.

- **Detail:** Undo/redo has been an indispensible function for Office software for decades, but many of today's CFD software still do not comply with such a basic usability requirement.

Consistency and standards: Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.

- **Concept:** Numerous CFD software tools have a long history, worked on by generations of product managers and developers. Software modules may have been acquired or licensed, making this task harder still. It must be a high priority to develop appropriate user interface guidelines and apply them to all parts of the software.

- **Detail:** Platform conventions are often ignored for the sake of development cost reduction for multi-platform software packages. This does not only apply to the visual appearance of the interface, but importantly to many standard activities such as file load/save, print, search etc.,... and of course undo and redo.

Error prevention: Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.

- **Concept:** This requirement is a major challenge for CFD software, due to the complexity of the underlying physical models, numerical methods, etc. Actually, some sort of artificial intelligence will be needed to address this challenge properly. In future this aspect will play a distinguishing role regarding UX, because this is the critical factor for ensuring that non-expert users can successfully use CFD software to produce reliable, high-quality answers.

- **Detail:** It seems to be easy to try to build in warnings for every possible situation, but this is not the solution. Focus on critical situations only, and provide an undo/redo function.

Recognition rather than recall: Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.

- **Concept:** Key to the conceptual design of a good user interface is to understand the user, his work context, and his workflow(s), and design the software usage based on this research in a way that it feels natural to him.

- **Detail:** Modern interactive User Interface concepts are already based on this principle. But many details can improve usability dramatically, such as recent file lists, status information, wizards, etc.

Flexibility and efficiency of use: Accelerators -- unseen by the novice user -- may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.

- **Concept:** Again, this leads to the requirement that the software must fit to the workflow, the work context, and the individual capability of the user, and not vice-versa. The software needs to help the user grow in expertise and adapt to that growth.
- **Detail:** Windows already has the concept of keyboard shortcuts that many users are familiar with, so let's use this concept. Touch interfaces have the concept of gestures, which should also be utilized, even if by mouse movement. Scripting capabilities will help experienced users to setup their own automation functions at relatively low cost.

Aesthetic and minimalist design: Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.

- **Concept:** The quality of usability is not measured by the number of buttons in the user interface. If the software is designed well, it knows the user, predicts his next steps correctly and presents exactly those functions which are relevant for this next step.

- **Detail:** For feature-rich products like CFD software, often less is more. Only present the available options and functions rather than gray out the unavailable functions. Automatically provide access to context-sensitive functions close to the object of activity.

Help users recognize, diagnose, and recover from errors: Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.

- **Concept:** Particularly the latter (constructively suggesting a solution), seems to be a major area for improvement. Again, error handling has the same priority as error prevention as a distinguishing factor for UX and related purchase decisions.

- **Detail:** An absolutely important requirement is to trap possible user errors and software malfunctions with dedicated, not universal, error messages - it's not a lot of effort to at least provide a proper description of what went wrong.

Figure 11: Front cover of "Usability Engineering" by Jakob Nielsen (Nielsen, 1993)

"Every detail of the user interface will require attention. Many user interface elements of today's CFD software date back to the early days of software development, even if they have been replaced by new, visually-appealing surfaces. The problem is not just with the surface detail, but is often located deeper in the software and its behavior."

Help and documentation: Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

- **Concept:** Help doesn't mean some textual and graphical explanations only; it must employ all available communication means. This includes short videos, direct access to internet resources, links to user communities and vendor technical support, etc.
- **Detail:** A picture paints a thousand words: This principle applies particularly to engineers as the main CFD users.

Concluding Remarks

Commercial CFD software for industrial applications has already celebrated its 30th birthday. Three decades of successful CFD simulations by hundreds of thousands of scientists, engineers, and students have made this technology an indispensable tool, and it is becoming embedded in the product design process across virtually all industries today. While classic CFD technology has matured to a great extent, new exciting concepts and technology to address the challenges of future CFD applications are approaching fast. After two main waves of commercial CFD, each with their own paradigm shifts, we are currently experiencing the third wave, again a paradigm shift towards embedding CFD software into the design process. There will certainly be a next, fourth wave of CFD simulation software to come. The authors anticipate this will be a step on the road to the 'Holy Grail' of CFD: real-time, push-button, automated, easy-to-use, CAD-embedded, bi-directional, multi-physics enabled CFD… leaving behind the classical CFD software of the second wave.

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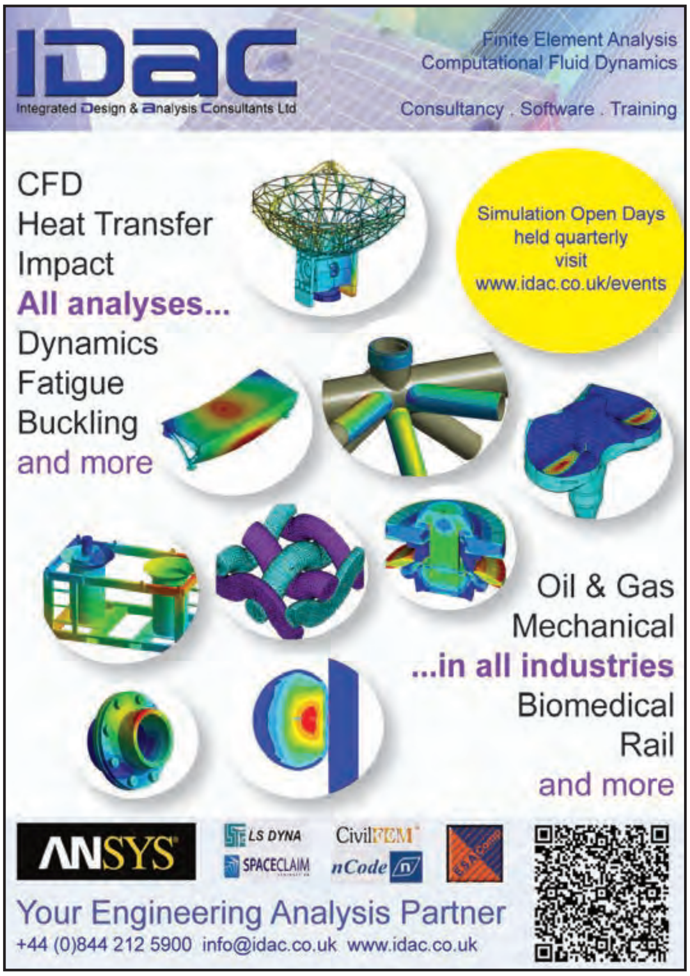
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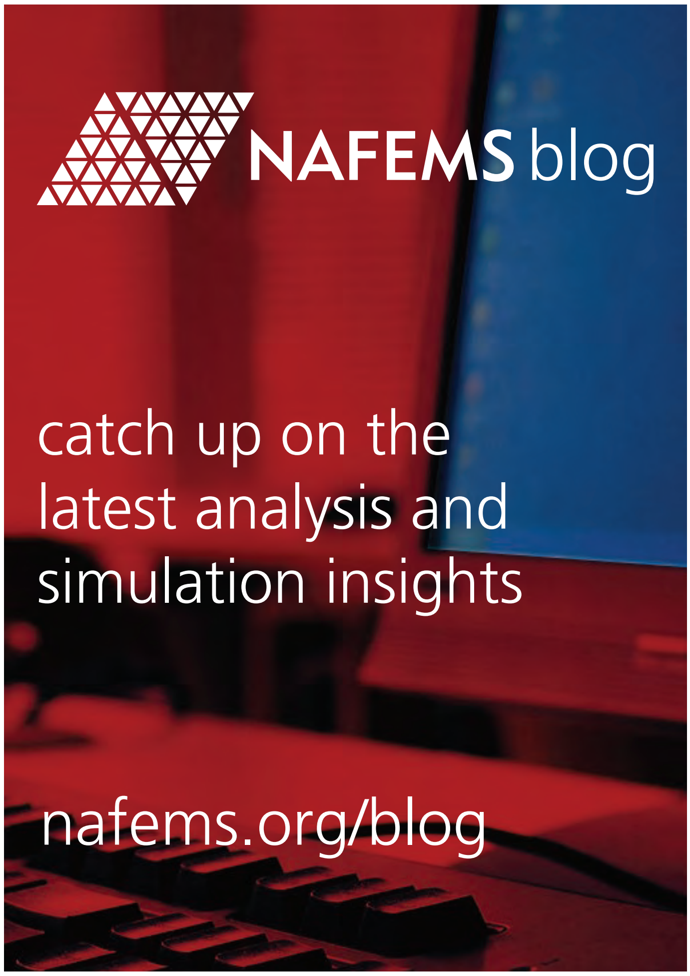
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Carrying a Torch for FEA

Simulating the manufacturing process for the 2012 Olympic Torch

Trevor Dutton & Paul Richardson - Dutton Simulation

The 2012 London Olympic Games were hailed as an almost universal success, not just in sporting terms, but also for the way that the activities to support the Games involved so many people around the host country. One of the major factors in engaging the British public was the Olympic Torch relay. Over the course of 70 days, starting from Land's End in Cornwall on May 19th to its arrival at the Olympic Stadium in London in July, some 8,000 runners carried the flame on its 8,000 mile route throughout the UK. Each runner ran with their own torch meaning that a total of more than 8,000 torches had to be produced. The contract for manufacturing these was awarded to The Premier Group in Coventry, and this article discusses some of the detail of the manufacturing process and use of FEA.

The torch has won many awards, including Design of the Year 2012 from The Design Museum. Such high quality design naturally demanded the highest quality manufacturing process to ensure that every example produced met the same exacting standards. The torch has a triangular cross-section with slight curvature to the sides and more rounded vertices. The lower part has straight sides creating a handle for the runner to hold; half-way up the cross-section transitions into an outward tapering upper part housing the burner and gas canister with a valve covered by the Games logo towards the top. The main body is created by two perforated aluminium skins, one within the other, with caps on each end. Aluminium was chosen for weight saving and also because it is seen as a "green" material that can be recycled.

Every detail of the design has significance – and the manufacturing process had to re-produce these details to maximum precision. The triangular cross-section reflects the three elements of the Olympic motto Citius, Altius, Fortius (faster, higher, stronger); three was also significant as this was to be the third time that London had hosted the Games. The perforations in the two skins of the main body comprise exactly 8,000 holes, representing the 8,000 relay runners. The holes are arranged to align between inner and outer skins in a consistent pattern that echoes the five ring Olympic emblem. The holes change in size over the length, increasing in diameter as the cross-section grows towards the top, requiring the alignment to be modified continuously from handle to burner.

The requirement for high quality, as well as the number of torches to be produced, demanded a reliable and repeatable manufacturing approach. The Premier Group was appointed to fabricate the main body (as well as take care of the final assembly) and it was determined that press forming using CNC cut tools should be adopted to make the two skins. The process for each skin required an initial blank to be cut from sheet stock - a laser was used to cut both the outer profile and all of the required holes. The blank was then formed into the tapered triangular shape using a sequence of forming operations – the number and type of operations was not initially known. When formed, each skin would be closed with a laser weld requiring a very tight tolerance where the two folded edges met.

The first challenge for the manufacturing process was to determine the required shape for the outer profile, i.e., to develop the flat pattern for the two skins. This required calculation of not only the outline for the blank but also the location and shape of each of the perforations. Determining the precise blank shape to achieve a consistent seam with virtually no gap was not trivial, particularly through the transition from straight to taper. Standard CAD unfolding methods proved to be unable to predict the correct profile. In addition, the slight distortion of the pre-cut holes in the blank, especially at the vertices of the triangular form where the amount of curvature was greatest, needed to be calculated to ensure that, when formed, the holes were perfectly circular and correctly aligned between inner and outer skins.

Premier turned to NAFEMS member company Dutton Simulation Ltd for help with developing the flat patterns. Dutton Simulation, founded in 2003 by Trevor Dutton, offer specialist analysis services and solutions focussed chiefly on metal forming processes. The company provides CAE software for forming simulation and cost estimation to many UK manufacturers and is supplier for FTI's FormingSuite software. FormingSuite includes the FASTBLANK module for blank development which takes 3D geometry and, using an inverse finite element method,

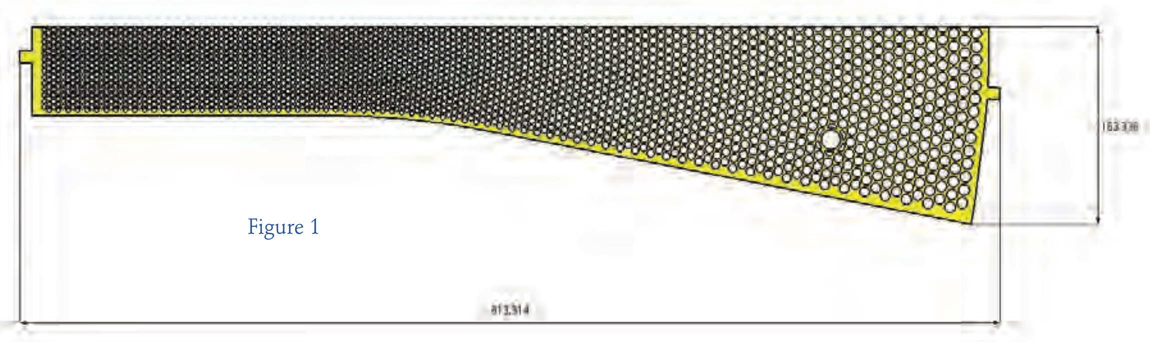

Figure 1

determines the 2D flattened form. Using an FEA approach rather than simply a geometry-based calculation means that the strain in the material due to forming is taken into account resulting in a very accurate blank shape prediction. FASTBLANK has become the default method for calculating a 2D flat pattern for complex 3D stampings in the sheet metal industry, particularly in the automotive sector.

Applying FASTBLANK to the challenge of calculating the flat pattern for the two skins required some attention to detail; the input geometry had to be carefully managed to handle the large number of trimmed holes in the surface model, and the material properties had to be accurately captured to ensure that the relatively low strains in the part were correctly predicted. FASTBLANK not only calculated the blank outer edge profile, taking into account material stretch and compression, but also predicted the shape and position for the thousands of holes to ensure that the final result was as required after forming; the blank was then exported from the software directly to the laser cutter (Figure 1). The predicted shapes for both inner and outer skins proved to be perfect when the torch was fabricated, giving the required alignment of holes and a consistent narrow gap for laser welding. The blank for the outer skin, complete with the tabs added for manufacture, is shown – a half model was used for the calculation.

Blank development was the first challenge to be met in order to develop a successful manufacturing method for the torch; the forming process itself also had to be verified, to establish the number and type of forming operations and the tooling geometry for each one. Both The Premier Group and Dutton Simulation have considerable experience in forming and simulating manufacture of automotive panels in aluminium and one of the main challenges is correcting the tool geometry for the inevitable springback. With the process proposed for the torch, the correction had to be extremely precise or else the taper angle would vary from edge to edge when viewed from different directions – clearly not an acceptable outcome.

A number of forming processes ranging from two to four operations were initially proposed for investigation. Dutton Simulation used another of the CAE tools in its portfolio, ETA's DYNAFORM, to simulate alternative sequences of operations. DYNAFORM is a toolkit of pre- and post-processing software that creates and submits FEA models to be analysed using the LS-DYNA incremental solver from LSTC. The combination of implicit and explicit solution methods seamlessly integrated in LS-DYNA allows the best possible combination of accuracy and analysis efficiency to be attained.

It was determined that the best approach to forming the skins would be a modified form of press brake bending with bespoke tooling. Four such operations were found to be required, using three sets of tooling (the final set being used twice, once for completing the final bend on each of the triangular vertices with the part re-positioned between operations).

The challenge here was to model the full sequence of forming operations to confirm that they would create a high quality result – this meant that the method should not only analyse the forming of the material to flat but also predict the resulting springback (i.e., the geometry change due to recovery of elastic strain at the end of the forming operation). This led to use of a fully integrated shell element to model the blank, with seven through-thickness integration points, to reliably predict the stress distribution due to both bending and membrane stretching through the material thickness. In addition a very small element size was needed to capture the perforations with suitable smoothness around each hole. These requirements led to use of the implicit approach for simulating the forming operations; this avoided the need for mass scaling to speed up the calculation.

Mass scaling is a useful technique to help engineers simulate complex processes with detailed models in a practical turnaround time. Small elements of a given material require a small time step in order to satisfy the Courant stability condition. When applying mass scaling, each element in the blank is checked against a target time step and, if necessary, its density is increased to maintain stability. It is a great help in single and double action process simulation where the material is well supported but can potentially introduce additional inertial forces if the elements with higher density undergo large accelerations. The bending-like processes proposed for the torch meant that large regions of the blank were unsupported for much of the time and hence mass scaling would have been problematic, especially with the small element sizes being used. However, using the implicit method avoids the need for mass scaling as the Courant condition does not

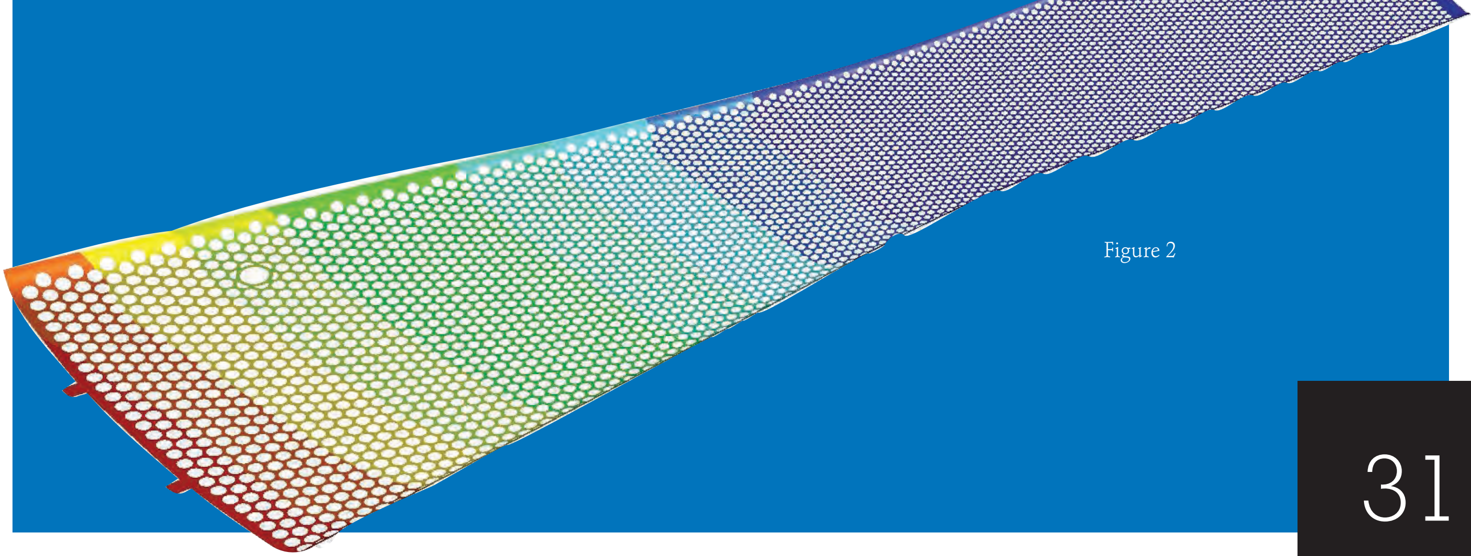

Figure 2

apply. Correct modelling of contact between tool and work piece to ensure solution convergence can be challenging with an implicit approach but LS-DYNA's combination of robust time step control and specially adapted contact algorithms made the solution relatively straightforward.

The first round of forming simulation was carried out using tooling models built directly from the final CAD geometry, knowing full well that this would not end up being the final tooling shape – this would simply set the baseline for the springback analysis. The first forming operation was to introduce a slight break from end to end to initiate the transition from straight to tapered shape, and also form the two edges up by half the final vertex radius; the plastic strain in this operation was very low and considerable springback (over 20mm) was predicted, as shown in Figure 2. The second operation was to bend the pre-form into a "U" shape, wiping up the two sides. Again considerable springback was predicted, as shown in Figure 3. Finally, two modified "V" bend operations tightened the angles in the corners to create the triangular cross-section and bring the edges together.

Once the preferred manufacturing method had been established, DYNAFORM's Springback Compensation Process was applied for each operation in turn, using the desired shape compared to the predicted shape to adjust the shape of the tooling. The LS-DYNA code includes a special solver that generates a modified finite element mesh for the tooling (upper and lower) based on the error between predicted and target shapes. The modified shape can be scaled according to the user input – usually ~80% correction is tried in the first iteration as 100% usually results in a new formed shape that goes too far in the opposite direction. The updated tooling is then imported back into the original model replacing the first set of tools, and the process re-simulated to check the results against the design data once again. More than one round of compensation is often required, especially where springback displacement is relatively large. Compensation was applied for each set of tooling required for the torch forming so that the form transferred from one operation to the next was as close as possible to the desired shape.

Springback not only causes overall gross errors in the geometry but also leads to much smaller but nonetheless problematic distortions in the formed surface. These distortions, often just a few 10's of micron deep, are enough to cause cosmetic defects that are quite obvious to the naked eye, especially with highly polished finishes. The DYNAFORM Post-processor includes a reflect line option that simulates the appearance of a panel under strip lights, as shown. Dutton Simulation were able to use this result to fine tune the amount of overbend or over-crown in each of the tooling stages to eliminate the distortion (Figure 4).

The combination of one-step and incremental finite element analysis codes proved vital to developing a successful manufacturing process for the 2012 Olympic Torch. Working to a tight schedule, Dutton Simulation were able to provide tooling geometry that not only corrected for the springback but also confirmed that the high quality cosmetic finish required would be achieved, allowing Premier to proceed with production of the 8,000+ Torches in good time for the Torch Relay that led up to the 2012 Games.

Dutton Simulation Ltd has been designated "Supplier of manufacturing simulation services (Olympic Torch) to the London 2012 Games".

For more information on the work of Dutton Simulation and their forming simulation software please contact
Trevor Dutton on +44 (1926) 732147
or visit www.duttonsimulation.com

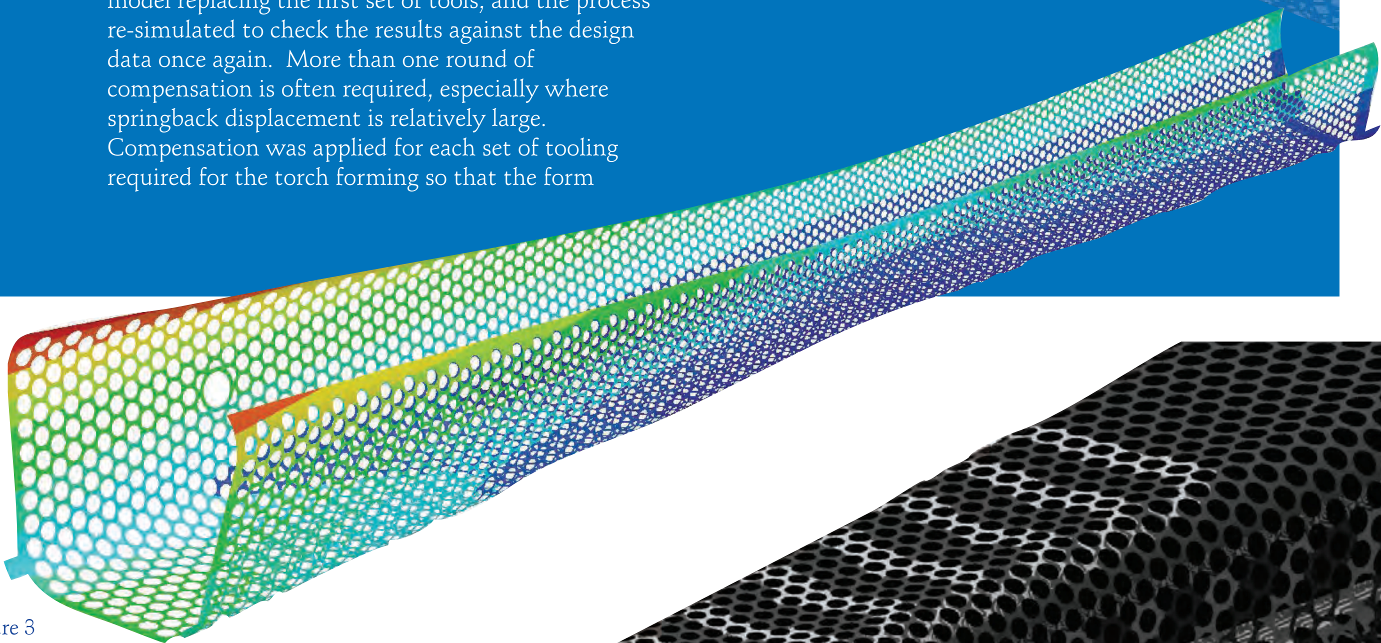

Figure 3

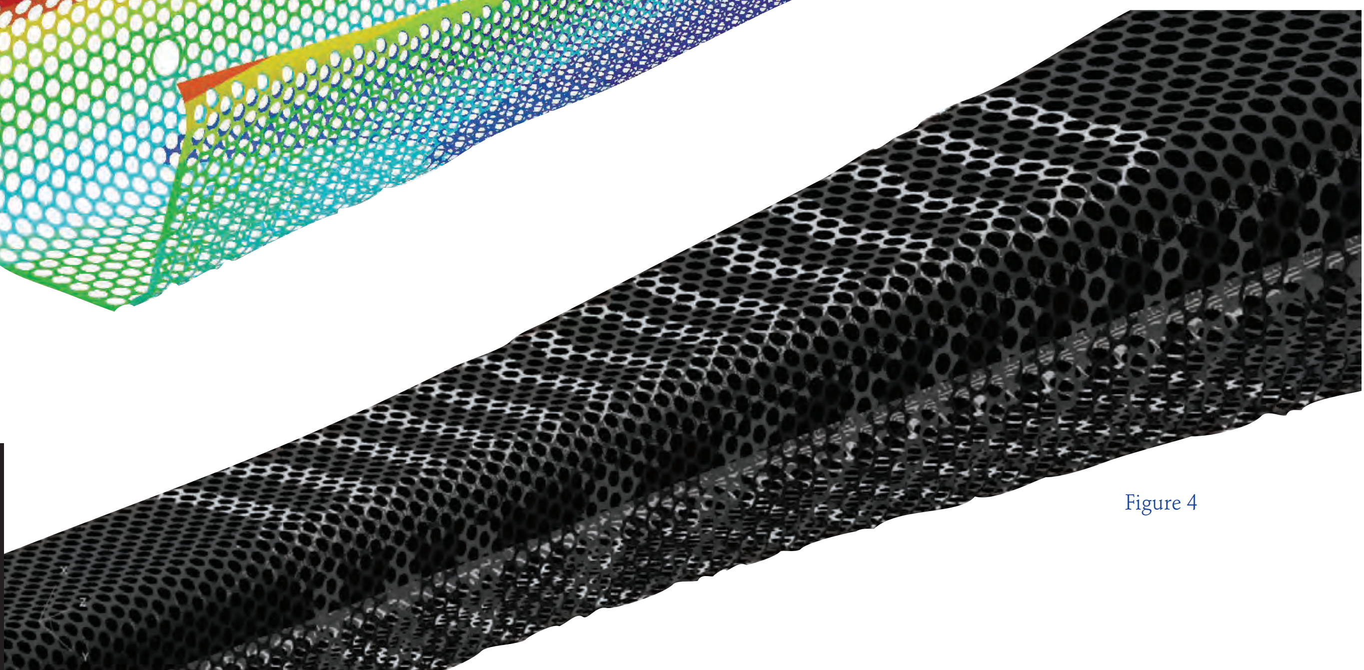

Figure 4

Icons of CFD

Prof. Antony Jameson

The next time you fly on a commercial aircraft, take a moment to reflect on its aerodynamic design; for this will almost certainly owe a huge debt to the CFD technology and computer codes developed by Prof. Antony Jameson.

The Boeing 767, 757, 747-400, 777, 737-700 and the 787 Dreamliner have all have been designed using aerodynamic codes based on CFD methods devised by Prof. Jameson. His methods have also been used by the European aerospace industry. And we haven't space to list all of the numerous McDonnell-Douglas aircraft, as well as many regional and business jets, whose aerodynamic design also benefited from his CFD expertise.

Amongst Prof. Jameson's many awards is the 2006 Elmer A. Sperry Award, sponsored by the ASME, IEEE, SAE, SNAME, AIAA and ASCE, and given in recognition of distinguished engineering contributions which, "through application, proved in actual service, have advanced the art of transportation, whether by land, sea or air". It was Elmer A. Sperry (1860 – 1930) who coined the phrase 'automotive'. Previous recipients include Igor Sikorsky and Sir Geoffrey de Havilland. It is important to note that this award is only given for engineering contributions that have been proven through application; nor is it awarded every year. Prof. Jameson's citation reads as follows:

"To Antony Jameson in recognition of his seminal contributions to the modern design of aircraft through his numerous algorithmic innovations and through the development of the FLO, SYN and AIRPLANE series of CFD codes".

What attributes made these algorithms and CFD codes so successful? To find the answers we should examine some of the engineering challenges that Jameson has tackled, but let us turn first to his background.

Antony Jameson began using computational methods in aerodynamic design in 1970, at the age of 36, as an employee of the Grumman Aerospace Corporation in New York – which he joined in 1966. Previously he had been working at Grumman, but on control theory for stability augmentation systems; his experience in this field proved of considerable utility some two decades on, when he redirected his research into aerodynamic shape optimisation (about which more is said later). Prior to Grumman he had been chief mathematician at Hawker Siddeley Dynamics in Coventry.

Jameson is a graduate of Cambridge University, Trinity Hall, 1958, with 1st class honours in engineering, where he stayed to gain his PhD in magnetohydrodynamics, followed by a period as a Research Fellow at Trinity Hall.

His first job on leaving Cambridge in 1964 was actually as an economist with the UK Trades Union Congress. Jameson lists Len Murray, former Head of the TUC Economics Department and later General Secretary, as being one of several significant people in his life. Earlier, he had served as a lieutenant in the British Army, Malaya.

Clearly, Jameson had wide-ranging experience before he focused on CFD in his mid-thirties. It was then that he wrote his first two CFD codes: FLO 1 and SYN 1 . These programs solved for idealised fluid flow (non-viscous and irrotational) over 2-D airfoils, with FLO 1 calculating the pressure distribution for a given airfoil, and SYN 1 calculating the inverse problem, i.e. the shape of an airfoil given a target pressure distribution. As computer memory was very limited, Jameson ensured that the memory requirements were small. These codes also ran fast, taking between 5 and 10 minutes. The efficiency of Jameson's codes is characteristic of his work.

The computation of transonic flow over airfoils soon became his main focus, and in 1972 Jameson moved to the Courant Institute of Mathematical Sciences, New York University, to further pursue this topic.

In transonic flow the Mach number is a little below unity in most parts of the flow field, i.e. the flow is mostly subsonic. However, locally it becomes supersonic. This is a crucial flow regime for commercial aircraft, as cruising speed needs to be high to give good range, but when locally supersonic flow occurs on a wing it can potentially lead to strong shock waves that give large increases in drag. Large commercial aircraft typically operate at a Mach number of about 0.8, which is in the transonic regime, so their wing shape needs to be designed to minimise the strength of any shocks and ideally to avoid them altogether. Jameson1 provides an overview of the wider challenges and constraints in airfoil design.

At the Courant Institute, Jameson wrote a CFD code for the prediction of idealised transonic flow past swept wings, known as FLO 22, in collaboration with David Caughey. FLO 22 was very robust, with convergence all but guaranteed. The code was immediately put to use by McDonnell-Douglas and others. FLO 22 is a remarkable code, as it has been run continuously since it was written, and is still in use today.

The methodology in FLO 22 was extended in FLO 27 and FLO 28 to be applicable to arbitrary meshes, so that geometries such as complete wing-bodies could readily be computed. Boeing evaluated the extended code in 1978 and subsequently incorporated it in their own 'A488' software - which was the main computational tool used in wing analysis for the Boeing 757, 767 and 777 aircraft.

In 1980, Jameson joined Princeton University and from 1982 was the James S. McDonnell Distinguished University Professor of Aerospace Engineering. He moved to Stanford University in 1997, where he continues to research, teach and publish, as the Thomas V. Jones Professor of Engineering in the Department of Aeronautics and Astronautics.

Advances in computer hardware during the 1980s meant that it became possible to solve the Euler equations for flow over airfoils. This removes the restriction of irrotationality imposed by idealised fluid flow. It heralded a major step forward in aerodynamic design, especially for transonic flows, as shock strength and in particular shock location can be in error with idealised flow models. Jameson2 worked with collaborators at Dornier and the University of Tel Aviv to devise a groundbreaking 3-D Euler code, known as FLO 57, which allowed shocks to be predicted accurately for complex aerodynamic shapes. Prof Charles Hirsch, author of Numerical Computation of Internal and External Flows3, writes:

"The method developed by Jameson and co-workers is a remarkable combination of components such as efficient dissipation terms, convergence acceleration ingredients and multi-grid techniques, leading to (the) most efficient and accurate prediction codes"

The methods embodied in FLO 57, colloquially known as the 'JST' model, were quickly adopted by the aerospace community, including British Aerospace (now BAE Systems), Lockheed, Dornier and NASA.

Jameson made numerous other advances in numerical methods and algorithms throughout the 1980s, including the use of unstructured meshes to allow the very first computation of flow over a complete aircraft. This breakthrough was achieved using a new code developed jointly by Jameson, Timothy Baker and Nigel Weatherill, in 1985, called 'Airplane', which was adopted as the basis of aerodynamic codes used by McDonnell Douglas, NASA, Mitsubishi and EADS.

Together with his development of software for unstructured meshes, Jameson continued to work on improving the speed of solution algorithms, as well as the accuracy and robustness of discretisation schemes. In essence, he worked across all of the areas that were important in furthering CFD as a tool for aerodynamic design.

As he brought these methods to maturity, he redirected his research towards the challenge of finding the optimal shape of aerodynamic designs to meet performance targets, subject to a range of constraints, such as wing thickness - which determines structural weights. His work in this field is based on a merging of control theory and CFD.

This led to a new series of 'SYN' codes, such as SYN 87 and 88 for optimal wing design solving the Euler equations and, in 1997, SYN 107* solving the full Navier-Stokes equations that govern viscous fluid flows. In 2003 he wrote the code 'Synplane', allowing the optimisation of aerodynamic design for a complete aircraft. As an example, SYN 107 can handle several thousand design variables, and was used for the aerodynamic design of the Gulfstream G650 business jet which entered service this year and has a range of 6000 nautical miles at its high cruise speed of Mach 0.9.

Jameson's work on aerodynamic shape optimisation is as important as that of his earlier research on CFD methods and algorithms.

The most fitting end to this latest in the Icons of CFD series is provided by the summary of Prof. Jameson's overall achievements taken from his Elmer A. Sperry Award citation, 2006:

"The core elements of Antony Jameson's achievement are the following: First, based on his background in engineering, economics and mathematics, and his industrial experience in the jet engine and aircraft industries, he was able to identify key barriers which must be overcome to advance the practice of aerodynamic design. Second: he devised new and innovative mathematical and algorithmic solutions to previously intractable or infeasible problems that enabled the necessary advances. Third: he implemented these new algorithms in structured, modular and essentially error free software that was robust enough for sustained industrial use (30 years in the case of FLO 22), and actually enabled significant improvements in the aerodynamic performance of many aircraft now flying."

Some of the most significant algorithmic contributions introduced by Jameson:

1973	Rotated difference scheme for transonic potential flow
1981	Jameson - Schmidt - Turkel scheme2 for the Euler equations
1983	Full approximation multigrid scheme for the Euler equations
1986	Unstructured mesh scheme for complete aircraft calculations
1988	Lower-Upper Symmetric Gauss-Seidel (LUSGS) scheme for the Euler and Navier Stokes equations
1988	Aerodynamic shape design via control theory
1991	Dual time-stepping scheme for unsteady flows
2007	Kinetic energy preserving conservative scheme
2010 - 2012	Stability proofs for high-order-schemes and formulation of energy stable flux reconstruction (ESFR) schemes

Much more information on Prof. Jameson and his work can be found on his home-page at Stanford University, **http://aero-comlab.stanford.edu/jameson/** , including copies of many of his publications – of which there are over 400.

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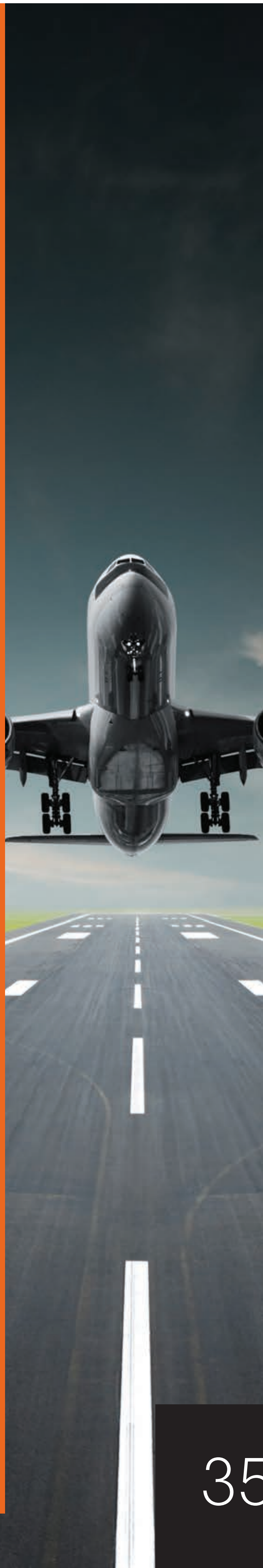
Author information

Chris Lea, Lea CFD Associates, UK,
chris@leacfd.com

*SYN107 is now commercialized under the name J-FLO, by Newmerical Technologies Int.



Closing the gap

If there's a challenge that's facing the simulation and analysis industry, it's achieving the much wider adoption of these valuable tools.

While I'm aware that I'm already preaching to the converted if you're reading Benchmark magazine, the facts are that there's a huge proportion of the design and engineering community that could be taking greater advantage of these tools.

Over the past couple of years, I've been conducting research into the attitudes and adoption of simulation technology amongst the design and engineering community.
What's consistently come up is that while adoption is growing, there are a couple of issues that are ever present. Some are common sense; some are a little more esoteric -

so let's explore some of each.

Wasted Investment

What I found was that amongst the CAD using designer and engineer crowd, a good percentage are using simulation to some extent.

In fact, based on the last couple of years, I'd say around 55 per cent (DEVELOP3D's audience is more tech aware than more wide focussing engineering publications).

That, to my mind, is progress.

Yet as ever, the negative responses are always as interesting as the positives. For example, of that remaining 45 per cent one-third of them have bought simulation tools but don't use them. That, in and of itself, is a curious fact to know.

> " Essentially, one in every ten of the simulation seats that are sold is not actively used. "

Consider that statement. Companies (or in some cases, individuals) have acquired simulation technology but it's not being used.

Essentially, that's cash down the pan. When asked why not, the answers were mixed. While some, inevitably, don't see the need for simulation, the overwhelming reason comes down to training, experience and knowledge.

It's an entirely valid question to ask- why would an organisation invest in and maintain something that it doesn't use?

The answer is, perhaps predictably, the nature of the most widely sold simulation tools.

Most of these are of the 3D CAD integrated variety. From looking at our research, it's clear that these systems are contributing most to this phenomenon.

When a system is sold it's predominately driven by the geometry and drawing creation aspects. Simulation is something that's bundled in with it, but not the core focus, for both sales and use.

There's often a perception from the analyst that simulation and analysis becoming a more mainstream activity in the engineering office is a bad thing.

Whether it's protectionism for one's specialism (a valid one, on a personal level, of course), whether it's concern over inexperienced users making poor assumptions and gaining poor output as a result or whether it's simply professional pride. All are valid reasons.But given a different spin, a better story could emerge: Imagine how the analyst or specialist in a company could become the spearhead for enabling accurate, realistic and useful adoption of simulation and analysis?

Guiding new, less experienced users, providing best practice and guidance where needed, and frankly, saving those interesting and challenging jobs for themselves.

We're all aware that simulation can have a predictive benefit on design. Optimisation holds the key to saving materials; saving energy and building break-through products.

To make effective use of it requires the expert's input and knowledge, but unless a company adopts different working practices and fosters greater sharing of knowledge between the expert and the design/engineering team, the tools already in place will lie dormant.

Time for a New Lexicon?

A more esoteric aspect that came up was the problem of linguistic differences between and a designer or engineer's knowledge of how a product works; what it does and the conditions it operates in, and how that maps to the field of simulation and the tools we use.

A perfect example is found in two sets of questions we asked. The first stage asked what the respondent was interested in finding out about in real world, engineering terms. Think durability of their products, rather than fatigue; think movement of an assembly rather dynamics and kinematics; think flow of heat inside a product rather than computational fluid dynamics.

From looking at the results, there's a big mismatch between the real world understanding and the name for the technology and the process involved in simulating that real world condition.

This is an issue that many users face: they know the product, they know the physics, but there's a gap between that knowledge and translating it into the realm of simulation and analysis.

Even some of the most progressive technology vendors will have issues for years to come. Even those 'mainstream' simulation tools aren't progressing quickly enough to close that gap and bring two distinct worlds together.

That said, progress has been made. Recent releases from some of the integrated tools see better assimilation between the engineering and design aspects of the systems and their simulation counterparts.

Items such as bolted connections can be transferred into automatically defined constraints; motion simulation can pass data to structural analysis; thermal properties passed from electronic components into CFD.

I'm sure the experts might throw up their arms in horror at some of these, but for the designer and engineer looking to adopt simulation as part of their workflow, it's undoubtedly a good thing - as ever, with the correct guidance. This leads me onto the final matter rather nicely: training.

Learn to Earn

Training is, as we've seen, key. Stepping back to the question of unused licenses, a quarter of those respondents said that what was holding them back was a lack of training.

When questioned further it became clear that, while the majority felt it was the employer's responsibility to fund that training, a more progressive 20 per cent saw that funding their own training would be something they'd consider.

Interestingly, when it comes down to **how** users want to be trained, the top requirements are either a live seminar offsite (presumably, to allow greater focus, rather than a bit of a jolly) with the back up of offline video and learning materials to learn at their own pace. Others felt that electronic learning would suffice.

There's also the question of how designers and engineers learn in the work place.

While structured learning has its place in the field, the real knowledge comes from sharing best practices, tips and tricks and finding out how other engineers solve issues and challenges.

I'm curious to learn what you think. Does your organisation have issues with underused licenses? Do you have designers and engineers looking to upskill and take on these tools, but who lack the fundamental training? Or do you think there are other core issues at play here?

Al Dean is Editor in Chief and Co Founder of DEVELOP3D

www.develop3d.com
al@x3dmedia.com

The CAE Guy

Potential. It is such a simple word and yet has such a complex meaning invoking all kinds of thoughts and concepts that relate to the past, present and future. As my daughters are becoming teenagers, faint echoes of my parents commenting on my own “potential” all those years ago accompanies my own words and thoughts as we (my wife and I) talk to them about whatever it is: school, sports, relationships, or simply life. This is one reason that I am convinced that life – as well as history – does not repeat, but rhymes[1]. I certainly feel my own potential to advance and move up through the company, but at the same time, I really do enjoy the CAE work that I do. I will say that I have probably taking longer to advance than “normal” and have witnessed colleagues and contemporaries that are “ahead” or have “past” me as they transfer to a management or track. However, I have never really felt the need to become a manager and am quite comfortable blazing my own trail in my career and, frankly, in life[2]. While I am currently in charge of the CFD group here, I see that position as a necessary stop in my career to give me a viewpoint of management. I was just having this conversation at a high school volleyball picnic, where some of the parents were commenting that it has been quite educational for them as they have volunteered to be line judges (this is common in the U.S. as the referees are paid, but the line judges are parent-volunteers). I have played volleyball of 25+ years and coached refereed off-and-on, which gives me a different understanding and viewpoint of the game. It is this different viewpoint that is invaluable and, frankly, when I did referee it made me a better player and coach as I realized that they do indeed see the game from a different point of view and allowed me to, frankly, on dwell on “bad” calls, but concentrated on plying or coaching. It is the same for CAE: you get a real appreciation by stepping up. As you also should know, I think the same for testing as I recommend all those doing CAE to help setup and attend tests as possible in order to get an idea of what that takes.

Certainly, by now you should know of my passion for sports, especially when I can involve math or science[3,4]. To that end, I have been watching (on TV) the 2013 America’s Cup sailing regatta in San Francisco. I have to think that CAE was heavily used to design these new catamaran yachts, called AC72s, that not only have hard sails (vertical wings rather than fabric sails), but also hydrofoils that can lift the hulls out of the water, thereby dramatically increasing top speed. Not only is the potential of quite apparent, but along with Formula 1, I think I can confidentially say that CAE was used heavily to design this new style of racing yacht. I will not discuss this any further, but if I can track down any CAE technical papers or information on AC72, I will certainly pass it along. Of any sport, I think I can make the argument that yacht racing is one of the most complex FSI problems.

Ultimately, though, the potential of CAE rests on convincing others that it is, in fact, useful. I am also reminded of the saying that I heard this summer as the NAFEMS World Congress in Salzburg, Austria: everyone believes test results except the guy that did the test and no one believes CAE results except the guy that ran the model. For the CAE community to realize the potential of CAE, this statement must be broken and everyone must realize that CAE is simply another type of simulation of a real world event (meaning it is also “correct”).

For my own potential within the CAE community, I will admit that the one thing I would have like to have seen more of at the NAFEMS World Congress this past summer was more industry papers. But the last I checked, not only am I an insider in the CAE community, but I also work at an automotive OEM. In my mind, this means I am part of this solution. Therefore, I am planning on not only attending, but writing a paper for, the 2014 North American NAFEMS Regional Conference. As for the potential of my daughters, we shall just have to see how that all plays out as what happens now is an investment in their future. I’ll let you know in about 10 years. I am hoping it will be less than that until CAE realizes its own potential.

What are your thoughts on this or anything else for that matter? Send me an e-mail at:
thecaeguy@nafems.org.

-The CAE Guy

"History does not repeat itself, but it does rhyme." Commonly attributed to Mark Twain, because Twain scholars agree that it sounds like something he would say, but they have been unable to find the actual quotation in his works. The earliest published source yet located is by Joseph Anthony Wittreich in Feminist Milton (1987) where he writes: "History may not repeat itself but it does rhyme, and every gloss by a deconstructionist need not be a loss, pushing us further into an abyss of skepticism and indeterminacy." http://en.wikipedia.org/wiki/Historic_recurrence & http://en.wikiquote.org/wiki/Talk:History.

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