3D Risk Management for Hydrogen Installations (Hy3DRM)

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Outline

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Motivation

- Gexcon develops the computational fluid dynamics (CFD) code FLACS
- FLACS includes the porosity / distributed porosity (PDR) solver Flacs for simulating flow phenomena in complex geometries
- FLACS is primarily an engineering tool used for consequence assessments in the process industry
- The modelling of complex 3D geometries in typical process facilities represents a significant investment for the owners and/or operators of the plants
Example: Medium-congested geometry with low degree of confinement
Motivation

Risk management is "the business of believing only what you have the right to believe"  DeMarco & Lister (2003): "Waltzing with Bears"
Motivation

The purpose of risk assessments include:

- Systemizing knowledge and uncertainties about phenomena, processes and activities in systems,
- Describing and discussing the results of the analysis in order to provide a basis for evaluating what is tolerable and acceptable,
- Comparing and optimizing different design options and risk reducing measures.

There is significant uncertainty associated with most risk assessments – however, this is of secondary importance as long as the use of procedures and information* is consistent.

* Data, Assumptions, Knowledge, etc.
Motivation

Numerous factors influence the level of safety an organization can achieve for a given system:

- Safety culture
- Potential for loss
- Maturity of the technology
- Risk perception / awareness
- Safety functions and processes
- Safety training & emergency preparedness
- Relevant standards and legislation
- etc.

Hierarchy of principles for risk reduction:

- Inherent safety
- Prevention
- Passive mitigation
- Active mitigation
- Procedural safety
- …
Motivation

Statistical records from accidents and near misses demonstrate that engineered safety and administrative procedures cannot replace risk awareness, competence and a healthy safety culture:

- Human errors account for about 80 percent of all events – only 20 percent involve equipment failure [DoE].
- About 70 per cent of the events caused by human error can be traced to latent organizational weaknesses – only 30 percent are due to mistakes by individuals.
Motivation

Management of the operational risk* in industrial facilities should take into account:

- The risk analysis/assessment
- Previous events and near misses
- Safety barriers / risk-reducing measures
- Modifications and the age of the installation
- Technological developments
- The likelihood of natural disasters and malicious attacks
- Safety culture, risk awareness, etc., etc.

* Risk management refers to a coordinated set of activities and methods used to direct an organization and to control the risks that can affect its ability to achieve its objectives.
What if …

- We could extend the use of detailed 3D models to other aspects of risk management than ‘simple’ QRAs?
- We could create a framework for risk management that facilitates learning in organizations through discussion and practice?
- We could use virtual site-specific geometry models, continuously updated (“as is”, not “as built”) in the daily operation of process plants?
- We could define the next paradigm in risk management!
3DRM
3D Risk Management (3DRM)

- 3DRM is an integrated risk management framework for a specific facility, characterized by interactive use of a detailed 3D geometry model, a CFD tool, and other models and libraries.

- Within the 3DRM framework, the quantitative risk assessment (QRA) becomes a (more or less) continuous processes that evolves throughout the lifetime of the facility.

- Realization of the 3DRM concept entails both development of software products and related consulting services.

- The 3DRM concept is inspired by Agile principles for software development, which put particular emphasis on people, teams, continuous integration and knowledge sharing in organizations.

- 3DRM is not an ‘expert system’!
# Typical workflow for QRA part

- Importing or constructing **3D geometry model**.
- Identifying and registering inventory of hazardous materials in **virtual 3D model**.
- Identifying and registering main safety functions in **virtual 3D model**.
- Identifying and registering potential ignition sources in **virtual 3D model**.
- Registering personnel densities in **virtual 3D model** (personnel risk).
- Registering relevant boundary conditions: wind rose, relevant codes and standards, …

### Simulating selected scenarios (automated process):

- Wind simulations – initial conditions for:
- Release and dispersion scenarios (flammable/toxic) – initial conditions for:
  - Jet and pool fire scenarios, and
  - Gas explosion scenarios
  - Escalating accident scenarios
- Estimating the effect (harm) on personnel caused by physical parameters (personnel risk)
- Calculating and visualizing risk contours in the virtual 3D model.

### Analysing results, implementing risk-reducing measures, updating calculation, …

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*Communication* can be automated
Towards 3D risk management

The operative use of the virtual 3D model may include:

- Visualization of 3D geometry model, including metadata, in the control room, at training centres, on portable devices, etc.
- Visualization of scenarios from QRA (training, …), incidents, etc.
- Hazardous area classification – visualizing zones and equipment
- Work permits – highlighting specific areas during maintenance
- Interactive training/site visits for employees, subcontractors, etc.
- ISO 9000 compliance – issue tracking, documentation, etc.
- Gas detector optimization based on QRA – various optimization criteria: detecting leak, minimizing damage, etc.
- Emergency preparedness and emergency response: GPS tracking in 3D geometry, visualizing sensors and alarms, etc.
- Etc.
Pros and cons of 3DRM

Advantages:
- Step-wise implementation
- Communication with and/or between stakeholders
- Competence building: CFD vs. Engineering models, …

Limitations:
- Implementation cost
- Not an expert system
- Full implementation requires dedicated end-user
Hy3DRM

- The Research Council of Norway (RCN) supports the Hy3DRM project under the ENERGIX program.
- Partners: Gexcon and Telemark University College
- Cooperation with Sandia National Laboratories: linking 3DRM and HyRAM (see previous + next presentations here at ICHS)
- Norwegian contribution to IEA-HIA Task 37
Hy3DRM = 3DRM + Modelling + Validation + Experiments (HiT)
While we are waiting for the dedicated end-user …

Generic filling station: 100 kg day\(^{-1}\) reference \(^{[H2FIRST]}\)
- Compressor in 20 ft. ISO container compresses hydrogen from tube trailer to high-pressure storage tanks

Simplified fault trees (HyRAM / Sandia reports) and event trees for selected accident scenarios:
- 168 dispersion simulations
- 168 jet fire simulations
- 672 gas explosion simulations

FLACS simulations:
- 1008 simulations
- 3-4 days
Hypothetical filling station
Example: Jet fire scenario
Heat radiation contours: $f > 10^{-6} \text{ yr}^{-1}$
Frequency contours: $Q_{rad} > 5 \, \text{kw m}^{-2}$
Lethality frequency – jet fire
Frequency contours: $P_{ex} > 0.5$ bar
Over-pressure contours: $f > 10^{-6} \text{ yr}^{-1}$
Real filling station
Compressor in ISO container
Inside the container
HySEA

- Improving **Hydrogen Safety for Energy Applications** through pre-normative research on vented deflagrations

- **Call:** H2020-JTI-FCH-2014-1-FCH-04.3-2014 – “Pre-normative research on vented deflagrations in containers and enclosures for hydrogen energy applications”

- **Consortium:** Gexcon (Coordinator), University of Warwick, University of Pisa, Fike Europe, Impetus Afea and University of Science and Technology of China (USTC)

- **Start-up** 1 September 2015

- **Information:** [www.hysea.eu](http://www.hysea.eu) + **Poster & Handouts outside**
Summary

A preliminary proof-of-concept study for a generic filling station indicates that 3DRM can become a powerful tool for risk communication in organizations.

Main applications:
- Site-specific model – for larger industrial facilities
- Generic model – for series of similar installations, such as filling stations (base-case QRA, training, risk communication, etc.)
The way ahead

- From Python scripts to C++ …
- Closer integration with HyRAM
- More realistic/complex systems
- Comparing CFD and simpler models
- Optimizing and exploring methodology

**Wanted**: Dedicated end-user!
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3DRM
Because the world is three-dimensional