Introduction

Matt Straw

- PhD University of Nottingham, CFD in wind engineering (natural ventilation)
- 15 years oil and gas engineering consultancy including
  - Subsea & flow assurance
  - Process & separation
  - Safety
  - Marine operations

Norton Straw Consultants

- Oil & Gas engineering, focussed on simulation-based services
- Technical management & business development

Our work with CD-adapco

- Sector management for oil and gas (upstream)
- Help to understand industry needs for current and future simulation
- Industry and application experience
Industry challenges & breadth of simulation
Overview of how STAR-CCM+ is used in the industry
Focus on a selection of applications and
  - Provide some of examples of Norton Straw Consultants current projects
  - Look beyond current simulation methods– CD-adapco development
  - Trying to avoid duplicating topics from other talks in the session
Upstream oil and gas

Engineering challenges
- Safety
- Challenging environments
- Costly and complex intervention
- Complex fluids including solids
- Long design life (25 years +)
- Many uncertainties
- Large structures

Wide range of simulation required
- Multiphase flow
- Solids production & transport
- Conjugate heat transfer
- Complex chemistry
- Complex rheology
- Fluid-structure interaction
Upstream oil & gas areas of application

- **Sub-surface**
  - Reservoir
  - Drilling
  - Downhole

- **Subsea**
  - Production systems
  - Pipelines
  - Riser & umbilical systems
  - Flow assurance

- **Offshore structures & facilities**
  - Safety
  - Process & separation systems
  - Structural & marine

- **Marine operations**
  - Vessels operations
  - Deployment
Relatively new area for detailed simulation

Reservoir
- Multiphase
- Complex fluids, phase change
- Wide scale disparity from reservoir down to pore-scale
- Interaction with wellbore

Drilling & downhole
- Complex fluid structure interaction issues (6 DOF)
- Complex rheology
- Solids

Wide range of physics applicable
- DEM, Eulerian & Lagrangian gives us multiphase, solids and emulsions
- Phase change, real gases (steam injection)
- Chemical reactions and behaviour for Enhanced Oil Recovery
Subsea & flow assurance

- Flow assurance – guaranteeing the flow
  - Multiphase flow & solids
  - Hydrate & thermal management
- Integrity
  - Corrosion
  - Solids management/erosion (later talk)
- Vortex-induced vibration
- Flow-induced vibration (later talk)
- On-bottom stability
Co-simulation will continue to develop as we take on more physics.

- **STAR-CCM+ / OLGA coupling**
  - Large-scale disparity
  - 1D simulation advantageous for system-wide
  - 3D brings accuracy and physics
  - STAR-CCM+ - OLGA coupling can be used to couple 2 approaches together

- **STAR-CCM+ / Abaqus - Applications coupling fluid and structure**
  - Riser fatigue, subsea jumper and pipeline flow-induced vibration
  - Interesting talk at the conference to follow
Offshore facilities

- Safety (presentation later & tomorrow)
- Process & separation
  - Separator performance
  - Sloshing
  - Heat exchangers
  - System integrity
- Structural & design
  - Wave loading
  - Green water
Oil & gas marine operations

- Pipeline and structure installation
- Vessel costs are significant (~$20k to ~100k/day)
- Need to understand limiting sea-state
- Drag, added-mass & slam load required
- Simulation can reduce conservatism
Case studies
Flow assurance - Hydrate management

Hydrate

- Ice-like solid formed between hydrocarbon gas and water
- Avoidance is a major design and operational consideration
- Can block a production system; complex and expensive to remedy

Current design strategy

- Methanol injection during production (expensive to inject and reclaim)
- Avoid temperatures below which hydrates form
- A challenge during a shutdown for more complex structures (rather than pipelines)
- Usually requires insulation
Hydrate management-current method

- Start with production condition
- Turn off production and allow to cool
  - Monitor minimum fluid temperature
  - Fails when reaches hydrate appearance temperature
- Typically build in conservatism e.g.
  - Assumed to be in extreme current
  - Worst-case insulation properties
  - Starting production fluid temperature
Thermal analysis can produce conservative designs

- Hydrate risk is often extremely low when production fluid reaches hydrate formation temperature
- Volume of fluid at hydrate formation temperature is typically negligible for a few hours after minimum fluid temperature reaches hydrate appearance

Impacts design & installation significantly
- Insulation application time and costs
- Structural design (avoiding cold spots)
- Dry weight for installation (vessel costs high)

How do we reduce conservatism?
- Understand the risk better
- Model hydrate formation?
Hydrate management - development

- Oil-dominated 3 phase flow (more prevalent in gas systems)

- Eulerian multiphase flow model:
  - Phase 1: Oil - continuous fluid
  - Phase 2: Gas - dispersed bubbles
  - Phase 3: Water/hydrate - dispersed droplets ($f_H=0$) turn into hydrate particles ($f_H=1$)

1. Methane ($\text{CH}_4$) gas bubbles dissolved into the oil
2. Water droplets contact dissolved $\text{CH}_4$, turn into hydrate particles when the below hydrate nucleation temperature
3. Dissolved gas is consumed in the hydrate formation process
Hydrate management - development

Temperature of oil
(Note areas cooler than hydrate nucleation temperature of 15.6 °C)

Hydrate fraction in water
(Hydrate starts to form when temperature drops below 15.6 °C)

This can easily be implemented in STAR-CCM+
Flows with low water cut
- Gas with water cut is complex to model
- Empirical models not suitable so
- Follow the water - Use liquid films to identify risk

Solids deposition
- Sediment deposition can lead to accumulation of sulphide-reducing bacteria
- Follow the solids - use DEM, Eulerian or Lagrangian
Corrosion & electrochemical development

- An area where, in oil and gas, we have not seen
- CD-adapco electrochemical development working in collaboration with Prof. John Harb, BYU
- Actively developing case studies, input valued if data available
Simulation use in upstream continues to grow and develop

STAR-CCM+ gives us wide range of physics

Speed of meshing and set-up is key to spending more time solving the engineering problem

Continued development in STAR-CCM+ continues to improve simulation and subsequent engineering

Co-simulation opportunities widens our applications