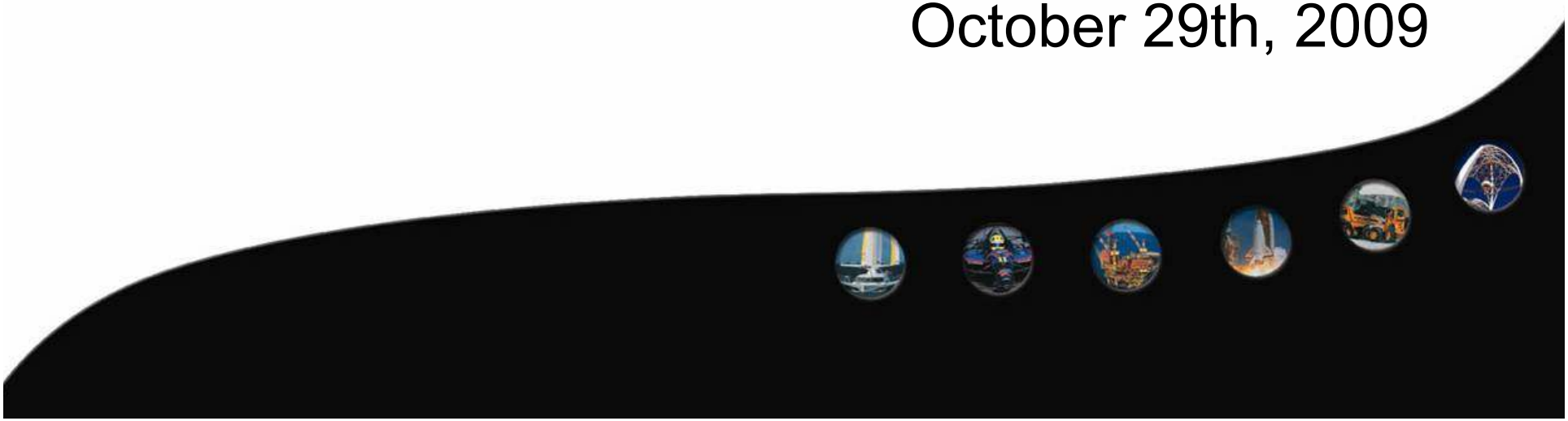
NAFEMS

Practical CFD

October 29th, 2009



Agenda

Practical CFD

October 29th, 2009

7am PDT (Seattle) / 10am EDT (New York) / 2pm GMT (London)

- Welcome & Introduction (Overview of NAFEMS Activities)
  - Mr. Matthew Ladzinski
- Practical CFD
  - Dr. Althea de Souza
- Q&A Session
  - Panel
- Closing

Ladzinski

de Souza

THE INTERNATIONAL ASSOCIATION
FOR THE ENGINEERING ANALYSIS
COMMUNITY

An Overview of NAFEMS Activities

Matthew Ladzinski
NAFEMS
NAFEMS North America

Planned Activities

Webinars

- New topic each month!
  - How to Ensure that CFD for Industrial Applications is Fit for Purpose – November 19th, 2009
- Recent webinars:
  - Practical CFD – October 28th, 2009 (today's webinar)
  - Composite FE Analysis
  - 10 Ways to Increase Your Professional Value in the Engineering Industry
  - Dynamic FE Analysis
  - Modal Analysis in Virtual Prototyping and Product Validation
  - Pathways to Future CAE Technologies and their Role in Ambient Intelligent Environments
  - Computational Structural Acoustics: Technology, Trends and Challenges
  - FAM: Advances in Research and Industrial Application of Experimental Mechanics
  - CCOPPS: Power Generation: Engineering Challenges of a Low Carbon Future
  - Practical CFD Analysis
  - Complexity Management
  - CCOPPS: Creep Loading of Pressurized Components – Phenomena and Evaluation
  - Multiphysics Simulation using Implicit Sequential Coupling
  - CCOPPS: Fatigue of Welded Pressure Vessels
  - Applied Element Method as a Practical Tool for Progressive Collapse Analysis of Structures
  - A Common Sense Approach to Stress Analysis and Finite Element Modeling
  - The Interfacing of FEA with Pressure Vessel Design Codes (CCOPPS Project)
  - Multiphysics Simulation using Directly Coupled-Field Element Technology
  - Methods and Technology for the Analysis of Composite Materials
  - Simulation Process Management
  - Simulation-supported Decision Making (Stochastics)
  - Simulation Driven Design (SDD) Findings

To register for upcoming webinars, or to view a past webinar, please visit: www.nafems.org/events/webinars

- Established in 2009
- Next courses:
  - Simulation-Supported Engineering: Addressing Variability with Stochastic Simulation – October 28th, 2009 (*four-week course*)
  - Composite FE Analysis – November 24th, 2009 (*four-week course*)
  - Dynamic FE Analysis – January 2010 (six-week course)
- Proposed course offerings:
  - Non-linear – January/February 2010 (*four-week course*)
- For more information, visit: www.nafems.org/e-learning

NAFEMS Events

- Multiple opportunities to attend conferences, seminars/workshops and training courses

Dynamic FE Analysis
6th Oct 2009
Course
e-Learning,Online

Recent Advances in the Fatigue Analysis of Welded Structures
7th Oct 2009
Seminar
Gaydon,UK

FEM Basic 1 - Praxisorientierte Strukturmechanik / Festigkeitslehre
19th Oct 2009
Course
Wiesbaden,Germany

Simulation-Supported Engineering: Addressing Variability with Stochastic Simulation
28th Oct 2009
Course
e-Learning,Online

Multidisziplinäre Simulationen
9th Nov 2009
Seminar
Wiesbaden,Germany

Practical CFD Analysis
11th Nov 2009
Course
Wiesbaden,Germany

FEM Basic 2 - Praxisorientierte Grundlagen für FEM-Analysen
23rd Nov 2009
Course
Wiesbaden,Germany

Introduction au Calcul de Structures, aux Éléments Finis et à la Simulation Numérique
24th Nov 2009
Course
Paris,France

Composites FE Analysis
24th Nov 2009
Course
e-Learning,Online

Practical Stress Analysis & Finite Element Methods
1st Dec 2009
Course
Midlands,UK

Analisi sismica: metodi & applicazioni
2nd Dec 2009
Seminar
Bologna,Italy

Simulating Composite Materials and Structures
2nd Dec 2009
Seminar
Esbjerg,Denmark

Modélisation Système et Réduction de Modèles
3rd Dec 2009
Seminar
Paris,France

- Let us know if you would like to schedule an on-site training course

For more information, please visit: www.nafems.org

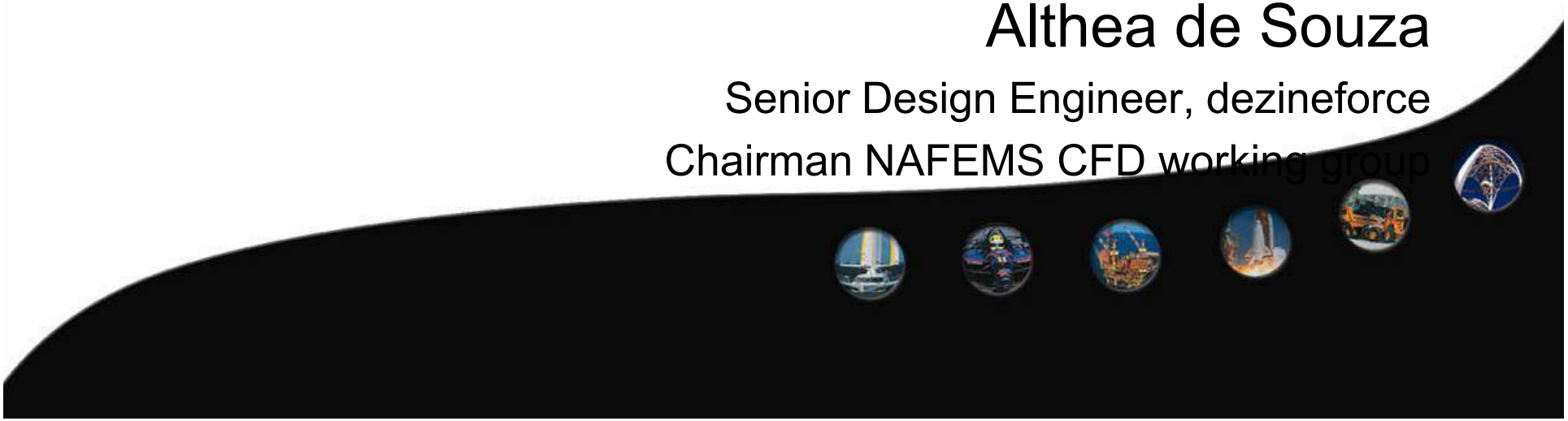
Practical CFD:

Overview
Hints and Tips

Althea de Souza

Senior Design Engineer, dezineforce

Chairman NAFEMS CFD working group



Contents

- Who am I and why am I here
- Overview
  - What is CFD
  - Why use CFD
  - When to use CFD and alternatives
  - Terminology
  - Stages in the process
  - Stages in the project
- Hints and Tips
  - Dangers and perils
  - Key issues
  - Validation
  - Simulation driven design
  - Getting help
  - Useful resources
- NAFEMS and CFD – getting more out, putting more in

Who am I &
Why am I here

- 15 years experience of applying CFD to industrial applications
- Chartered Engineer, member of IMechE & RAeS, Eur Ing
- Senior Design Engineer at dezineforce empowering designers
- Mentored and taught graduates and design engineers
- Passionate about the benefits of CFD and encouraging effective use of the tools in industry
- Chairman of NAFEMS CFD working group
- Desire to expand NAFEMS CFD profile & activities

dezineforce

empowering designers

- World-leading optimisation for systematic design improvement, coupled with third party design analysis and simulation tools
- Integrated workflows to streamline the design, simulation and optimisation process, utilising powerful compute cluster processing capability
- Exploration of design or operating spaces, offering the ability to model the full design envelope and interrogate the design influences, as well as identify key performance criteria (best, worst, safety limits, etc) within complex design challenges
- Decision support interface to interpret and communicate

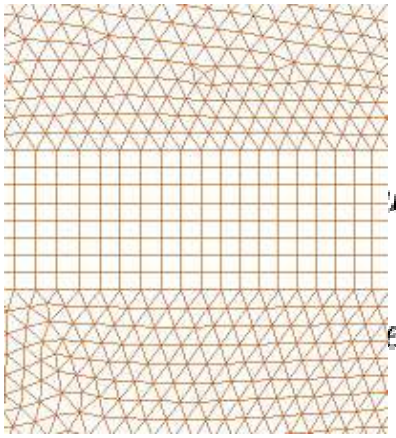
www.dezineforce.com

Overview

- What is CFD
- Why use CFD
- When to use CFD and alternatives
- Terminology
- Stages in the process
- Stages in the project

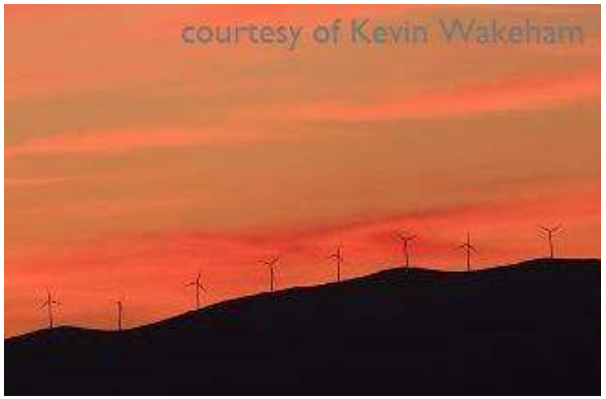
What is CFD?

- Computational method to solve Navier-Stokes equations
- Predicts behaviour of fluid systems
- Iterative method using discretisation
- Similar method to FEA
- Just a tool
- POWERFUL
- DANGEROUS



$$u_j + p\delta_{ij} - \tau_{ji}] = 0, \quad i = 1, 2, 3$$

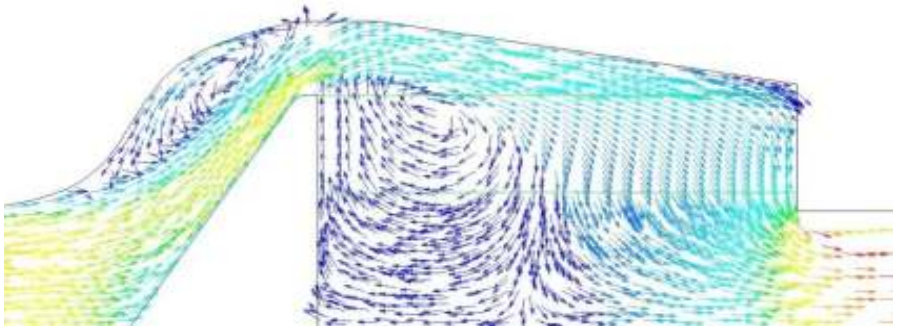
$$e_0 + u_j p + q_j - u_i \tau_{ij}] = 0$$



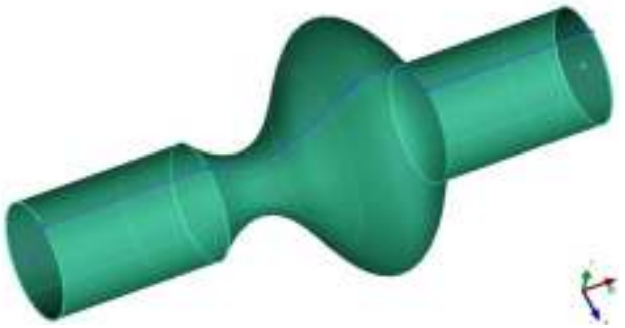
What is CFD?

- Difficult question...
  what flow field hidden within?
  computer reveals
  - CFD Haiku (CFD Review)

Why use CFD?



- To check performance
  - Prevent operational failure
  - Drive designs
  - Reduce testing
- To understand performance



- Suitable for hazardous environments
- Comprehensive (spatially and temporally)
- Engineering tool (only as good as the engineer)

When to use CFD & other options

- When other methods are neither practical ethical
- When insight is otherwise hard to obtain
- Relatively: cheap – fast, accurate

Complementary or alternative to:

- Hand calculations
- Alternative computations
- Testing
- Experience
- Luck?

What does it all mean - Terminology

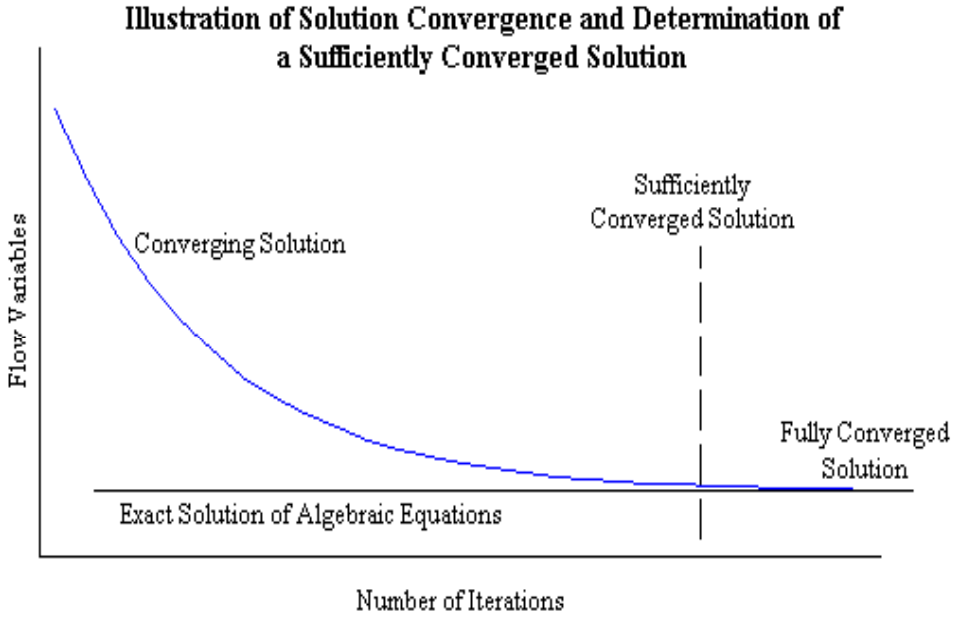
- CFD – Computational Fluid Dynamics
- Boundedness, conservativeness, transportiveness
- RANS – Reynolds Averaged Navier-Stokes
- k-ε – widely used turbulence model
- LES / DES / DNS
- Iterations, convergence, residuals
- Cells, discretisation, higher order schemes

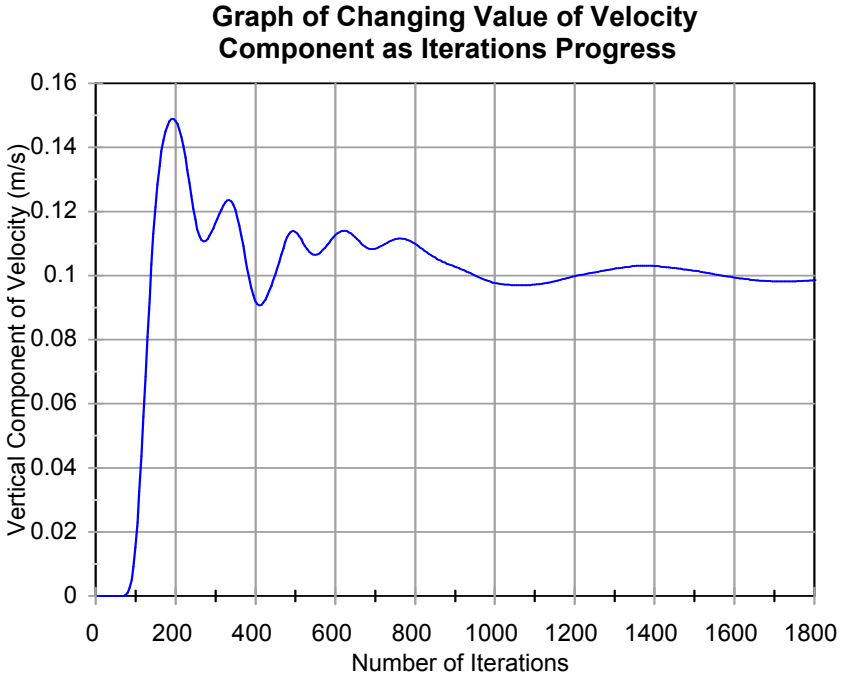
Terminology

- NAFEMS publication: How to Understand Computational Fluid Dynamics Jargon

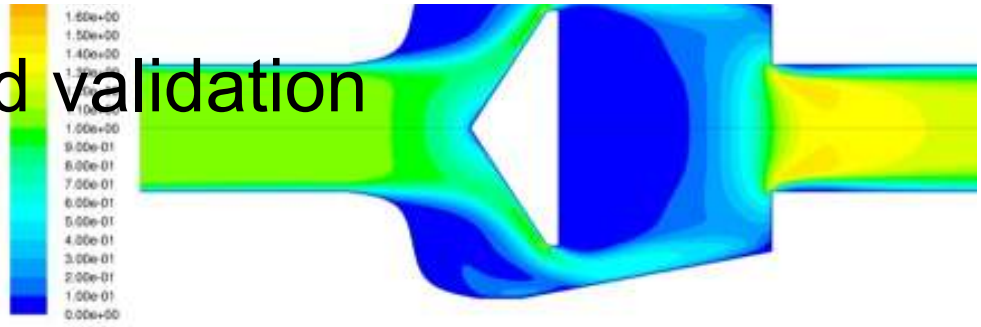
- Available online at www.nafems.org/resources/CFDJargon/
- Do you disagree or is something missing?
  - let us know at cfd.jargon@nafems.org
  - or using the form on the website

Stages in a CFD simulation



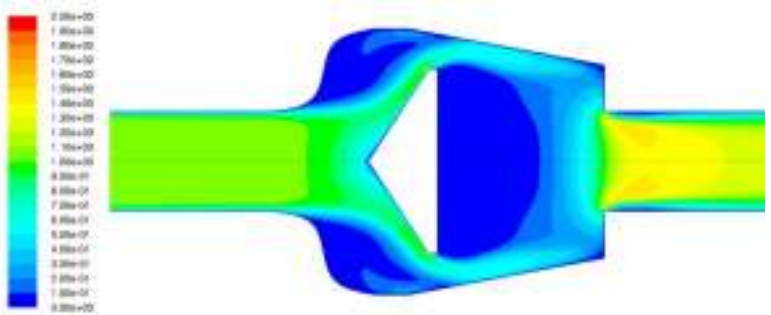


8. Solution verification and validation



Stages in a CFD project

- What is needed – why am I using CFD?
- What physics is important?
- Do CFD (see previous slide)



- Did the simulation provide the required information?
- Reporting

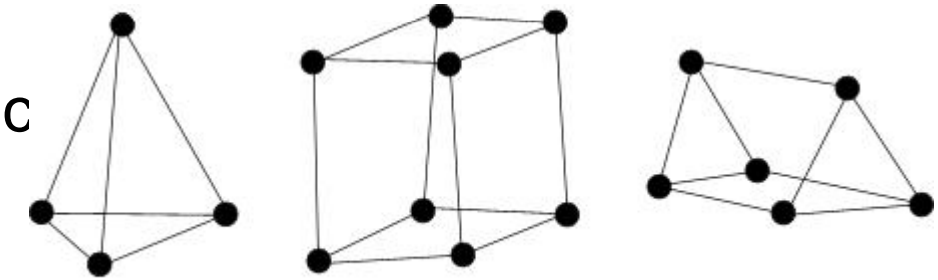
Hints and Tips

- Dangers and perils
- Key issues
- Validation
- Simulation driven design
- Getting help
- Useful resources

Dangers and Perils

- Turbulence
- Simplification
- Mesh issues
- Boundary conditions
- Other physics (heat transfer, c
- Convergence
- Getting the answers out and c processing)
- GIGO

K-Epsilon now....
then something far more complex!
Does it matter much?
CFD Haiku, CFD Review



Tetrahedron, Hexahedron, and Prism Cell Shapes

NAFEMS publication: How to plan a CFD analysis

On two occasions I have been asked,—"Pray, Mr. Babbage, if you put into the machine wrong figures, will the right answers come out?" … I am not able rightly to apprehend the kind of confusion of ideas that could provoke such a question.

Charles Babbage

Error and Uncertainty

- An error is something which can be removed with appropriate care, effort and resources, whereas an uncertainty cannot be removed as it is rooted in lack of knowledge.

(Source: ERCOFTAC Best Practice Guidelines,2000)

Errors

- Error: see accuracy, convergence error, diffusion error, discretisation error, dispersive error, dissipation error, floating point errors, grid independence, ill-posed problem, modelling errors, order of accuracy, residual, round-off error, truncation error
  - NAFEMS Guide to CFD Jargon.

Potential sources of error / uncertainty in CFD

- Problem classification
- Flow physics
- Physical properties
- Computational domain and boundary conditions
- Geometry and mesh
- Discretisation
- Convergence
- User

Key issues

- Idealisation
- Validation
  - NAFEMS CFD publication due next year
- Planning
- Fitness for purpose
  - Next NAFEMS CFD webinar on 19th November
  - Book due out soon

Validation

"The process of determining the degree to which a model is an accurate representation of the real world from the perspective of the intended uses of the model" (AIAA, 1998)

"A procedure to test the extent to which the model accurately represents reality"

(ERCOFTAC Best Practice Guidelines, 2000)

Verification

"The process of determining that a model implementation accurately represents the developer's conceptual description of the model and the solution to the model" (AIAA, 1998)

"A procedure to ensure that the program solves the equations correctly"

(ERCOFTAC Best Practice Guidelines, 2000)

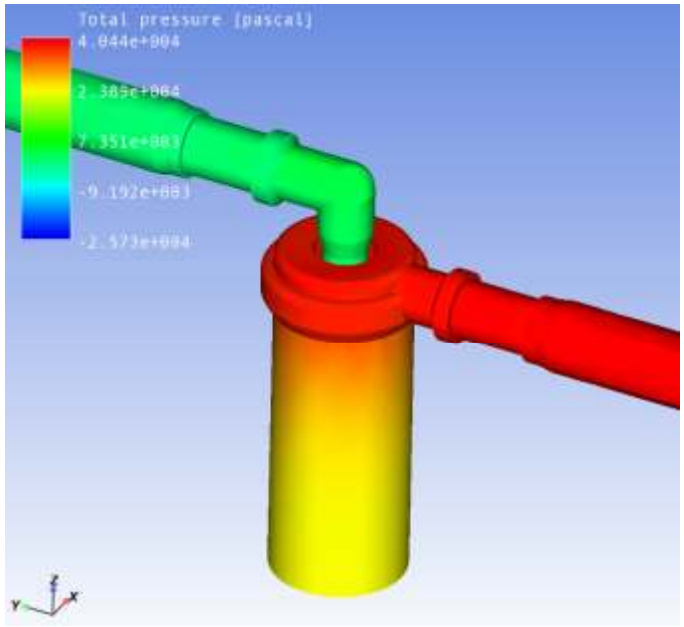
Validation (and verification)

- Was the right problem solved
- Was the mathematics solved correctly
- Was the physics represented accurately

Was it fast enough, accurate enough, cost effective

Simulation driven design

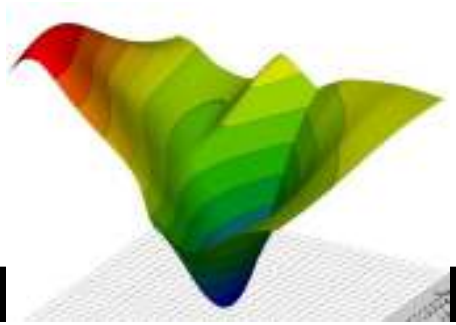
- Using CFD to influence the design:
  - Of a Component
    - e.g. efficiency of a jet engine
    - Downforce on a F1 car wing
    - Pressure loss across a blood filter
  - Of a Process
    - e.g. applying chocolate to a new biscuit
    - Filling a shampoo bottle
    - Ensuring adequate mixing in a mixing tank
- Before the component / process has actually been built / started



Why do simulation driven design?

- Ensure what you build will work
  - Save on multiple tests, costly redesigns, customer recalls, penalty payments.
- Consider multiple designs

- Test designs that would be too expensive / difficult to test in situ
  - Jet engines running at altitude / wind farm / Nuclear build
- Optimise the design
  - Reduce costs, increase performance, efficiency etc…



Getting help

- Your code vendor
- University courses (undergraduate, postgraduate, short courses)
- Other courses (eg von Karman Institute for Fluid Dynamics)
- NAFEMS resources (publications, website, events)
- CFD Online & CFD-wiki
- ERCOFTAC
- Engineering Institutions / professional bodies
- Consultants

Useful Resources

- Web resources
  - NAFEMS CFD: www.nafems.org/resources/CFD/
  - CFD Online: www.cfd-online.com * * * * *
  - QNet-CFD: qnet.cfms.org.uk
  - CFD Review: www.cfdreview.com
- Books
  - ERCOFTAC best practice guidelines
  - An Introduction to Computational Fluid Dynamics: The Finite Volume Method, H.K. Versteeg and W. Malalasekera
  - Computational Methods for Fluid Dynamics, Joel H. Ferziger, et al

Getting more out of NAFEMS

- Read the publications
- Attend the events (physical and online)
- Use the website
- Read Benchmark (esp. October issue)
- Propose topics and activities

Putting more into NAFEMS

- Submit papers for the CFD Journal
- Submit tenders to write books
- Present at events
- Comments and suggestions for the jargon book

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Questions & Answers
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Questions

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Thank you!

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