Modelling of Fires with Computational Fluid Dynamics
Status of Modelling

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Content

- Introduction
- Important Physical Processes
  - Examples of fire scenarios
- What we need to model
- What can be modelled with an acceptable(?) degree of accuracy
- What cannot currently be modelled
- Conclusions

Introduction

- Combustion is very complex!! It involves
  - Large number of chemical species, even for simple fuels
  - Large number of reactions
- Important questions to ask:
  - What do we know about the problem?
  - What do we need model?
  - Do we have an appropriate model?
  - How successful (accurate) can we expect our model predictions to be?
- Experiments (physical and numerical) and modelling are complementary

Important Physical Processes

- Ignition
- Blow-out
- Blow-off
- Lift-off
- Extinction
- Chemical kinetics
- Interactions between different physical processes
  - Flame-turbulence
  - Flame-radiation
  - Turbulence-radiation
- Interaction with obstacles or walls

Visible jet flame from a shrouded vent

Examples of Fire Scenarios—1(2)

- Jet flame
  - High pressure release
  - Jet released approx. 1.25 m above ground
  - Essentially free jet with some interaction with the ground further downstream
  - Nearly invisible flame
  - Thermal imaging camera required to properly visualise the flame

Examples of Fire Scenarios—2(2)

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- Jet flame
  - High pressure release
  - Jet released at about 1.25 m above the ground
  - Horizontal distance to the plate is around 2.5 m
  - Flame impacts on a metal plate at 60° to the ground
  - Test performed as part of the HyPer project

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What we need to model

- Combustion (one from)
  - Non-premixed combustion
  - Partially premixed combustion
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  - Laminar flow
  - Transitional flow
  - Turbulent flow

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- Interactions (possibly all of)
  - Interaction with structures
  - Interactions between different physical processes

What Can We Model

- Combustion processes
  - Detailed chemical kinetics—hydrogen-air mixture
    - 9 species
    - 29 reactions
  - Reduced chemical kinetics
  - Simplified models
    - Laminar flamelets
    - Single irreversible global reaction
    - Conditional moment closure
    - Empirical correlations
  - Non-premixed combustion
  - Partially premixed combustion
  - Premixed combustion
- Lift-off
  - Crude approach
- Ignition
- Shorter time steps are usually required
- Set of stiff equations to solve
- Detailed/reduced chemical kinetics is not always required
- Modelling detailed and reduced chemical kinetics for industrial applications is not always feasible due to the demand it places computer resources

What We Cannot Readily Model

- Blow-off
- Blow-out
- Combustion in vitiated air
- Extinction
  - Recent modelling suggests that just maybe this is possible
- Flames from cracks
- Heat transfer
  - Convection
  - Radiation
- Lift-off (accurately)

These are listed in alphabetical order and not in order of importance

- Turbulence
  - Not directly part of the combustion processes of course
  - However, the coupled nature of the flow means turbulence matters a great deal
- Various interactions
  - Flame-turbulence interaction
  - Flame-radiation interaction
  - Turbulence-radiation interaction
  - Flame-droplet interactions
  - Flames interacting with obstacles
- Ventilation-controlled fires

Conclusions

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- A number of physical process are important
- Combustion processes are very complex
- Combustion problems lead to systems of equations that are highly non-linear and strongly coupled
- We can model some of these processes
- There are also a number of processes for which
  - Our theoretical understanding is incomplete; and/or
  - Our models do not represent the physical processes

- Should we despair?
  - No, we can model a fair number of scenarios with acceptable accuracy, but
  - Clearly more research is required
    - Physical experiments
    - Numerical experiments
    - Model development

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Any Questions?