19951214 76

TURBULENCE REQUIREMENTS OF A COMMERCIAL CFD CODE

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Outline

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Profile of ASC

- Established in 1985
- Components of business
  - development
  - applications
  - licensing and service
- Geographic markets
  - North America
  - Europe
  - Pacific rim countries

Application Profile

- Rotating machinery components
  - hydraulic turbines
  - pump
  - compressors
  - turbines
  - stators
  - wicket gates
  - scrolls
  - volutes
  - inlets and diffusers
  - seals
  - stage
  - rotor stator

Application Profile cont'd

- Combustion
  - gas turbine combustor
  - coal fired boilers
  - gasification
  - fire suppression
  - emissions reduction
  - safety
- High speed external - ballistics
  - explosively formed projectiles
  - finned projectiles
  - sabot discard
- Heat transfer
  - turbine cooling
  - nuclear reactors
  - heat exchangers
  - electronics system cooling
- Typical uncertainties
  - geometry
  - initial and boundary conditions
  - transient effects
  - transition
  - limitations of physical models
  - numerical error

Client Profile

- Companies or divisions
  - industrial/manufacturing/research
  - 10 - 200 employees
  - limited or no access to high performance computing
- Users
  - design and/or analysis
  - < 3 people
  - network of engineering workstations
  - turnaround time in less than a day for analysis, hours for design

Clients' Needs

Needs are most readily identified through typical questions from clients.

- General
  - I am using k-ε or two-layer or k-ω, or RNG ..., what does it mean to my calculation? Tell me in words what the deficiencies of the model means for my application?
  - What is the relative price/performance of the various turbulence models?
  - Has the model I am using been validated for type of flows I am trying to model? If so, when, where, how ... ?
  - How well does the model handle the interaction between turbulence and rotation, curvature, adverse pressure gradients, separation, swirl, bouyancy, extinction, droplets and particles, anisotropies ...?
  - How can I use Navier-Stokes solvers for design? Can I tune the turbulence model to suit my needs? If so, what are the appropriate settings for my application?

Clients' Needs cont'd

- Grid
  - I don't have access to high performance computing, I don't have any more time, I have a coarse non-orthogonal mesh, is my CFD result useful?
  - I have just made my grid finer, why should I have to worry about whether y+ is in a given range?
- High speed flows
  - I am solving a flow with many speed regimes including low speed separations and shocks, why do turbulence levels become unphysical as the grid is refined through shocks?
  - How should experimental data be compared to results from time or Favre averaged calculations?

Clients' Needs cont'd

- Combustion
  - Which of the many different combustion models in combination with which turbulence model works best for my application?
  - How appropriate is the single scale implicit in the turbulence model for the combustion model?
  - How can the Bousinesq assumption be valid in the presence of counter-gradient diffusion?
  - How important are turbulent fluctuations to my problem?
  - If I had all the mean flow and fluctuating components of the the turbulent flow, how can the effects of stretch and curvature on the instantaneous flame front be modelled.
  - Can extinction due to vortex stretching be modelled?
  - What is the influence of the flame front on the turbulence?

Clients' Needs cont'd

- Calculated pdf models
  - If I use a more detailed chemistry model - like a pdf transport model - how much improvement can I expect in the results for my application? How can I measure that?
  - Is it the case that the results for my application will not be sensitive to the shape of the pdf? If not, then why should I incur the costs associated with a pdf transport equation.
  - I am solving a pdf transport equation, how much are the results dominated by the limitations of modelling of the diffusion transport term?

Clients' Needs cont'd

- Flamelet models
  - I am using a flamelet model in modelling my gas turbine combustor, but in some regions of the combustor the model is not strictly appropriate - can any of the results be used? If so, how much?
  - In some models like the flamelet model, it is assumed that the turbulent time scale is inversely proportional to the velocity gradient of a "laminar" model flame. What is the validity of this assumption?
  - How sensitive are my results to the assumption of statistical independence of the quantities in a joint pdf?

ASC's Directions

- Develop in-house model expertise
  - two-layer model
  - alternative two-equation models
  - second moment closure models
  - expanded EBU models
  - flamelet model
- Develop in-house expertise applying models
  - turbomachinery
  - combustion
  - heat transfer
- Promote high performance computing
  - parallel computing

How Can CMOTT Help?

- Model improvements to address between turbulence and
  - rotation
  - curvature
  - adverse pressure gradients
  - separation
  - swirl
  - bouyancy
  - droplets and particles
  - anisotropies ...

as well issues related to

- extinction
- trace species
- vortex stretching
- flame fronts
- time and length scales
- ...

- Great, but is this what users really want?

How Can CMOTT Help? cont'd

- Curator of information on existing models
  - define
  - validate
  - process
  - educate

as an independent agency

How Can CMOTT Help? cont'd

Define models

- unified conceptual framework
- establish baseline for various models
- set context for model improvements
- for each model
  - > document derivation
  - > identify assumptions
  - > clearly state implications of assumptions
  - > separate physics from numerics

How Can CMOTT Help? cont'd

Validate models

- fundamental flows
  - > validate assumptions
- benchmark problems
  - > select real engineering problems relevant to identified applications (in propulsion)
  - > review selection of benchmark on regular basis
- experimental data
  - > collect and review existing data
  - > define new experiments
  - > review quality of resulting data for validation of models

How Can CMOTT Help? cont'd

Process data

- collect
- distil
- review
- interpret
- describe
- compile

How Can CMOTT Help? cont'd

Educate

- document
- publish
- workshops
- seminars
- short courses
- market

Summary

Provide information so users, for their applications can:

- make an educated choice of model
- understand how to appropriately use existing models
- move forward with existing models and technology
- understand implications of improvements to existing models