Prototyping of CAPE-OPEN Hydrodynamic Interface Design Proposal

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An initiative of Hydrodynamic Special Interest Group of CO-LaN

CAPE-OPEN standard basics

- CAPE-OPEN defines rules and software interfaces that allow CAPE (computer-aided process engineering) applications and components to interoperate
  - For Thermodynamic modules (Physical Property Packages)
  - For Unit operations (process equipment modules, sub-networks, ...)

- CAPE-OPEN adopted by most of the software industry involved in process simulation

- CO-LaN (CAPE-OPEN Laboratories Network)
  - Neutral industry and academic organization promoting the standard
  - Free use of the standard and documentations : www.colan.org
  - Special Interest Groups (SIGs) supervise standard evolutions
    - Thermo SIG, Unit SIG, Method and Tools SIG, Hydro SIG

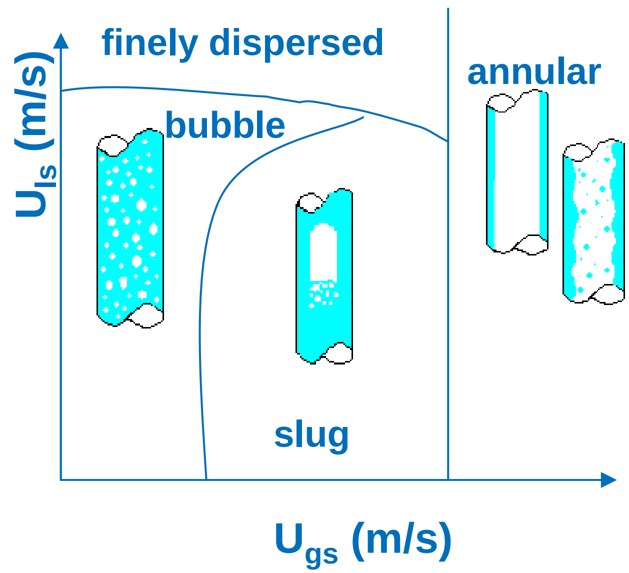
Context

- Multiphase flows in tubes, pipes and pipelines: A complex physics with a large domain of applications
  - Dynamics of heat exchanges in Nuclear industry
    - Loss-of-coolant accident (LOCA): mode of failure for a nuclear reactor
  - Heat exchangers in process industry and also spatial industry
  - Mineral transportation
    - Slurry pipelines over long distance
  - Multiphase production in Oil&Gas pipelines
    - Huge variety of multiphase conditions
      - Sand transportation, hydrate slurry flows, gas-oil-water flows, ...

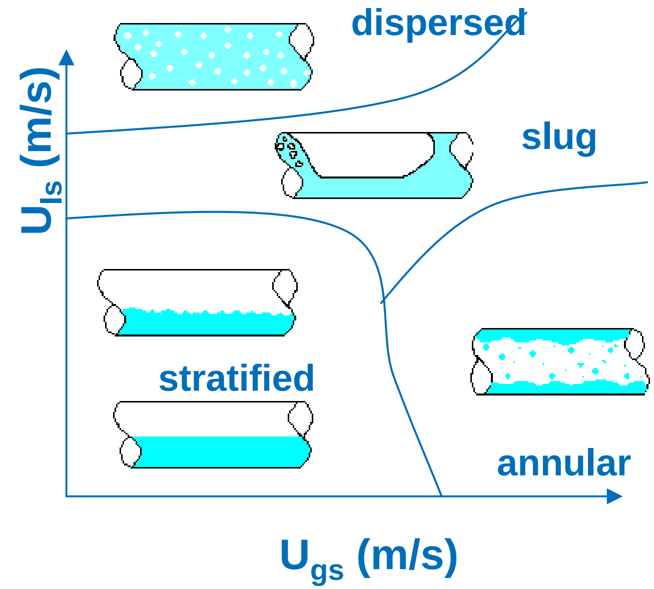
Context

Gas-Liquid
Flow Maps

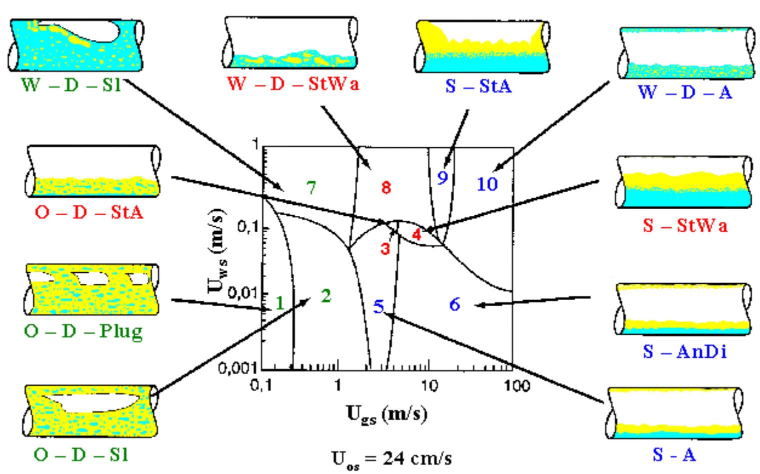
vertical flow



horizontal flow



Gas-Liquid-Liquid
Flow Maps



Context

- Oil&Gas industry
  - Design and controllability of installations required accurate understanding of multiphase flows and predictive tools

Total Indonesia slug catchers: 3200t, 14 legs

Context

- Hydrodynamic Point Models (Oil&Gas)
  - One-dimensional models for characterizing flow in a pipe element
  - Calculate phase hold-ups, average pressure drop, flow pattern, ...
    - Empirical models: Taitel, Beggs&Brill, ...
    - Semi-mechanistic models:
      - OLGAS 2P/3P (SPTGroup), TACITE Hydro (IFPEN), Leda Point Model (SINTEF), Unified Model (TULSA university), academic developments
  - Models are used as closure laws in steady-state and transient pipe software tools
  - Enormous investments in experimental programs to improve models
    - Ex: Tiller loop (SINTEF): 8", H 800 m, V 65 m, 5-90 bar, 10-50 °C
    - Ex: $150 million R&D investment in OLGA technology from 80s to 2007

Objectives

- Why a software standard for hydrodynamic point models?
  - To make easier the use of hydrodynamics ("Plug and play")
    - Reduce the time for the technology transfer from academic to industry
    - Allow users to plug their own models in more integrated solutions
    - Allow end-users to gather models with a unique communication format
- How to specify software interfaces for hydrodynamic point models?
  - Define relationships between hydrodynamic components, unit operations and process modeling environment
  - Specifications should be as general as possible to take into account both developer's and user's needs
    - Take into account all multiphase flow specificities such as emulsion, solid, bed and deposit

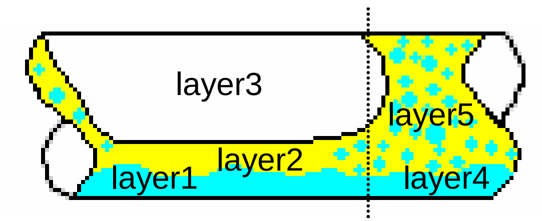
Hydro SIG charter

- Charter
  - Develop hydrodynamic interface specification
- Key Responsibilities
  - Manage the development of the hydrodynamic interface specification
  - Develop prototypes to prove the applicability of the standard
  - Contact organizations and companies that may be interested in hydrodynamic interfaces and propose then to join the SIG (CO-LaN membership mandatory)
- Deliverables
  - Didactic documentation to promote the utility of the standard
  - Document describing the hydrodynamic interface specification and the main scenarios of usage for these interfaces
  - Scope of work, responsibilities and planning for the implementation of prototypes
  - Prototypes implementing the interface specification

Accomplishment

- Current SIG members
  - IFP Energies nouvelles (SIG leader up to now), SPT Group, Total, Kongsberg O&G Technology, RSI-Dynamic Simulation Solutions, Infochem Computer Services, SINTEF
- Specification document content
  - Glossary: standard based on Layer, Field and Phase concept
  - 10 Use Cases
    - UC-001: HPM
    - UC-002: HPM association
    - UC-003: HPM validation
    - UC-004: Hydrodynamic calculation
    - UC-005: Impose flow regime
    - UC-006: Hydrodynamic specific property calculation
    - UC-007: Input properties
    - UC-008: Delivered properties
    - UC-009: Calculation initialization
    - UC-010: HPM tuning
  - This document needs to be reviewed and accepted by a large group of organizations involved in hydrodynamics

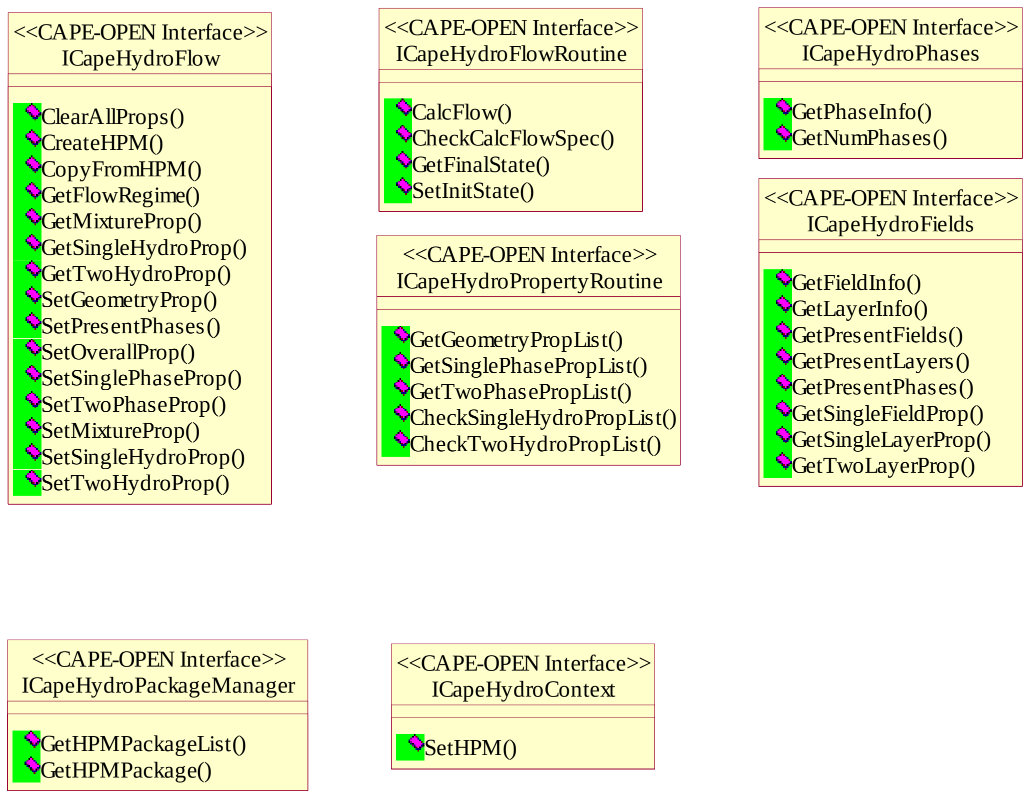
Slug flow example

	**Present phases** *water* *liquid* *gas*
Layers	**Fields**
Label *layer_1* **Volumetric fraction** value	
Field labels *field_1* **Volumetric fraction** value [1] **Stratified | Annular** Stratified **Slug | Pocket | Continuous** Pocket **Dispersed** No **Continuous field** *field_1* **Length Fraction** value **Interface perimeters** values [1] **Wet perimeter** value	**Label** *field_1* **Phase labels** *water* **Volumetric fraction** value [1] **Velocity** value **Emulsion** No **Continuous phase** *water*

…

Current interfaces

- Hydrodynamic software interfaces
  - Use of existing CAPE-OPEN thermodynamic interfaces if convenient
  - Proposed hydrodynamic interfaces



Current interfaces

Example

Interface Name	ICapeHydroFlowRoutine
Method Name	**CalcFlow**
Returns	**CapeError**

Description

The Calculate method is used to compute the standard hydrodynamic properties: pressure drop, phase velocities and phase holdups.

Arguments

Name	Type	Description
[in] *specification1*	CapeString	First specification identifier for hydrodynamic calculation. below for details.
[in] *specification2*	CapeString	Second specification identifier for hydrodynamic calculation. below for details.
[in] *flowRegime*	CapeString	Specified flow regime identifier for calculation. May be UNDEFINED if no flow regime is specify for calculation.

Prototype demo

- Client: Excel application
  - Intanciates an HPM
  - Sets input data
  - Calls methods to perform calculations
  - Shows results
- Server: simple Hydrodynamic Point Model
  - Supports 3 thermodynamic phases (one vapor and two liquid)
  - Based on Zuber-Findley flow correlations (1965)

$$\text{Input data} : U_k, \rho_k, \mu_k$$

$$U_M = \sum U_k$$

$$V_O - V_W = 0$$

$$V_G - V_O = \left(2 U_M + 0.35 \sqrt{g D}\right) \sin \theta$$

$$\frac{dP}{ds} = \frac{f_D}{D} \rho_M \frac{U_M^2}{2} + \rho_M g \sin \theta$$

Prototype demo

Snapshot of called standard interfaces and associated methods

Prog ID of the hydro server

View of hydro server specificities

View of configuration properties

Realize

- ICapeIdentification
- ICapeHydroPhases
  - GetPhaseInfo
  - GetNumPhases
- ICapeHydroFlow
  - ClearAllProps
  - CopyFromHPM
  - GetFlowRegime
  - GetMixtureProp
  - GetSingleHydroProp
  - GetTwoHydroProp
  - SetGeometryProp
  - SetMixtureProp
  - SetOverallProp
  - SetPresentPhases
  - SetSinglePhaseProp
  - SetTwoPhaseProp
  - SetSingleHydroProp
  - SetTwoHydroProp
- ICapeHydroPropertyRoutine
  - CalcSingleHydroProp
  - CalcTwoHydroProp
  - CheckMixturePropList
  - CheckSingleHydroPropList
  - CheckTwoHydroPropList
  - GetGeometryPropList
  - GetSingleHydroPropList
  - GetSinglePhasePropList
  - GetTwoPhasePropList
- ICapeHydroFlowRoutine
  - CalcFlow
  - CheckCalcFlowSpec
  - GetFinalState
  - SetInitState
- ICapeHydroFields
  - GetFieldInfo
  - GetlayerInfo
  - GetPresentFields
  - GetPresentLayers
  - GetPresentPhases
  - GetSingleFieldProp
  - GetSingleLayerProp
  - GetSinglePhaseProp
  - GetTwoLayerProp

Release All

Hydro 3-Phase GOW

Hydro 2-Phase GW

Hydro Point Model Package

HydroServer.HydroServer_IFP.1 Load

Create Hydro

Hydro Configurations

Hydro Deliverables

Hydro Calculate

Hydro Results

Hydro Fields

Delete Hydro

Specification

Server for HPM Simple Hydro calculations				
Nb of Phases		3		
Description		Vapor	Liquid Organic	Liquid Aqueous
CalcFlow options	Us	Available		
	Rk-Um			
	Rk-Vm			
	Us with regime			

Configuration

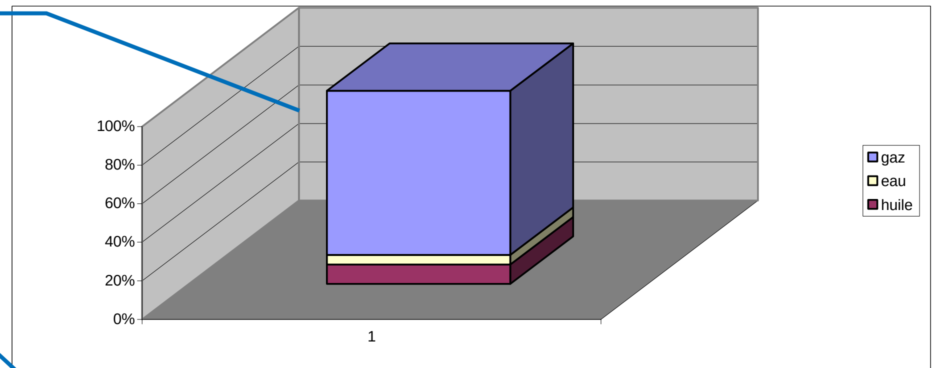
Pipe geometry		
	diameter	0.15
	inclination	0.5
	roughness	0.00001

1-Phase				
Thermodynamic	labels	gaz	huile	eau
		Vapor	Liquid Organic	Liquid Aqueous
	density	10	850	850
Hydrodynamic	superficialVelocity	1.97659	0.18809	0.09404

2-Phase Thermodynamic		

Prototype demo

View of calculation results: phase volume fractions in the pipe element



Main calculation results

Results				
Flow				
	Regime	Separated	StratifiedSmooth	
	pressureDropTotal	-711.501145		
1-Phase				
Hydrodynamic	labels	gaz	huile	eau
	superficialVelocity	1.97659	0.18809	0.09404
	volumeFraction	0.85041656	9.97E-02	4.99E-02
1-Phase				
Hydrodynamic	absoluteVelocity	2.32426095	1.8861045	1.8861045
	superficialVelocity	1.97659	0.18809	0.09404
	volumeFraction	0.85041656	9.97E-02	4.99E-02
Flow	pressureDropFrictional	-46.1374536		
	pressureDropGravity	-665.363691		
	pressureDropTotal	-711.501145		
Layers & Fields				
Nb of Layers				
Layer	labels			

Conclusions and Perspectives

- Documentation ready to use
  - Available on CO-LaN website
- First prototype illustrates the applicability of the standard
  - Source code available soon on CO-LaN website
- Necessity to perform extended interoperability tests
  - Test component integration from different suppliers to check the real applicability of the standard
  - Candidates are welcome !
- For more information
  - Visit: www.colan.org
  - Contact
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    - Michel Pons: technologyofficer@colan.org

Thank you for your attention!