DRILLING LIBRARY – A MODELICA LIBRARY FOR THE SIMULATION OF WELL CONSTRUCTION

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WELL CONSTRUCTION – BASICS

Phase 1. **Drilling**

- Wide hole drilling
- Casing & cement
- Small hole drilling towards target
- Drilling fluid
  - Transport cuttings
  - Cool down equipment
  - Control flow of formation fluid

Phase 2. **Completion**

- Make well ready for production
- Equipment installation
  - Sensors
  - Pumps
  - Flow control devices

WHY A NEW MODELICA LIBRARY ?

Multitude of mature domain specific tools

- To develop and validate well designs
- Not suitable for new technology development
- Vendor proprietary format
- Few or no extension interface
- Clear separation between top-side automation & downhole processes

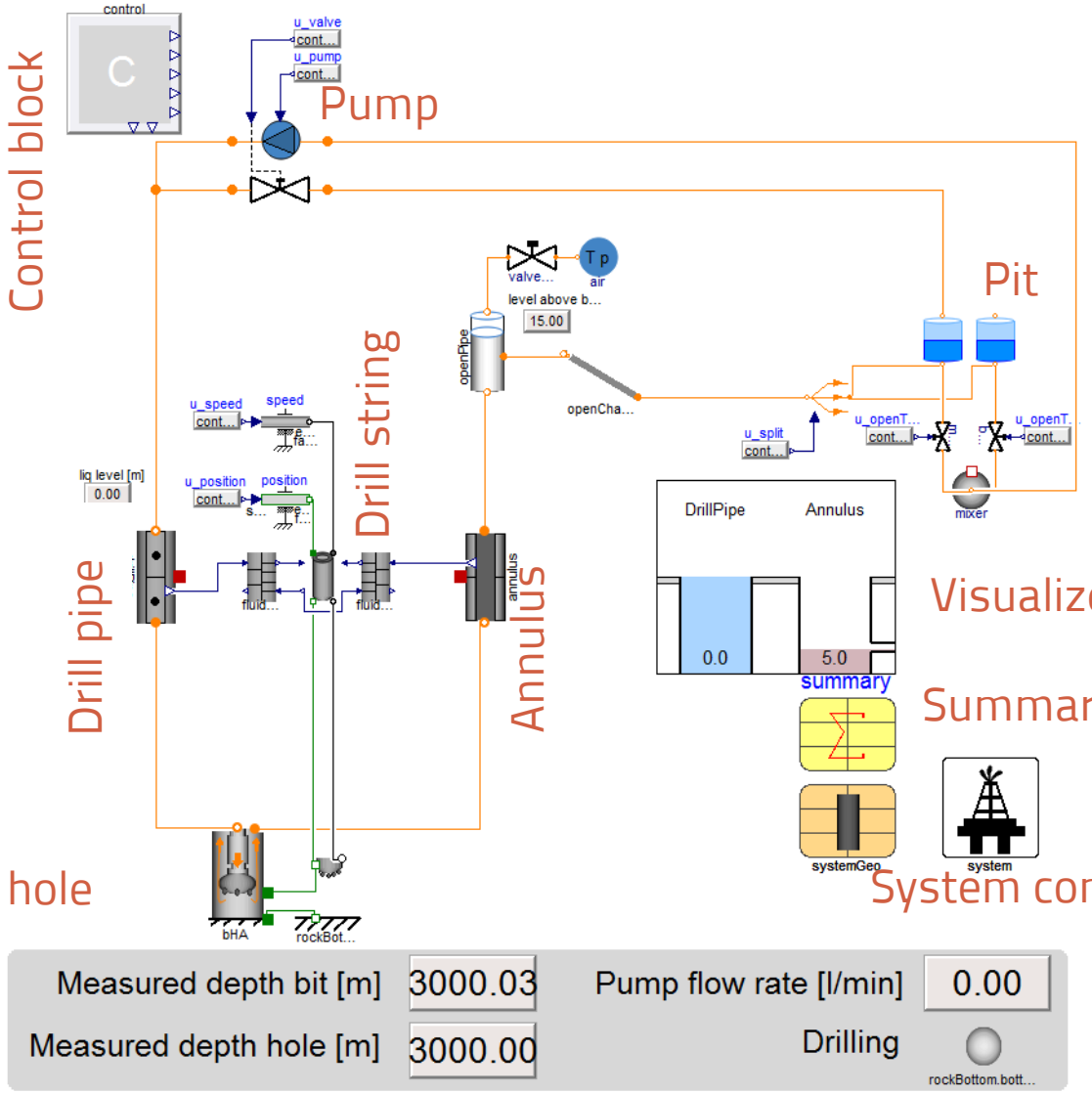
THE DRILLING LIBRARY

A versatile & extensible Modelica library to represent all parts of a drilling system

- Well hydraulics
  - From the main pump at the surface to the drill bit
  - Pressure, flow and composition along the well

- Drill string mechanics
  - Detailed mechanics of the string (torsion and elongation)
  - Rotational & translational friction
  - Interaction of the drill bit with the surroundings to describe the bore hole growth

COMPLETE ASSEMBLY

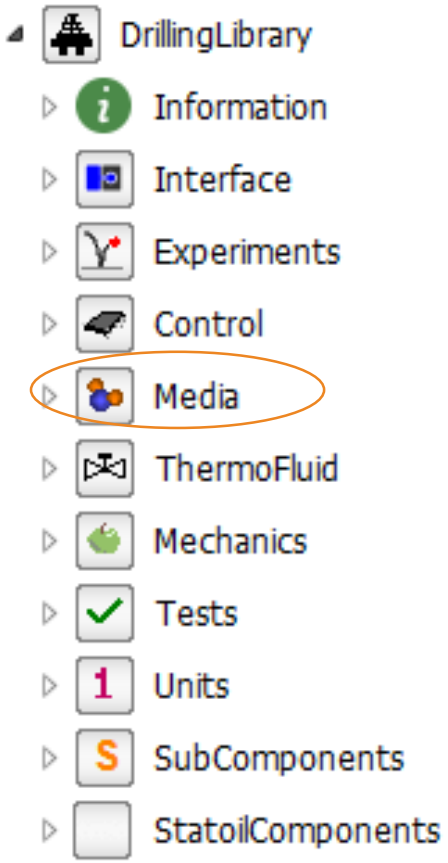


EXAMPLES OF APPLICATION

- Improved Managed Pressure Drilling
  - Fast and robust hydraulic models
  - Continental and off-shore drilling
- Torque and drag monitoring
  - Automation of standard friction test
- Borehole growth
- Mud-mixing and change of drilling fluid
- Kick detection and handling
- Drillstring vibration, detection and handling

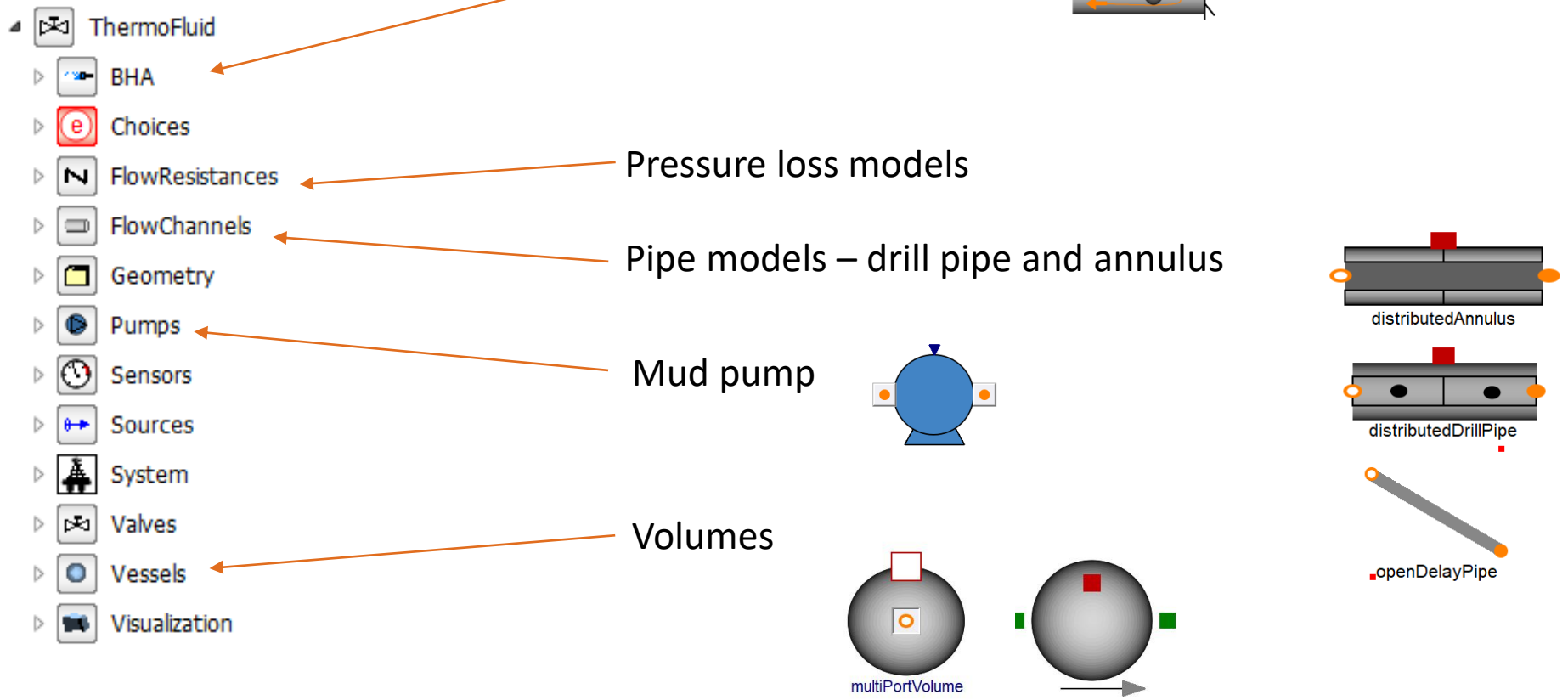
LIBRARY OVERVIEW

MEDIA PACKAGE



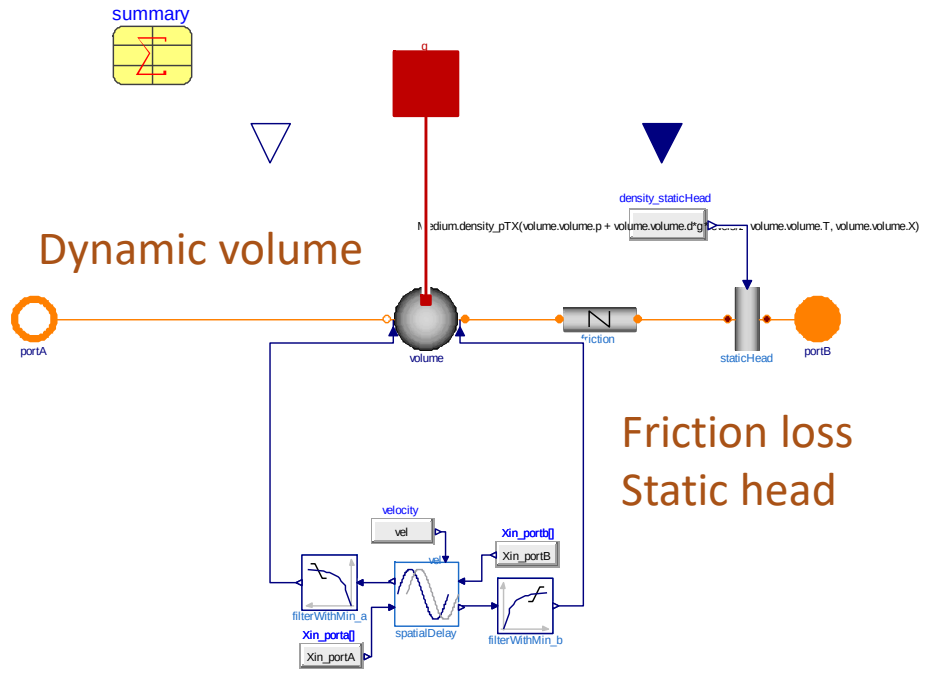
- Drilling mud described as a mixture of
  - Two liquids:
    - Brine and base oil
    - Bilinear equation of state $\rho(p, T, X)$
    - Enthalpy $h(T, X)$
    - Non-Newtonian (Herschel-Bulkley + power-law)
  - Two solids:
    - Low and high gravity particles
  - Gas
    - Ideal gas
- Arbitrary time-varying composition

THERMOFLUID PACKAGE



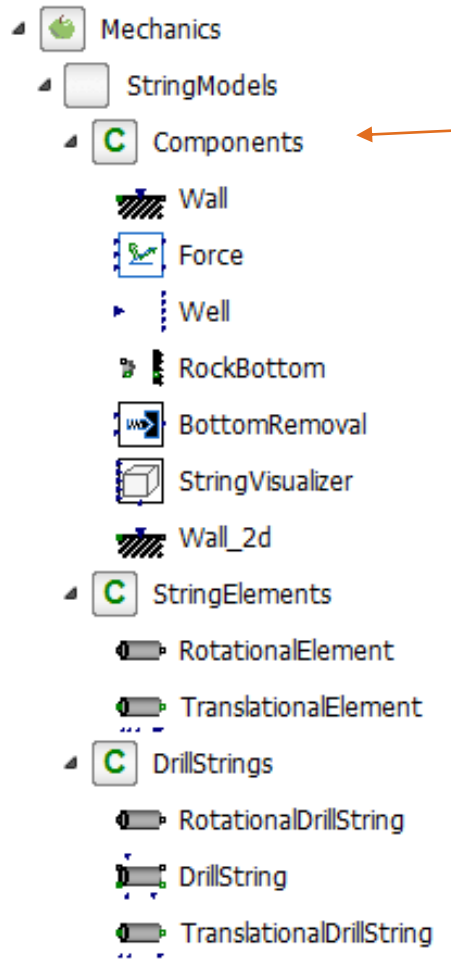
DRILLSTRING & ANNULUS

- **Dual** approach for robustness & performance
- Finite Volume
  - Dynamic energy & mass balances
  - Friction loss & static head
- Spatial distribution (delay)
  - Transportation of mass fractions
  - No numerical diffusion
  - Accurate residence time & tracking of fronts
- Support reversal flow



SpatialDistribution – delay

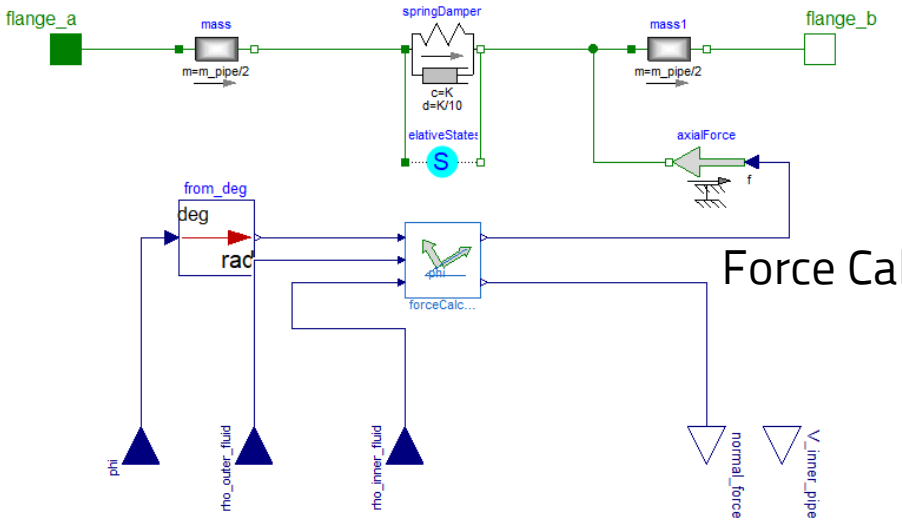
MECHANICS PACKAGE



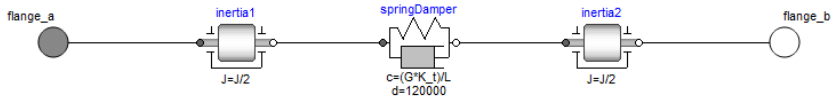
- Auxiliary components
  - Wall with friction
  - Force computation
  - Well geometry
  - Rate Of Penetration
  - Visualization
- StringElements
  - Single pipe elements
  - Rotation & Translation
- DrillStrings
  - Complete drill string (discretized, coupled rotation & translation)
  - No thermodynamics

STRING ELEMENTS - SINGLE

1d translational element



1d rotational element

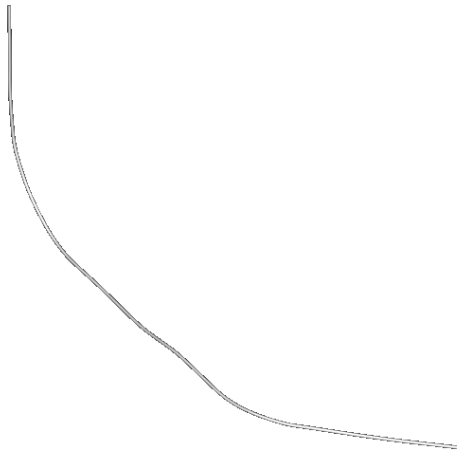


Force Calculation: axial and normal forces due to mass & buoyancy

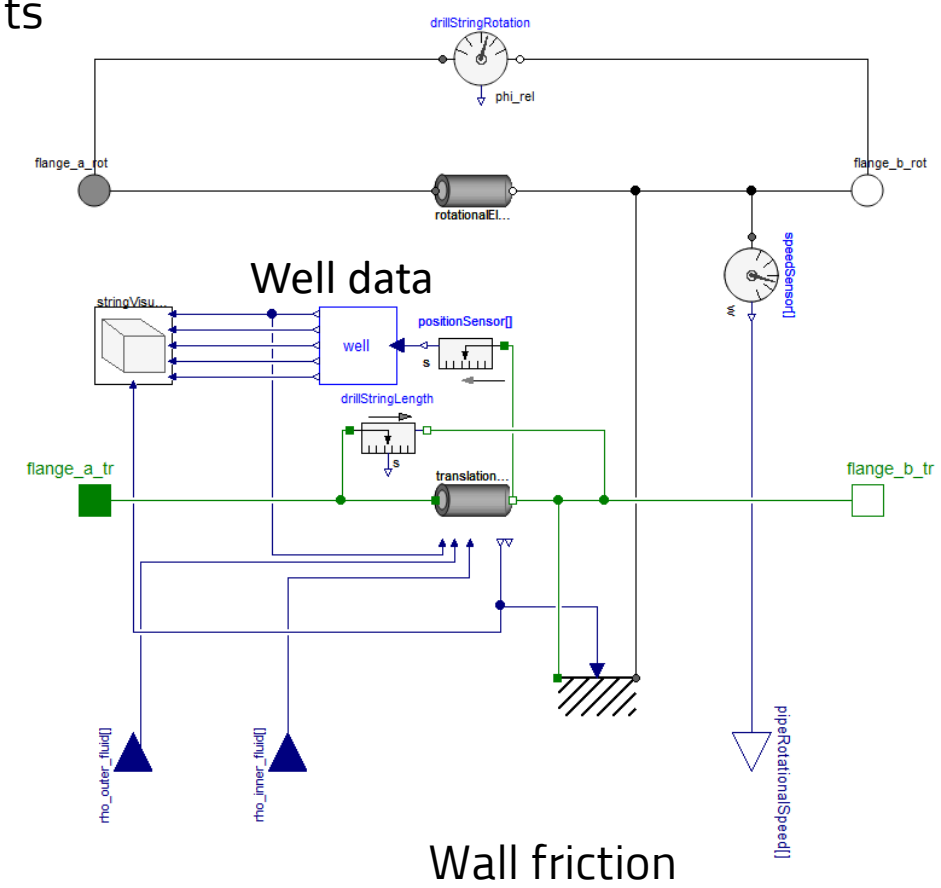
Parameterized to comply with static deformation

STRING ELEMENTS - AGGREGATE

Drill string vectorized, N-elements



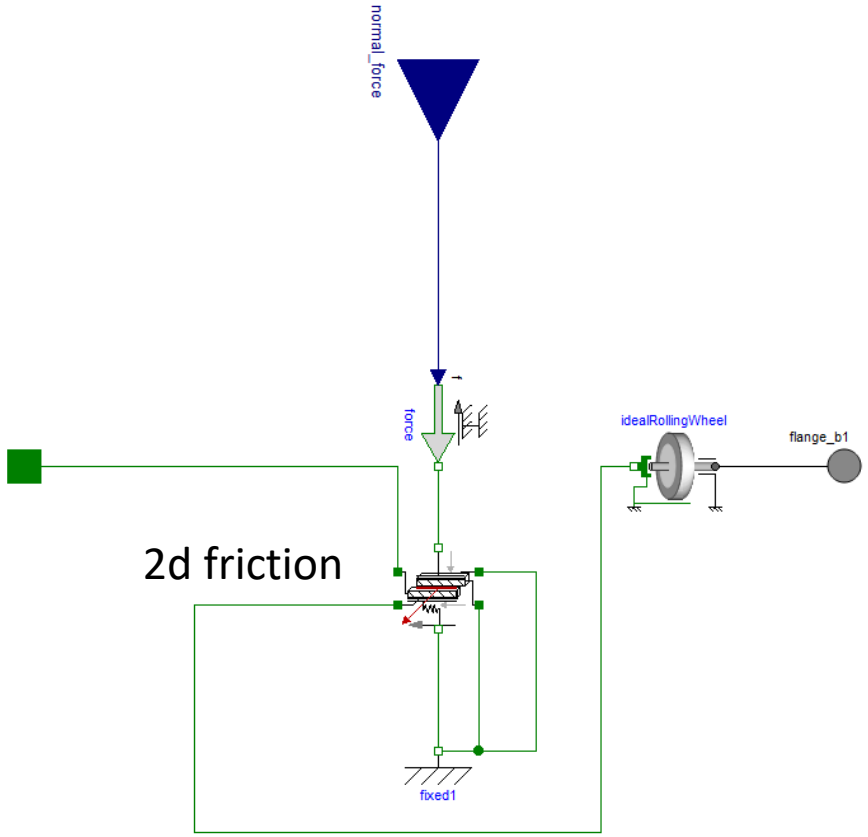
Visualizer



Wall friction

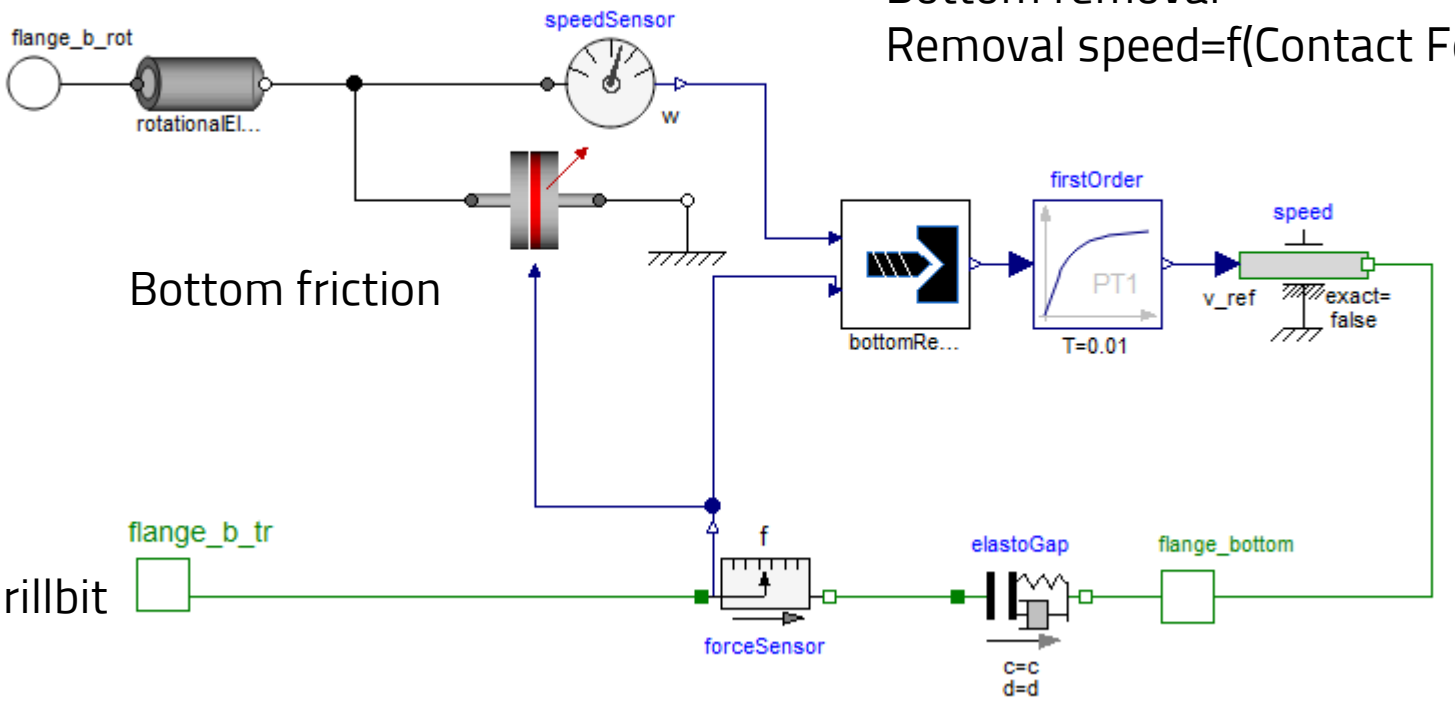
WALL FRICTION

- Computes friction forces
  - Coulomb friction
  - Viscous damping
- 2D friction model
  - Rotation
  - Translation
- Efficient computation
  - High discretization level
  - Short computation times
- Assumptions
  - String is assumed to lay on bottom
  - No rolling
  - No buckling



BOTTOM REMOVAL

Bottom removal
Removal speed=f(Contact Force, Rotational Speed)



Bottom friction

flange@drillbit

Bottom contact

flange@bottom

DRILLING LIBRARY – USE CASES

- Thermofluidic experiments
  - Mud pump start/stop
  - Addition of high gravity solids
  - Surge and swab
  - Heave and wave propagation

- Mechanical experiments
  - Borehole growth
  - Friction tests

USE CASE – FRICTION TEST

In long, near-horizontal wells

- Need for monitoring of friction between drillstring & borehole
- Deviation from expected behavior
  - Poor-cleaning performance
  - Well path tortuosity

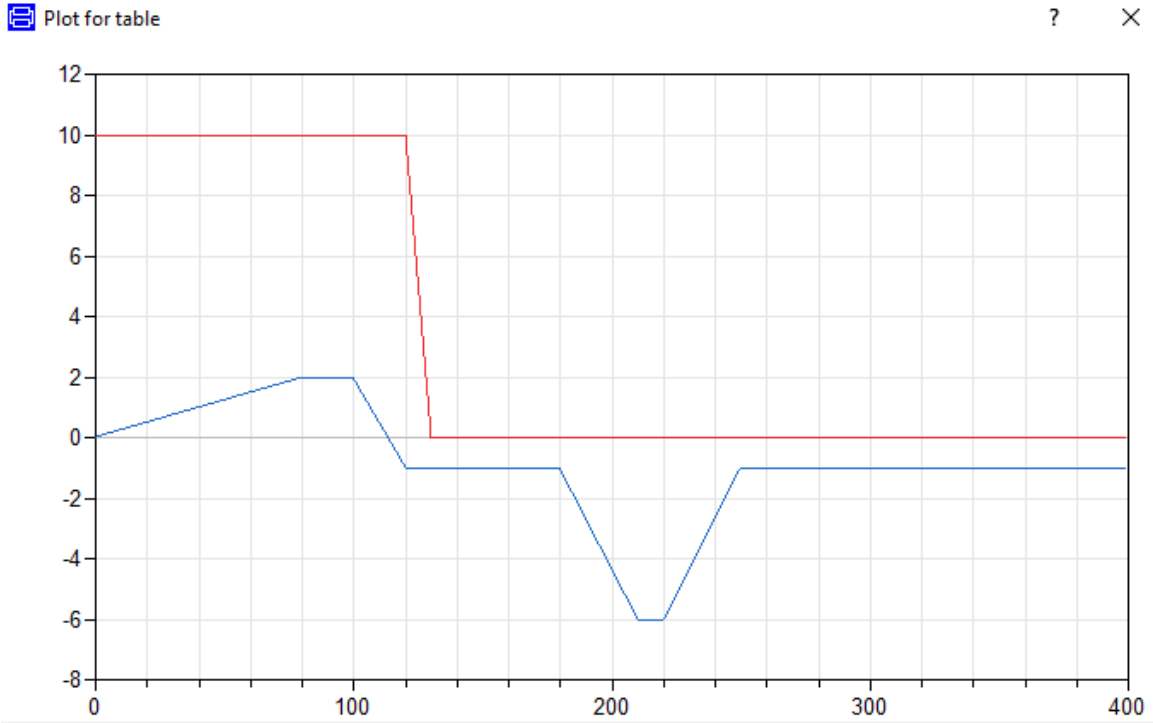
Goal of the simulation

- Design of automated friction tests
- Derive torque and drag profiles
- Improve understanding of transients
- Winding and unwinding times

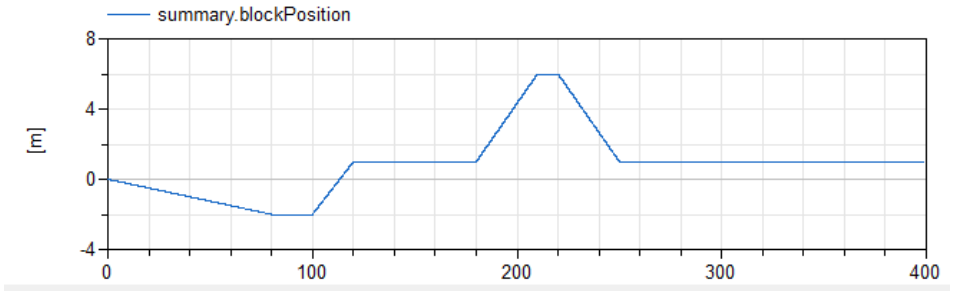
DESCRIPTION: FRICTION TEST

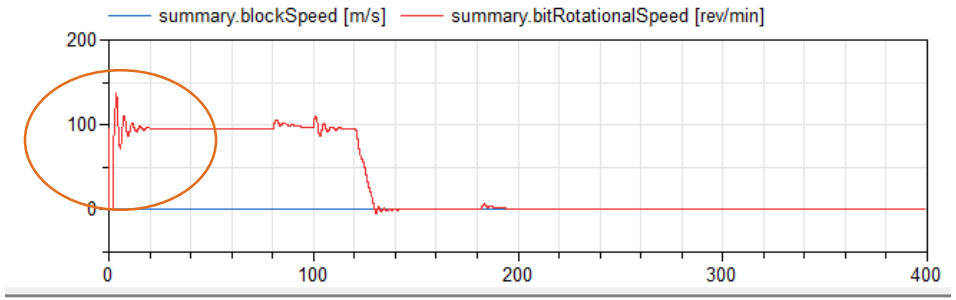
- Initially string is placed along annulus
- No contact between drill-bit and bottom
- No rotational windup.

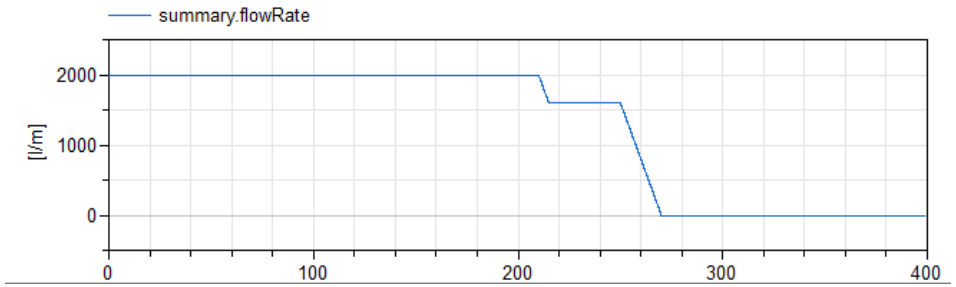
- Rotating drillstring (10rad/s)
- 0-80, Drill 2m
- 80-100 Drill off bottom
- 100-120 Pull up 3m
- 120-130 Stop rotation
- 180-210 Pull up 5m
- 220-250 Push down 5m

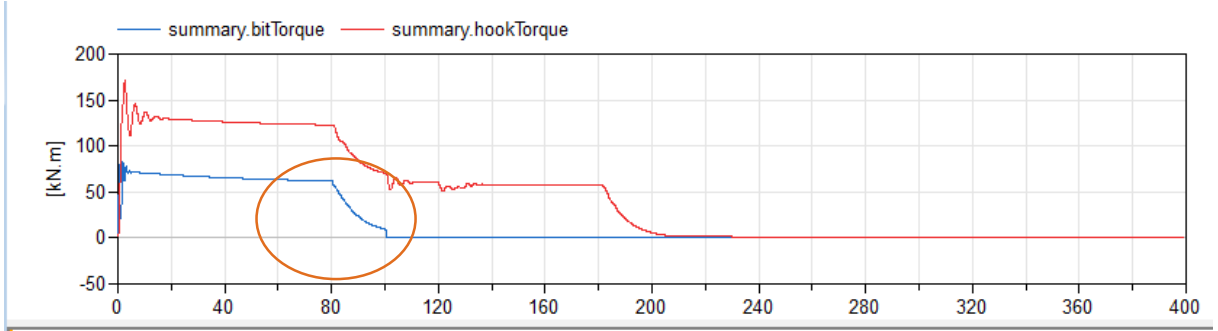


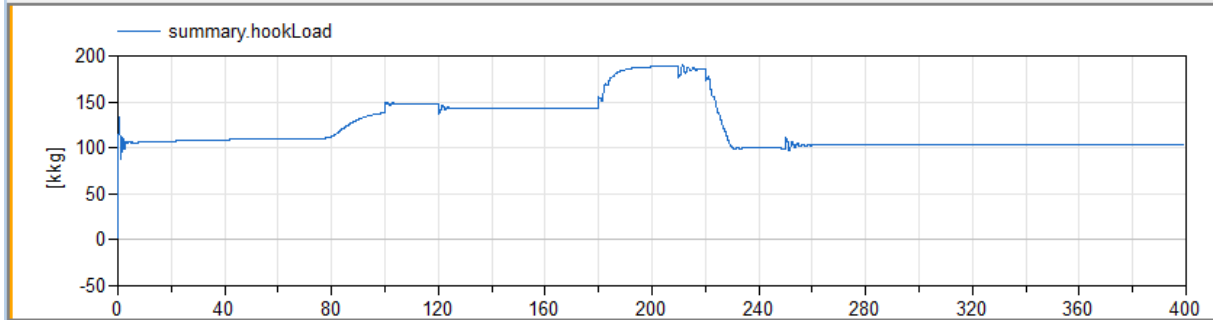
SIMULATION RESULTS

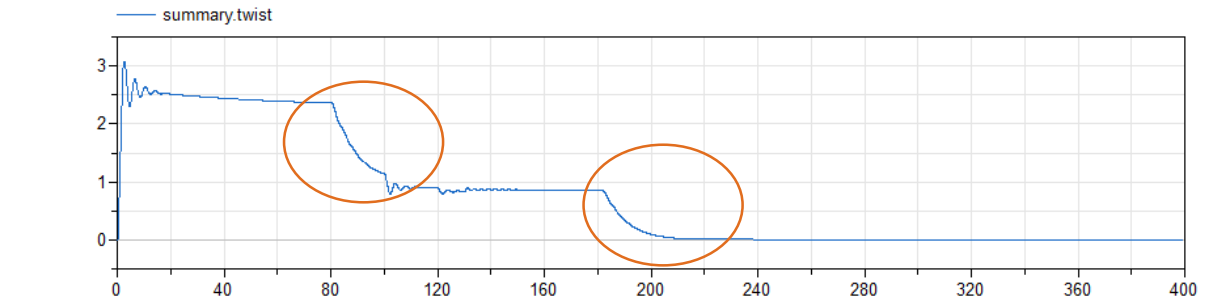












CONCLUSION

- Modelica library for well drilling simulation
- Fast and robust computations of the entire rig
  - Thermodynamics
  - Mechanics
- Suitable for
  - New technology dev, monitoring, control
- Library development driven by customer needs
- General & versatile framework
- Easily extensible for other analyses and applications

Industrial partners for library development are welcome !