Forschungszentrum Karlsruhe
Technik und Umwelt

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Numerical Simulation in Energy and Safety Technology

Physical Phenomena

- turbulence
- mixing
- chemical reaction
- ignition
- radiation
- heat transfer
- condensation

Numerical Codes

- **Distribution Code GASFLOW**
  Implicit code for long problem times with gas structure energy exchange
- **Slow Deflagration Code V3D**
  Implicit code for slow premixed and diffusion flames
- **Fast Deflagration Code COM3D**
  Explicit code for fast turbulent flames with eddy-break-up model and k-ε turbulence model
- **Detonation Code DET3D**
  Explicit code for Euler equations with detonation chemisty

Criteria

- **Ignition**
  - Ignition limits
  - Ignition temperature
  - Minimum ignition energy
- **Flame Acceleration**
  Minimum expansion ratio σ for flame acceleration
- **Deflagration to Detonation Transition**
  Minimum detonation cellsize λ

Experiments

- 12 m FZK tube

- 60 m RUT facility

Validated Codes

Application

- large scale
- complex 3D geometry
- full range of combustion regimes

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Simulation of Hydrogen Distribution in Reactor Containment

Contact person: P. Royl

Problem

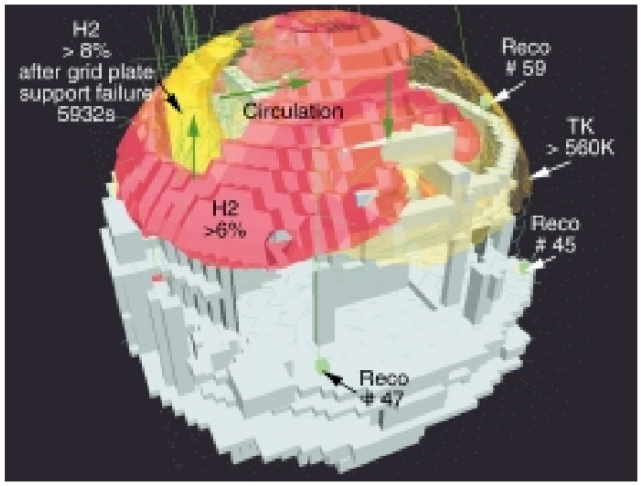
Investigation of risk reduction during severe accidents (e.g. surge line LOCA) in German KONVOI plant by hydrogen control measures

Solution

- 3D distribution calculation with simulation of catalytic H_2 recombiners using GASFLOW
- calculation on VPP5000 with 140.000 computational cells

Result

- Investigated recombiner concept showed effective reduction of released H_2 mass in containment within 1 h without adding additional risk
- Results were used in licensing procedure for installation of recombiner systems in German nuclear power plants



Calculated H_2 distribution

Combustion Simulation in Reactor Containment

Contact person: A. Kotchourko, U. Bielert

Problem

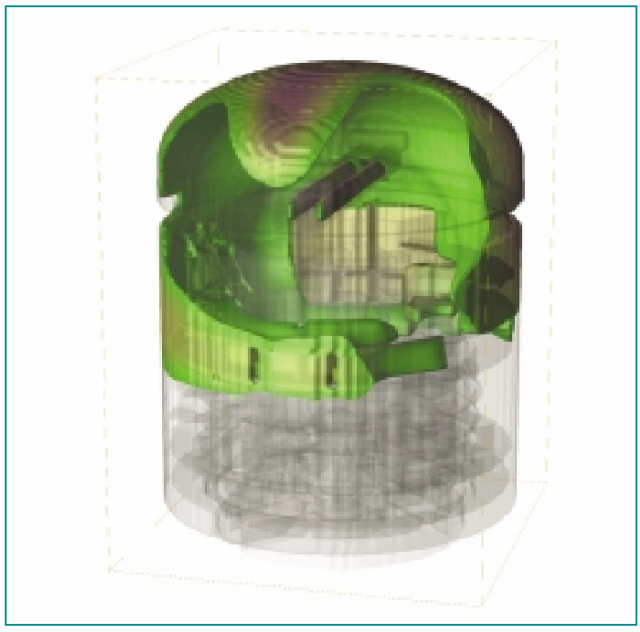
Determination of mechanical loads during combustion event after severe accident (SBLOCA)

Solution

- Full 3D containment calculation on Cray T3E with COM3D
- Simulation of turbulent combustion
- Computational cell size 0.4 m; 2 million cells

Result

- Peak pressure occurs at internal structures
- Maximum pressure on outer containment < 3 bar
- Containment design pressure not exceeded



Calculated H_2 concentration

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Nuclear Fusion Reactor Accident Analysis (ITER-FEAT)

Contact person: R. Redlinger

Problem

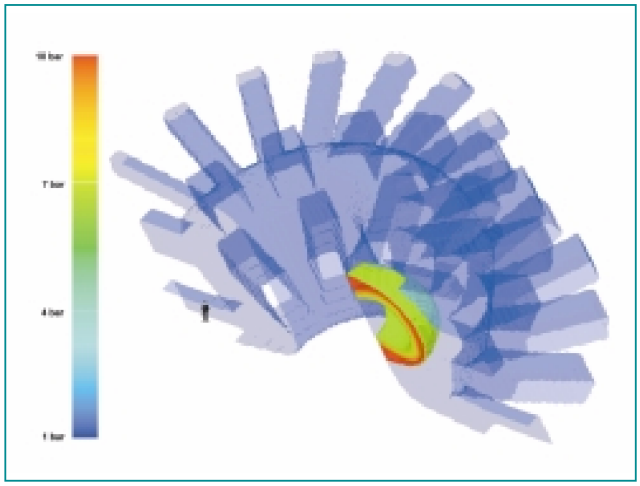
Identify maximum possible pressure loads to vessel from accident scenarios with combined air ingress and hydrogen production

Solution

- 3D detonation calculation with DET3D
- Full 360° geometry model
- Ignition of stoichiometric mixture of 5 kg H_2 in air at 1 bar and 140 °C

Result

- Peak pressures:
  side-on orientation 10 bar
  normal reflection 25 bar
- Reflected detonation impulse 5 kPas
- Maximum gas temperature 3500 K



3D geometry with expanding spherical detonation front

Hydrogen Car Accident in a Tunnel

Contact person: U. Bielert

Problem

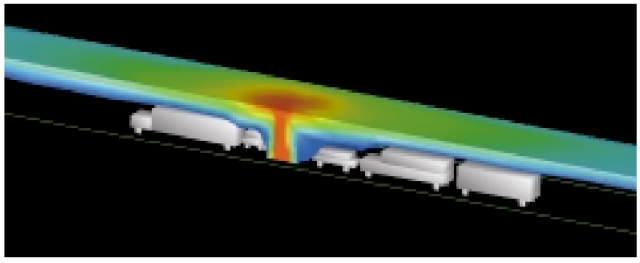
Risk analysis for hydrogen powered passenger vehicles in confined accident situations (e.g. tunnel, garage)

Solution

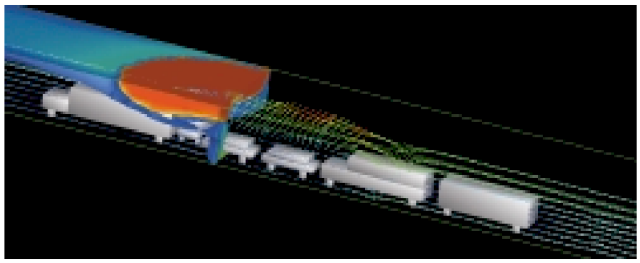
- 3D GASFLOW distribution and deflagration calculation
- Application of criteria for combustion regimes

Result

- Early ignition leads to standing diffusion flame
- Late ignition of extended H_2 cloud leads to slow deflagration
- Potential for flame acceleration exists only during release phase



H_2 concentration near release location



H_2-air deflagration: H_2 concentration, burned gas temperature and flow velocity

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