CFD Based Approach for VCE Risk Assessment

2009 MKOPSC International Symposium

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Objective

- Determine the maximum design load at a specified frequency
- Provide a detailed risk picture for large offshore platform
- Provide recommendations on design issues based on CFD analysis results
CFD Based Approach Adopted

1. Start
2. CFD references database
   - Geometry modelling FLACS
     - CFD explosion
       - Explosion load Response surfaces
     - CFD ventilation and dispersion
       - Ventilation and cloud size distribution
3. Probabilistic distribution of leak sizes, wind rose, etc.
4. Probabilistic assessment EXPRESS
5. Acceptec criteria, QRA, design
Major Steps

- Identification of critical leak scenarios
- CFD model (FLACS)
  - Geometry model – grid calculation
  - Ventilation and dispersion analysis
  - Explosion analysis
- Probabilistic analysis (EXPRESS)
- Sensitivity studies
- Design recommendations
Ventilation

**Purpose**
- Select the leak location, leak rate, and wind speed to find the largest flammable cloud
- Determine the time to start leak in dispersion model
Dispersion Analysis

- **Purpose**
  - to find the maximum flammable cloud size
Dispersion Analysis

- Set up a series of scenarios
  - Wind speed, wind direction, leak rate, leak direction and leak location are varied systematically
  - Select condition giving largest cloud size
Approach Limiting CFD Runs

- Problem: CFD analyses are major calculations and time consuming
- Solution: DNV adopted a “Frozen Cloud” approach
- Assumption: a linear relation between gas concentration, $c$, and leak rate and the wind speed is assumed for each leak scenario

\[ c(x, y, z) \propto \frac{\dot{m}}{u} \]

- The effect on the flammable gas cloud size from running slightly smaller and larger leak rates can be assessed without CFD simulation of additional cases
Frozen Cloud Results

- Case study shows that for this area, the highest filling, 60% of the process area, is expected to occur when $R=0.15$ (Ratio of volume flow of combustible gas to air)
Complete Cloud Response Surface

Huser et al, OTC 12951, 2001
Explosion Analysis

- Once cloud dispersion is established, the explosion calculation can also be executed by CFD modeling.

- Consider the effect of:
  - Geometry: size, confinement, obstruction, minimum distance between decks/plates, corner constant
  - Gas mixture: composition, location, quantity

- Critical locations for explosion load determination:
  - Control rooms, vessels, columns, decks

- Critical loads is a combination of:
  - The maximum pressure pulse measured on monitors is used as reference pressure
  - Maximum drag
Explosion Analysis from FLACS
Explosion Database of CFD Cases and Experiments

- 19 explosion models
  - One process platform (plant) for each model
  - 15 to 50 explosion simulations performed in FLACS for each model
  - Maximum explosion overpressure used to develop the correlations
- 15 experiments
  - Various module sizes
  - Different congestion levels
  - Different explosion venting areas
Simulation Overpressure vs. Cloud Size Trend

$P \sim V_f^{5/3}$

Smart Process

- New Installation
  - Conditions
    - New Ventilation
      - New Dispersion
        - New Explosion
          - Exceedence Curve
          - Frequency
  - Database
Explosion Risk Analysis, EXPRESS

- Purpose – Frequency of exceeding explosion load vs the load

- Selected critical loads are used in probabilistic analysis

- DNV Probabilistic tool EXPRESS is applied to find pressure exceedence curves
  - EXPRESS establishes a response surface using a limited number of CFD runs
  - The response surface rapidly generates the exceedance results
  - Pressure on other targets are found as a linear relationship between the reference pressure and the other target
CFD Based Approach Adopted

Start

CFD references database

Geometry modelling FLACS

CFD explosion

Explosion load
Response surfaces

CFD ventilation and
dispersion

Ventilation and cloud size
distribution

Probabilistic
distribution of leak sizes,
wind rose, etc.

Probabilistic
assessment EXPRESS

Acceptec criteria,
QRA, design
Frequency/Probability

- Leak frequency (for each leak category)

- Probability of ignition – Time Dependent Internal Ignition Model (TDIIM)
  - Pump
  - Compressor
  - Generator
  - Electrical equipment
  - Personnel
  - Hot work
  - Other

- Explosion frequency
Time Dependent Internal Ignition Model (TDIIM)

- Intermittent ignition sources
  - The total cloud size

- Continuous ignition sources
  - The increase in cloud size
Monte Carlo Simulation

- Select specific outcomes of all stochastic variables from their statistical distributions
- Calculate ignitable time dependent cloud size and ignition probability
- Select ignition time from the ignition time probability distribution
- Calculate explosive cloud size at time of ignition
- Calculate explosion loading from explosion load response surface
Pressure Exceedence Curves

Accumulated frequency (1/year) vs. Explosion pressure load (barg)

- ESD close after 60 s
- ESD close after 30 s

Reduction in explosion load due to rapid initiation of ESD
Prevention/Mitigation

- Leak frequency reduction
- Localized enclosure
- Ventilation
- Deluge
- Gas detection, shutdown and blowdown
- Reduced number of ignition sources
- Blast wall
Why Method is Appropriate

- Experimental explosion results used for the development of the correlation
- CFD results directly applied to find cloud dispersion/size and resulting maximum explosion pressure
- Special techniques allow fewer CFD runs
  - Frozen cloud approach
  - Response surface approach
- Combined CFD and probabilistic analysis gives the detailed risk picture
Typical Risk Based Design Activities for Offshore

- Explosion – FLACS & EXPRESS
- Fire – KFX, PFPro & EXPRESS
- WCI – Wind Chill Index
- Ventilation - ACH
- Gas detector location - GDOZ
Thank you!