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
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

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
• 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
• 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

\[ \varepsilon_j + p \delta_{ij} - \tau_{jij} = 0, \quad i = 1, 2, 3 \]

\[ \varepsilon_0 + u_j p + q_j - u_i \tau_{ij} = 0 \]
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 nor 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
- $k-\varepsilon$ – 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

1. Approximation of the fluid domain
2. Creation of the mesh
3. Selection of physical models
4. Setting of boundary conditions
5. Calculation of variable values
6. Determination of sufficiently converged solution
7. Post-processing
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, convection, etc.)
- Convergence
- Getting the answers out and communicating them (post-processing)
- GIGO

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/](http://www.nafems.org/resources/CFD/)
  - CFD Online: [www.cfd-online.com](http://www.cfd-online.com)
  - QNet-CFD: [qnet.cfms.org.uk](http://qnet.cfms.org.uk)
  - CFD Review: [www.cfdreview.com](http://www.cfdreview.com)

- **Books**
  - ERCOFTAC best practice guidelines
  - *An Introduction to Computational Fluid Dynamics: The Finite Volume Method*, H.K. Versteeg and W. Malalasekera
NAFEMS and CFD

Getting more out
Putting more in

Collaboration
Innovation
Productivity
Quality
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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