HARMONIZATION OF PRACTICES FOR ATMOSPHERIC DISPERSION MODELLING WITHIN THE FRAMEWORK OF RISK ASSESSMENT

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HARMO 15 – 7 May 2013, Madrid, Spain
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• Methodology and purpose of benchmark cases
  
  • Sum up of benchmark cases

  • Standardization of input meteorological profile

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Industrial risk management in France

2001, September the 21st: Major explosion in Toulouse (AZF factory)
  • 31 deaths
  • 2500 injuries

Consequences: Modification of the industrial risk prevention strategy

Circular October 2005: A new legal tool in France to protect people from industrial hazards
  → PPRT (“Plan de Prévention des Risques Technologiques”)
    • Requirement: prediction of impact area (thermal, overpressure and toxic effects), for potential accidents scenarios
    • Consequences: financial and human impact, protection measures to expropriation
    • Importance in computing precise safety distance to prevent from people exposure and realistic safety cost
Prediction of safety distances by modelling: current approaches

3 types of phenomena

- Fire
  - Radiation models
  - Integral, Gaussian, 3D approaches for smoke dispersion
- Toxic dispersion
  - Integral, Gaussian, 3D approaches
- Explosion
  - Integral, Gaussian, 3D approaches for vapour dispersion
  - Empirical model

→ Atmospheric dispersion modelling appears as a key issue for effect prediction

→ But sometimes huge discrepancies between safety distances
Objectives of the French tridimensional atmospheric dispersion working group

To create a guideline of best practices for 3D atmospheric dispersion modelling:

→ To forecast hazardous consequences within the framework of risk assessment

→ To harmonize practices and results

→ To provide a reading tool for the administration

Participants: Industrialists, Universities, Consulting services, Institutes

Coordination: INERIS
Schematic view on the organisation

- Fictive cases modelling
- Identification of the sources of differences
- Development of best practices
First case: free land atmospheric dispersion

3 different toxic gas releases with 8 bar pressure through 2 inch hole
- Heavy: 4.5 kg/s of $C_3H_8$
- Neutral: 3.6 kg/s of CO
- Light: 2.8 kg/s of $NH_3$

2 different wind profiles
- Stable: F3
- Neutral: D5

Users are fully free: no constraint on wind representation, turbulence modelling, boundary conditions, source term implementation, etc
First case: some results and analysis

Calculation 1
Calculation 2
Lethal effect (10 min)
Lethal effect (60 min)
Irreversible effect (10 min)
Irreversible effect (60 min)

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What we have learnt from case 1

4 major factors were identified:

- Interpretation of wind profile for CFD
- Turbulence models
- Mesh: cell size
- Source term implementation

Need to standardize the methodology for these 4 issues
Relation between wind profiles and CFD approach

French regulation requires atmospheric conditions as F3 or D5
- But these conditions cannot be translated easily
- For a condition, several profiles are possible
No interpretation rule exists to build profile for CFD models

Great effort in order to establish a consensus
Relation between wind profiles and CFD approach

The proposal is:

- **Requirements**: Pasquill Class, Wind module $u_{z_{ref}}$, $z_0$, $T_0$
Relation between wind profiles and CFD approach

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- **Requirements**: Pasquill Class, Wind module $u_{zref}$, $z_0$, $T_0$

- **Method**:
  - Relation of Pasquill class and LMO/$z_0$ within Golder approach
  - LMO for surface boundary layer profile
Relation between wind profiles and CFD approach

- **Method:**

\[
\frac{1}{L} = \frac{1}{L_s} \log_{10} \left( \frac{z_0}{z_s} \right)
\]

\[0.001 \leq z_0 \leq 0.5\]

<table>
<thead>
<tr>
<th>Pasquill stability</th>
<th>L_s (m)</th>
<th>z_s (m)</th>
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<tbody>
<tr>
<td>A</td>
<td>33,162</td>
<td>1117</td>
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<tr>
<td>B</td>
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<td>E</td>
<td>48,330</td>
<td>1,262</td>
</tr>
<tr>
<td>F</td>
<td>31,325</td>
<td>19,36</td>
</tr>
</tbody>
</table>

“Relations among stability parameters in the surface layer”

Relation between wind profiles and CFD approach

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- **Requirements**: Pasquill Class, Wind module $u_{zref}$, $z_0$, $T_0$

- **Method**:
  - Relation of Pasquill class and LMO/$z_0$ within Golder approach
    - LMO for surface boundary layer profile
  - Iterative calculation $\rightarrow u_*$
  - Extension within and above surface layer: Gryning et al. approach (2007)

Z_i height of the ABL
Case 2: modelling with obstacles

Some parameters were fixed:

- Wind profiles
- Simpler source term, propane release (45 kg/s)

Obstacles were introduced inside the domain

About 12 modellers:

Two main approaches

- RANS, mainly k-\(\varepsilon\)
- LES
What we have learnt from case 2

Differences in using similar models

- Buoyancy effects
- Roughness modelling
- Surface or volume source term
- Mesh

Specific work:

- Consideration of turbulence production by buoyancy effects
- Distance upstream first obstacles
Production of a list of best practices (I)

- **Validation procedure**
  - Need for the user to validate the code
  - CFD using requires physical sense for downstream analyse

- **Mesh building**
  - Mesh independence (COST 732)
  - Cell shape

- **Numerical criteria**
  - non dissipative numerical schemes
  - Numerical diffusion → artificial reduction of dangerous area
Production of a list of best practices (II)

- **Boundary conditions**
  - Wind profiles prescribed by the WG
    - correspond to Pasquill classification
  - Boundary conditions position (COST 732)
    - Necessity of a distance upstream first obstacle
    - Distance of the domain roof

- **Wind profile conservation along the domain**
  - Atmospheric turbulence has to be maintained
    - the criteria: F3 at the inlet ➞ F3 at the outlet

- **Turbulence model to take into account specific phenomena**
  - Production term due to buoyancy effects
Concluding comments

Regarding WG

- Simulations with the proposed **best practices** on an experimental case (Kit Fox Field)
- Still some differences but ... Is it worse than other models?

On CFD use for industrial safety

- A very powerful tool with a lot of input parameters
- And some physical sub models
  ➔ Requires a high level of physical knowledge for the user

Guideline of Practices Harmonization on CFD use for industrial safety

- Feedback of administration ➔ improvement
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