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Using the Cone Calorimeter for Toxicity Measurements of Materials by Raw Sampling

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presented by Abdulaziz Alarifi

For the 7th Saudi Students Conference on 1-2 February 2014
Edinburgh, UK
(Awarded best presented paper)
Outline

• Introduction
  • Why do we research Fire Toxicity?
  • How would Fire Toxicity research prevent (or reduce) fire fatalities?

• Objectives

• Experimental setup & modifications

• Results & Discussion

• Conclusions & future work
Introduction – 1

• Major Drivers of fire toxicity research
  • Disasters
  • Statistics

1977 Beverly Hills Supper Club fire, Kentucky, US
164 of the 165 fatalities were killed by toxic smoke inhalation

1980 MGM Grand Hotel, Las Vegas, US
79 of the 85 fatalities were killed by toxic smoke inhalation

1985 British Airtours Flight 28M, Manchester, UK
48 of the 55 fatalities were killed by toxic smoke inhalation
Introduction – 2

- Non-Fatal casualties in UK
• Fatalities in UK
• Drivers of fire toxicity research
  • Disasters
  • Statistics
• Performance based Design
  “Performance based design in fire engineering is the application of scientific and engineering principles to the protection of people, property and the environment from fire”
  • Practicality of performance based design
  • Available Safe Egress Time (ASET)
  • Required Safe Egress Time (RSET)
Available Safe Egress Time (ASET)

- Ignition, Fire growth, Spread of fire & smoke
  - Fire
    - Ignition (location + intensity)
    - Fire load (layout + material content)
    - Smoke nature (release rate + toxic content)
  - Compartment
    - Size (height) & layout
    - Ventilation
    - Active & Passive fire protection systems

Required Safe Egress Time (RSET)

- Occupants safety and Fire hazards
  - Fire + Occupants
    - Physiological influence of exposure to heat & smoke on escape behaviour
  - Occupants
    - Response to warning
    - Profile (age, physical/mental ability, pop. density)
  - Compartment
    - Pre-egress behaviour (way-finding, movement, crowd flow)

Occupants reach a place of relative safety

Ignition

Time
• Drivers of fire toxicity research
• Disasters
• Statistics

Performance based Design:

“Performance based design in fire engineering is the application of scientific and engineering principles to the protection of people, property and the environment from fire”

Required Safe Egress Time (RSET)

CFD applications in Fire Engineering
Objectives

• Introducing a suitable sampling system for the cone calorimeter in combination with FTIR analyser.

• Comparing measurements from both sampling points (raw and diluted) to investigate post combustion due to secondary dilution after the chimney.
Experimental setup

- the cone calorimeter:

- Oxygen Analyser
- CO\(_2\) Analyser (NDIR)
- CO Analyser (ADC)
- Oxygen Analyser
- Cold Trap
- FTIR
- Mass balance
- Heated gas lines 180°C
- Normal gas lines
- 1 Raw sampling chimney
- 2 Hood
- 3 Exhaust to safe disposal
Results & discussion – 1

- Effect of Appending Chimney on the combustion process
  - Auto-ignition time
  - Heat Release Rate (HRR)

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- Standard deviation: 2.3
- Average: 24

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- Standard deviation: 9.5
- Average: 54.4
\[ \dot{m}_{\text{diluted smoke}} = 29.4 \text{ [g/s]} = \dot{m}_{\text{dilution air}} + \dot{m}_{\text{air}} + \dot{m}_{\text{fuel}} \]
• Dilution Ratio
  • Determination of dilution ratio
• Dilution Ratio

• Determination of dilution ratio

• Measured and estimated CO & CO$_2$ based on the dilution ratio at both sampling points
Conclusions & future work

• Modifying the open cone calorimeter by adding the chimney can effect the combustion process due to the chimney effect created, increasing air entrainments around the combustion zone. However, this would not be the case with restricted ventilation enclosure as air supplied will be controlled.

• it has been shown experimentally that the post oxidation at the diluted sampling point is present even with freely ventilated setup.

• Raw gas sampling from compartment fires is the only way that the problem of post flame oxidation by dilution gases can be avoided and current toxic gas tests all involve post flame air dilution and hence underestimate the toxic yields.

• The cone calorimeter has been successfully modified to enable good toxic gas yields to be determined and should be considered as a reliable method for determining toxic gas yields in simulated compartment fire conditions with an imposed ventilation rate.
Any Questions please?