ConocoPhillips

The balanced plug:

Quality Improvement Project

October 2019

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Agenda

- Use of balanced plugs in drilling and P&A operations
- Refresher
  - CFD work
  - Rheology models
- Overview of ongoing improvement project
  - CFD model for the balanced plug
  - Fluids work
  - Potential field routine
- What we need
  - BHA

Introduction and refresher

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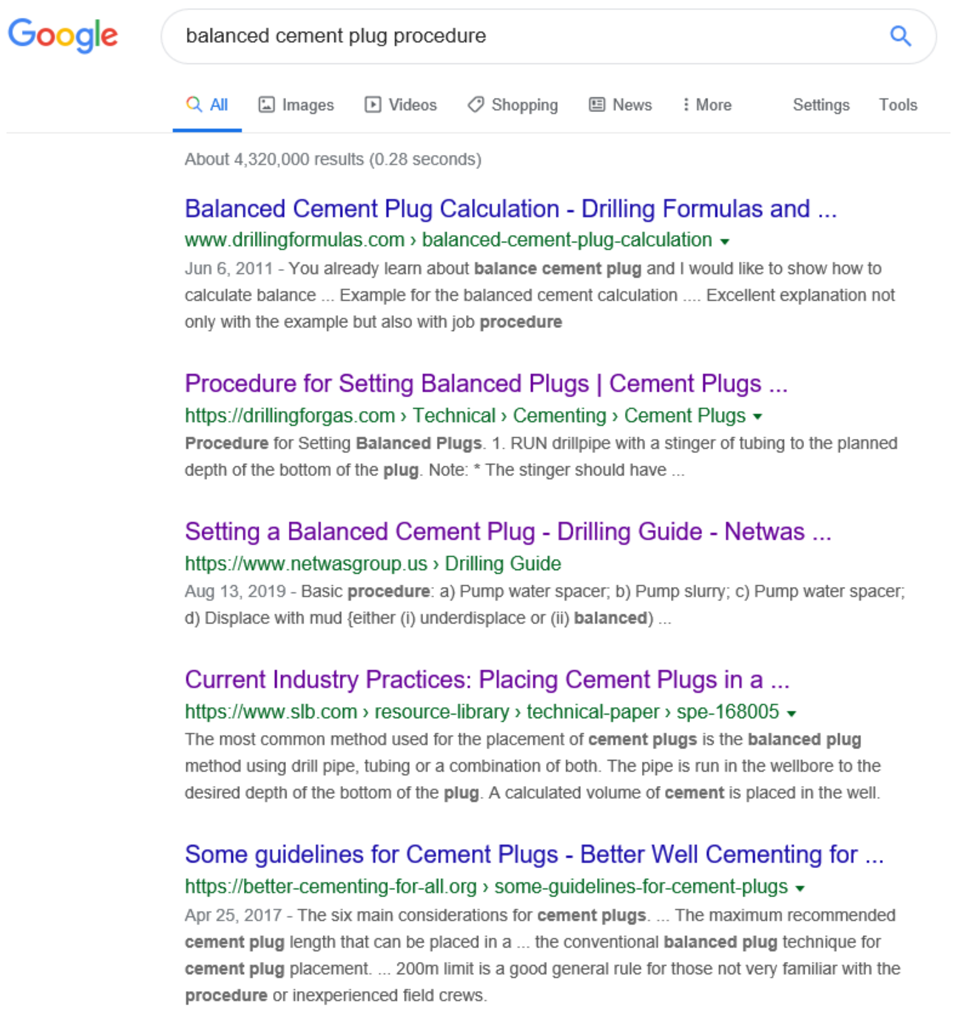
Use of balanced plugs

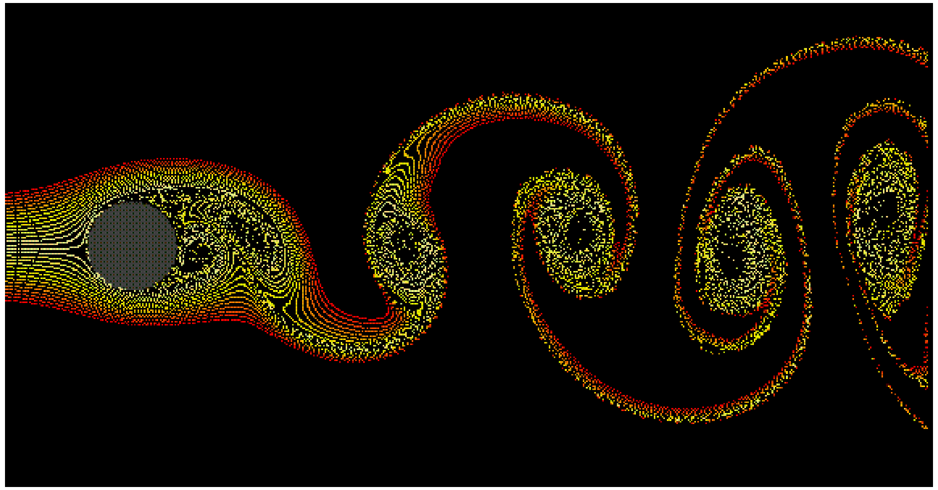
- Fill a dry hole
- Set a kick off plug
- Fundament (for something else)
- P&A of a casing where the casing by open hole has a existing Well Barrier Element
- Well known technique in the industry (illustrated right)
- **Project goal:** Set kick off plugs which require +/- 15 klbs average weight on bit to drill out (top part)

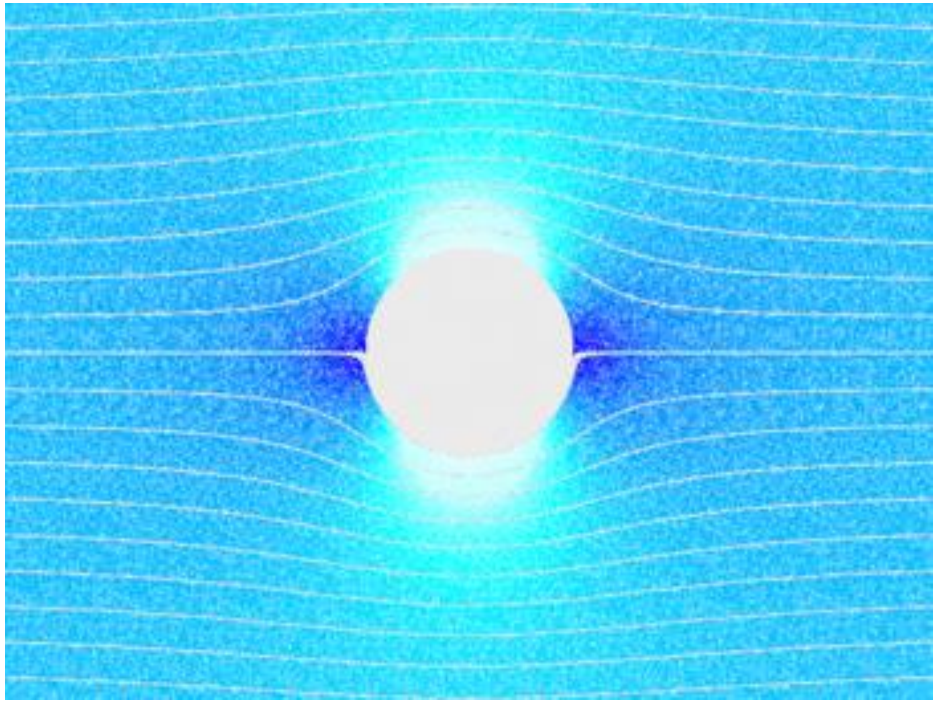


- Computational Fluid Dynamics = Numerical solution of fundamental equations of fluid motion to calculate velocity, pressure and other flow parameters of interest

- It is possible to consider multiple phases (e.g. gas and liquid), compressibility, non-Newtonian fluids, and other complex fluid properties

- Fundamental equations that CFD solves:
  - Continuity Equation (Conservation of Mass)
  - Navier-Stokes Equation (Conservation of Momentum)
  - Equation of State (Conservation of Energy)





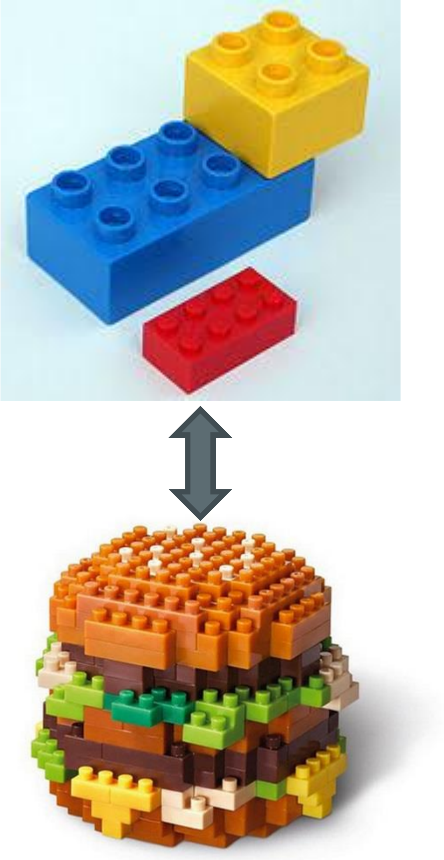
Refresher: Discretization Methods and Meshing used in CFD

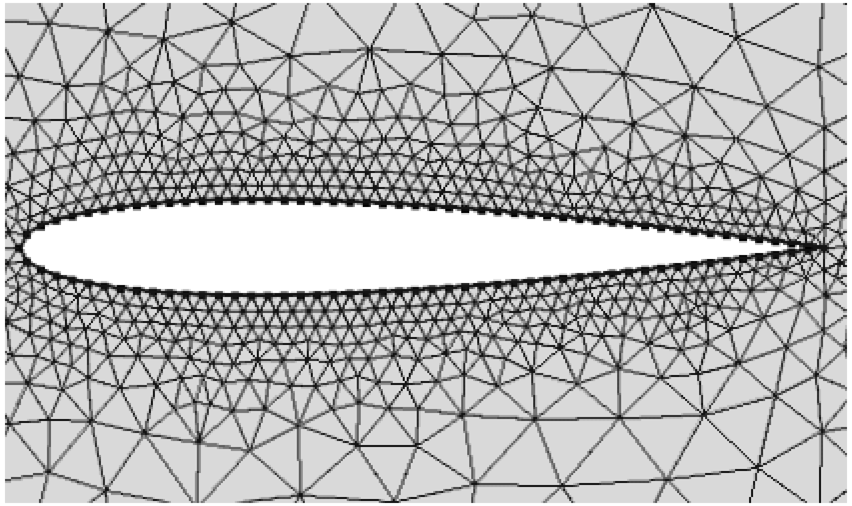
- Domain Discretization: Fluid domain is divided into a number of “cells” like pieces of Lego. They could range from thousands of cells to millions

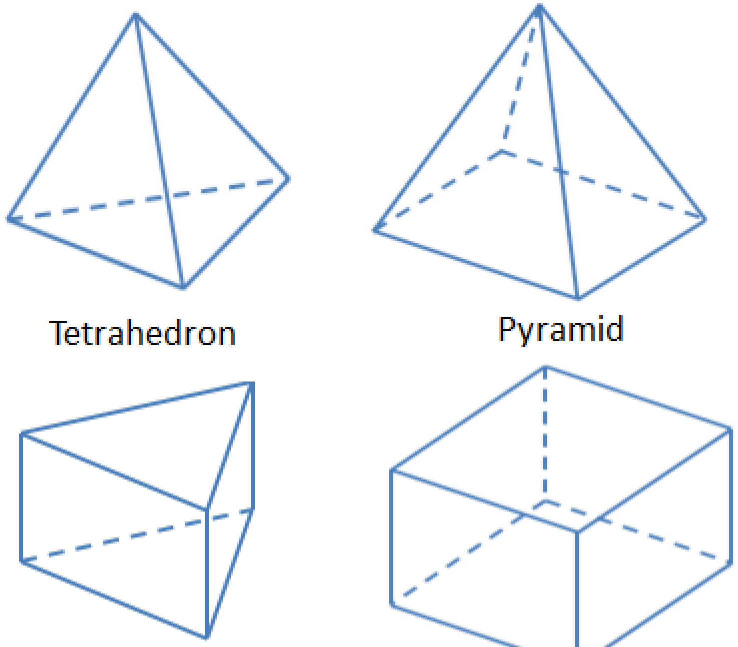
- Finer mesh (cells) in critical areas and coarser mesh in non-critical areas greatly improve computational efficiency

- There several discretization methods available
  - Finite Volume Method
  - Finite Element Method
  - Boundary element Method
  - Finite Difference Method

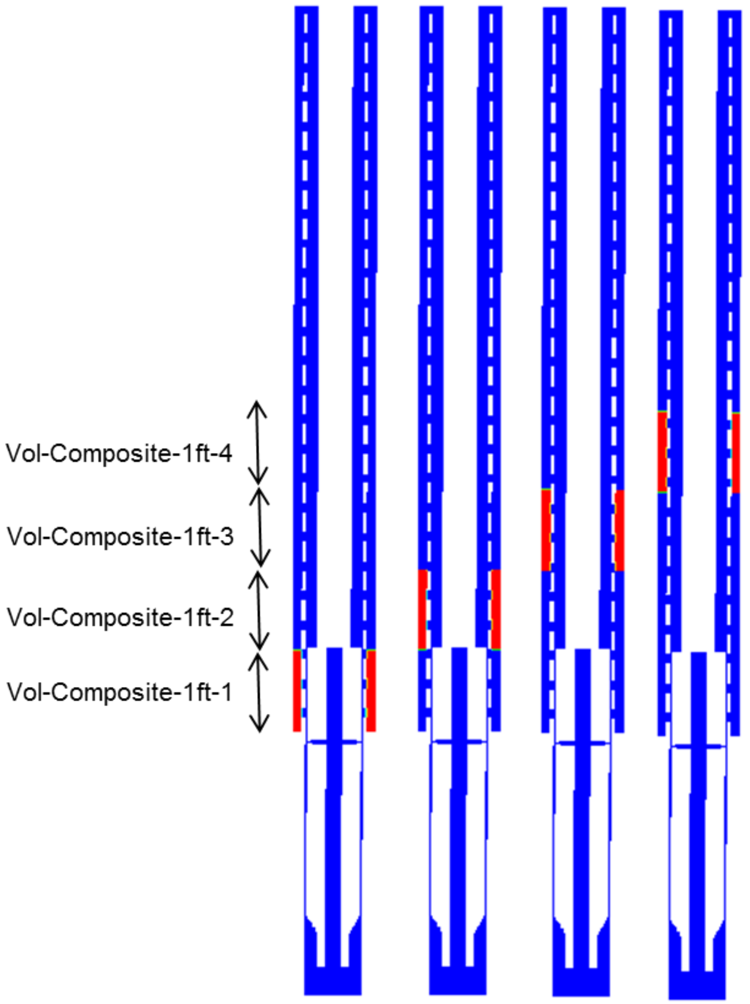
- Finite Volume Method is commonly used in CFD
  - Popular cell shapes are tetrahedron, hexahedron, Pyramid or similar

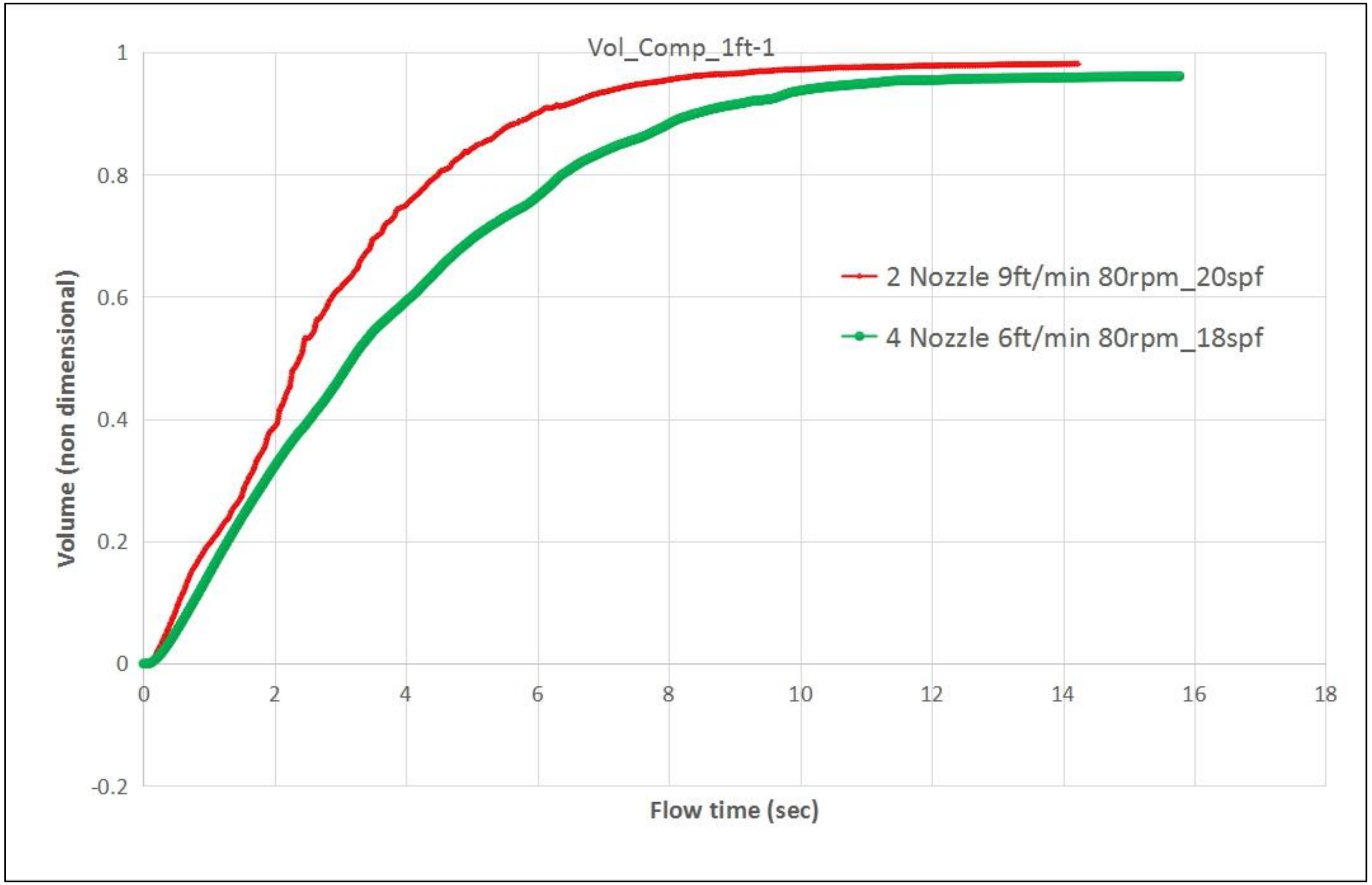




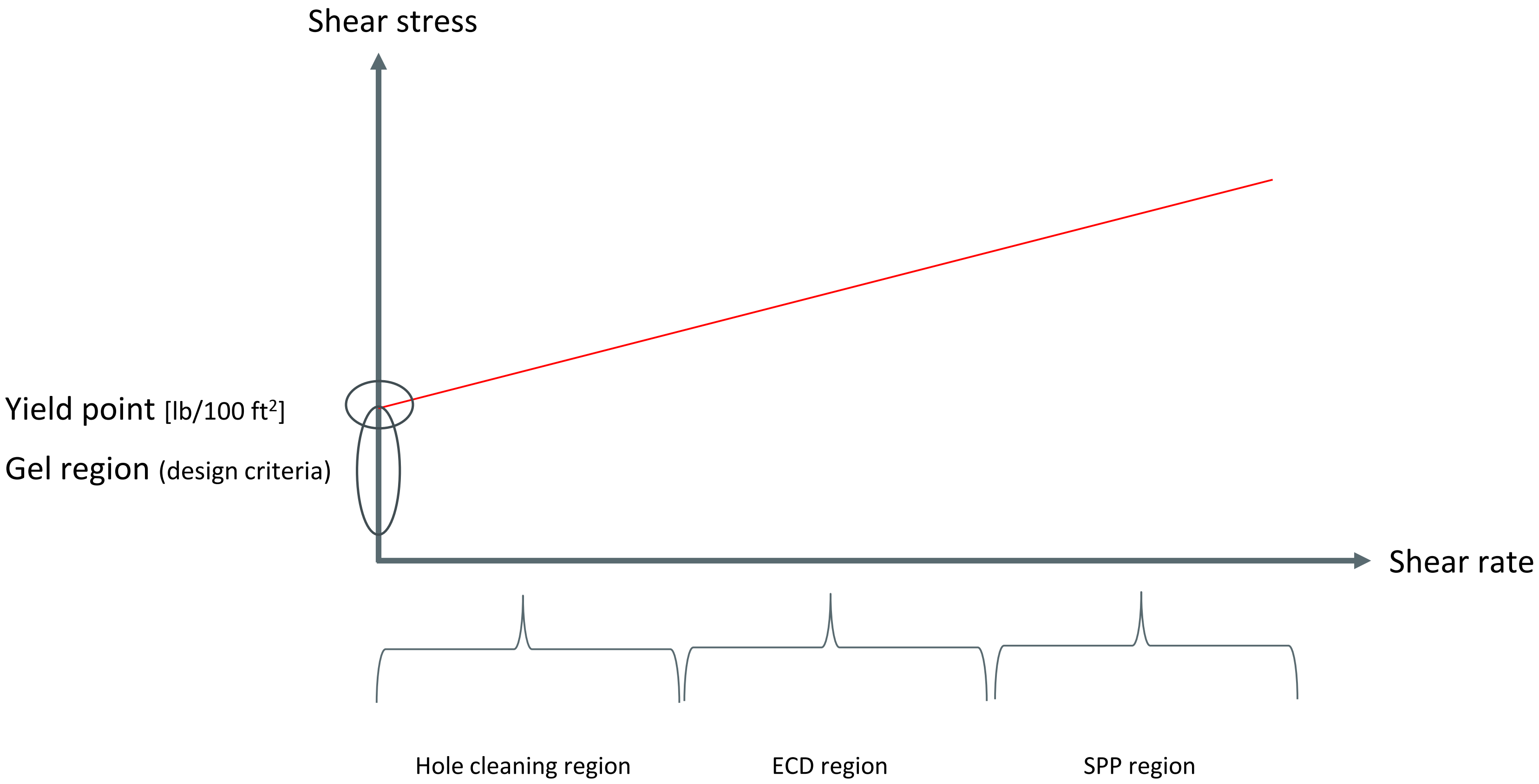


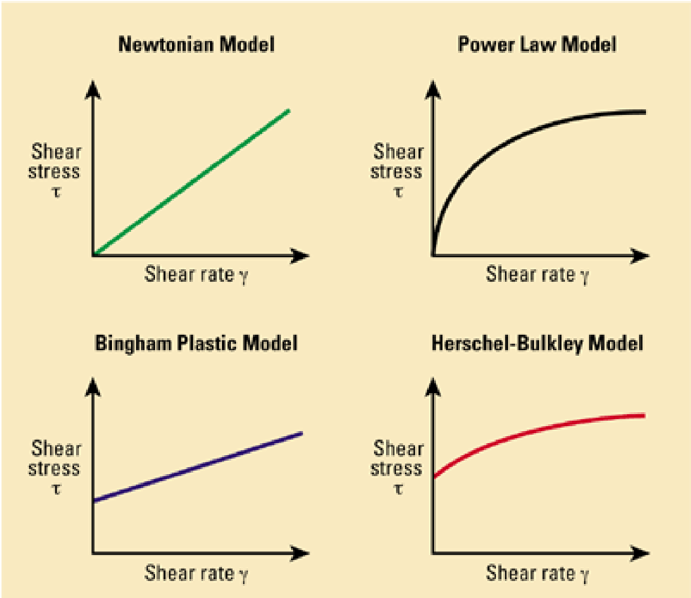
Refresher: Cementing in a P/W/C operation, pump/pull/rotate





Refresher – rheology models





https://www.glossary.oilfield.slb.com/en/Terms/h/herschel-bulkley_fluid.aspx

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Ongoing project

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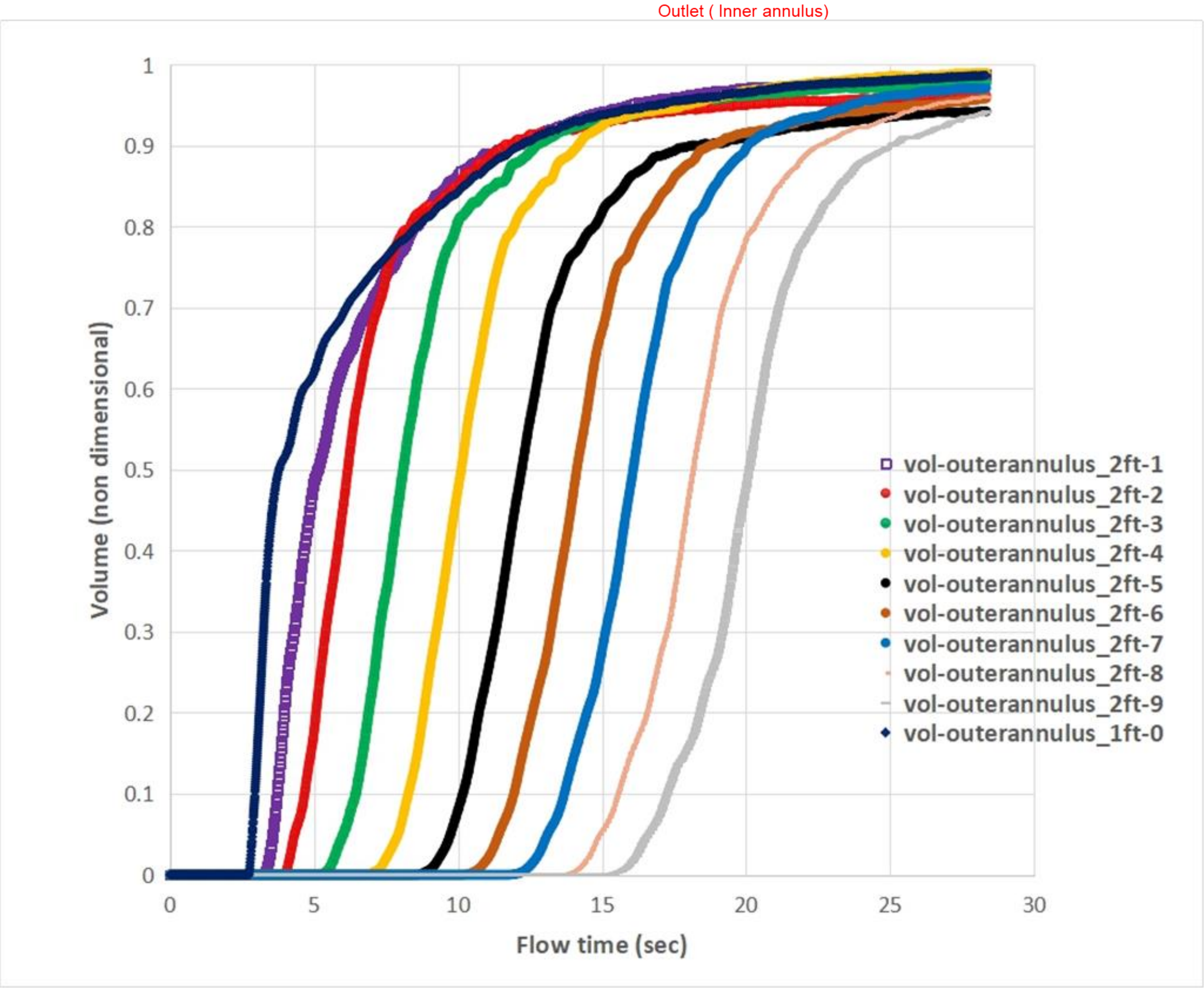
Project outline

- Done:
  - Pull and review best practice from COP globally
  - Ensured we worked accordingly and mapped GEA balanced plug operations from mid 2018
  - Outlined CFD model
  - Done initial CFD work
  - Modified CFD model – fluids input
  - Done a cross check to drilling based hole cleaning models

- Ongoing or to do
  - CFD based parametric optimization with open ended drillpipe
  - Select BHA
  - Input BHA into CFD model and do final parametric optimization

First case which was modelled in CFD

- 20 ft long
- Investigated first 18 ft, segmented into 9 x 2 ft
- Fluids:
  - 15 ppg water based spacer
  - 14.5 ppg OBM
- Displacement rate
  - 420 gpm
- 5 7/8'' pipe, static and low side, inside a 14 2/9'' slick hole
- Conclusion:
  - Simulation result or experience data is wrong



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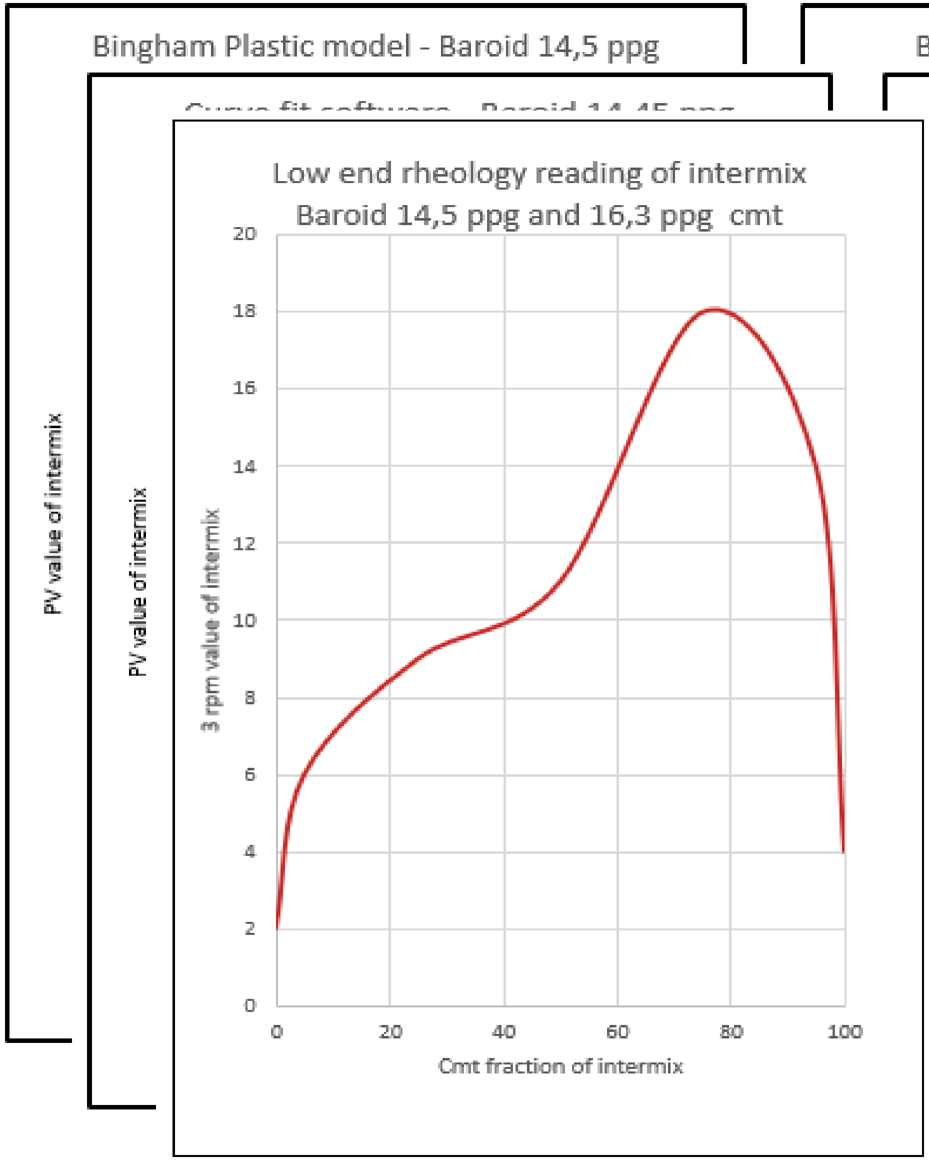
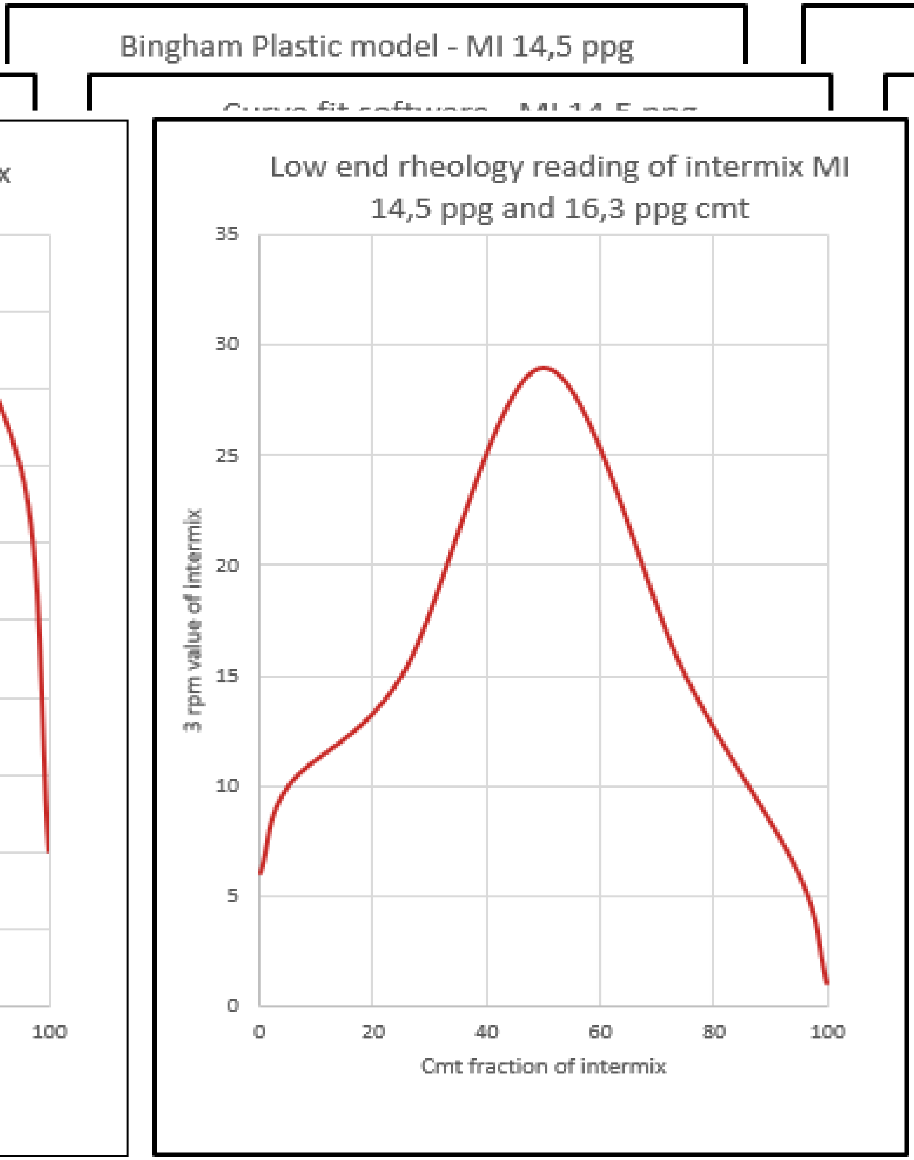
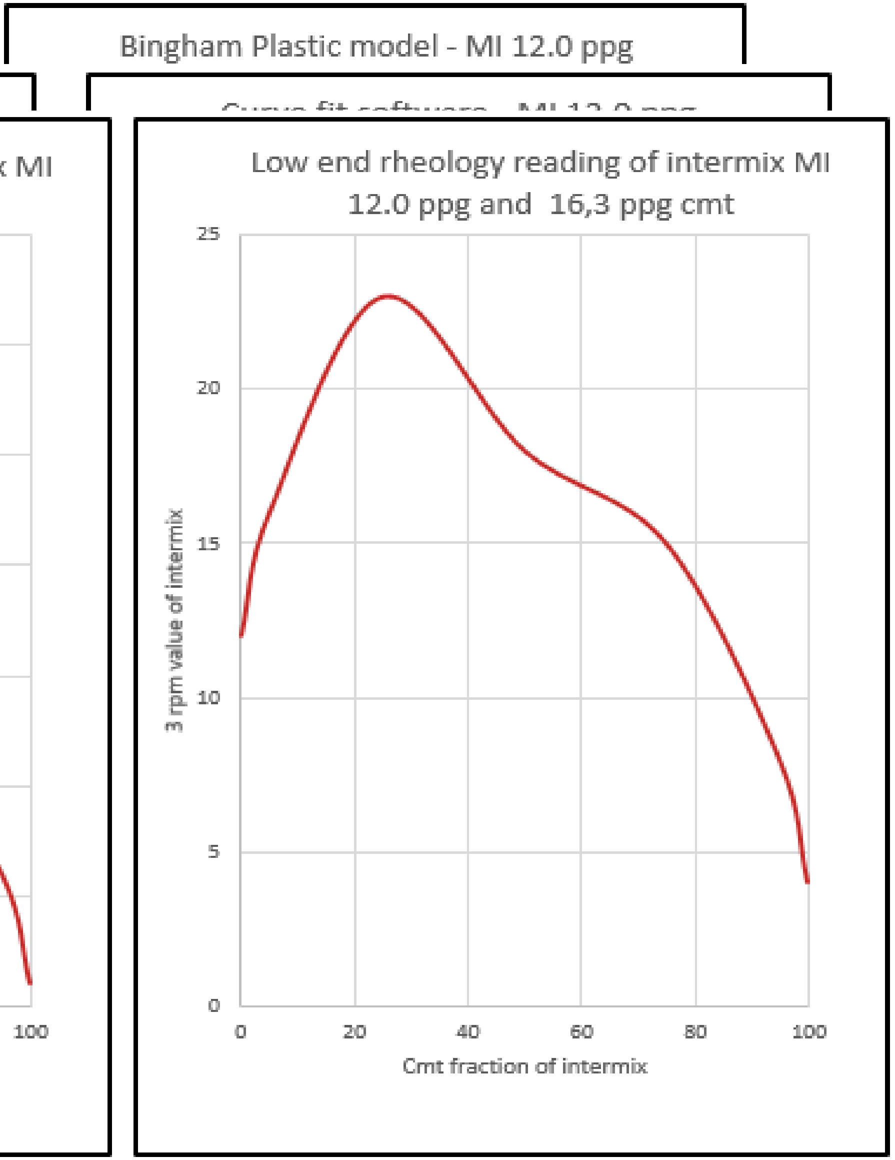
Balanced Plug CFD model – introduced intermix viscosity (WBM vs cmt)







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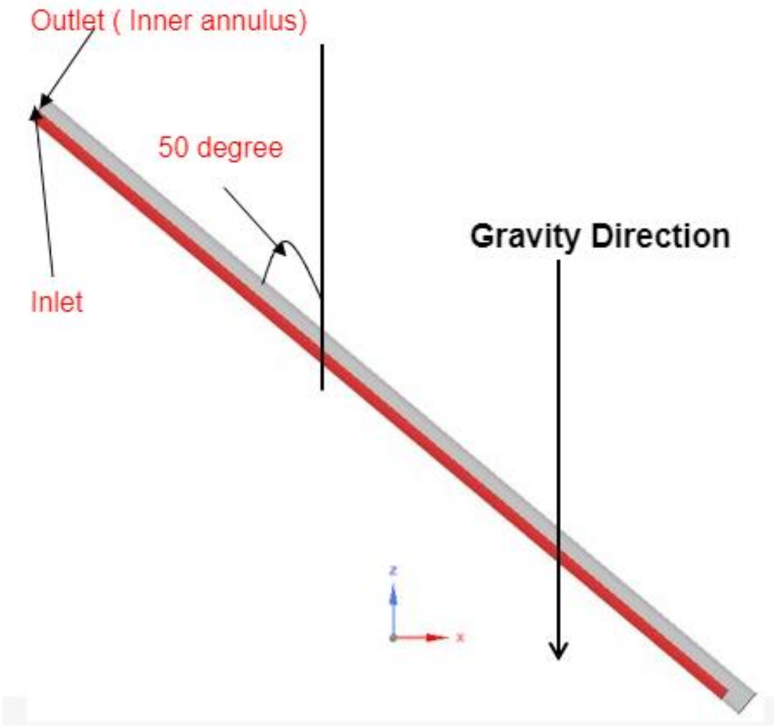
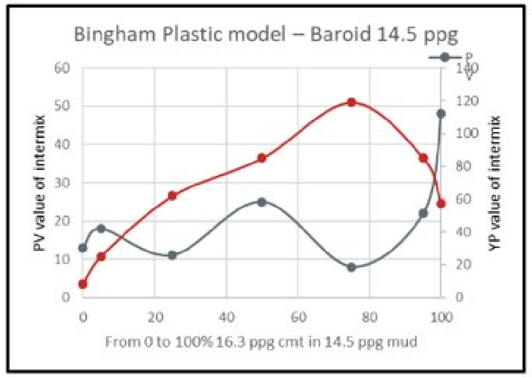
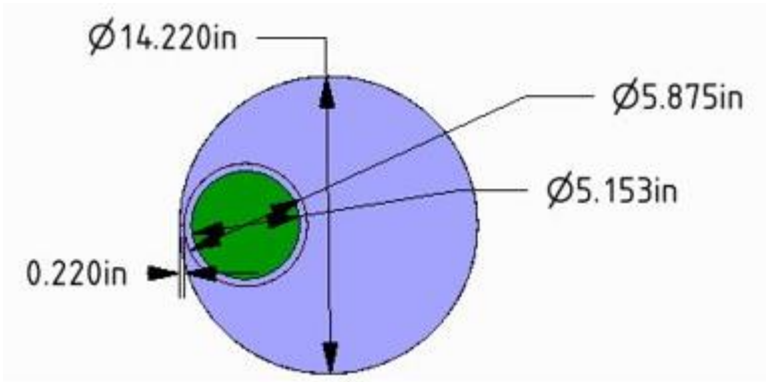
Input cmt/WBM intermix YP

- Model is 60 ft long
- Investigated first 40 ft, segmented into 20 x 2 ft
- Staring point: pipe static and low side
- Hole
  - 13 ½'' washed out to 14 2/9'' (reflects 30% excess)
- Fluids:
  - 16.1 ppg cement
  - 14.5 ppg WBM
  - Intermix of cmt and WBM
- Displacement rate
  - 420 gpm

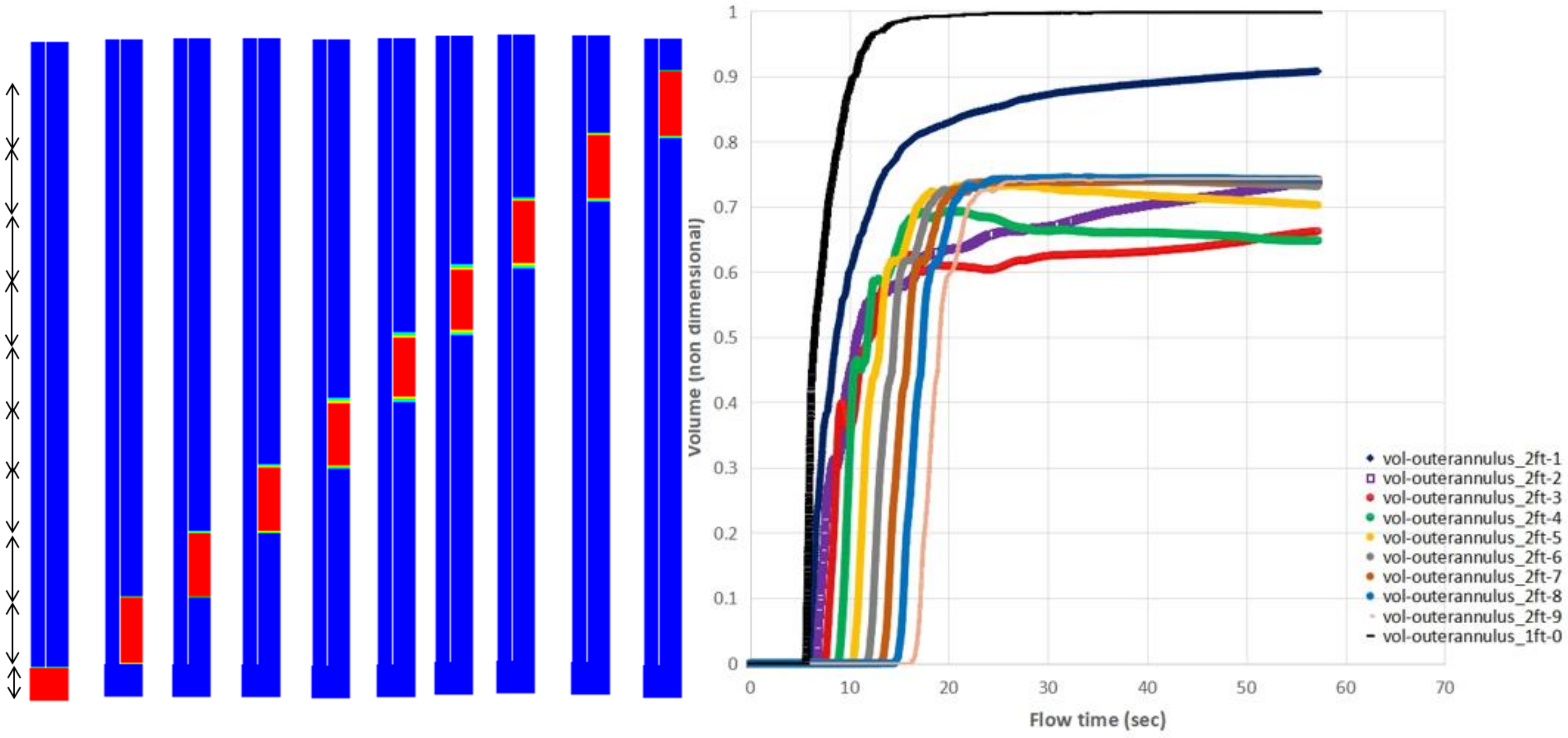




Fluids	MW	Viscosity (Bingham Plastic)	
	Density (ppg)	PV (cp)	YP (lbs/100ft2)
Cement	16.30	48.00	59.00
High viscosity intermix (75%C and 25%M)	15.85	9.00	119.00



Use of cmt/WBM intermix YP in the CFD model changed the picture



5 7/8'' DP, 1 ft standoff, looking at first 9 x 2 ft – which indicates 420 gpm is sub optimal, we get channeling

Time out:

- Decided to do a "drilling check"
- Does current model reflect drilling experience?

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The Drilling Check, standard hole cleaning simulation

- Case – September 2019 drilling operation
  - Drilling 9 1/2'' x 10 3/4 hole under 10 3/4'' liner
  - Assumed hole size 10 8/9'' (reflects 30% excess cmt) to cover for washout
  - Assumed 180 ft/hr ROP
  - Used standard P&A WBM (this is what we have intermix data on)
  - Assumed no chemical interaction (viscosity effects) between mud and cuttings
  - Cuttings density set to 2.1 SG, for reference cmt is +/- 1,9 SG
  - Checked w/ various DP sizes, open ended

- Output
  - Illustrations
  - ''Transport efficiency'' (TE) and annular velocity
  - Selected a target criteria
    - Transport efficiency > 80%
    - Annular velocity > 180 ft/min

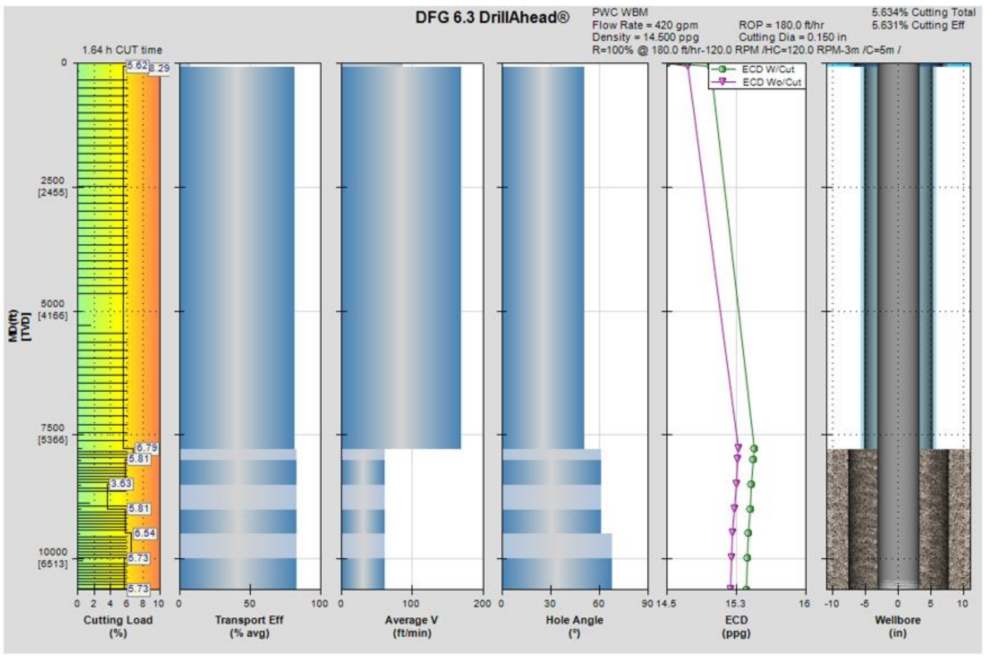
- **Conclusion from ''hole cleaning simulation''**
  - We should challenge the use of stinger in our parametric optimization work

- **CFD model indicates string out/channeling**
  - Observed? (yes)

- **Discussed gels**
  - model? (not)

- **Discussed based on reference operations**
  - Reference operation 1 in a 7,25'' hole, 850 ft long
  - Reference operation 2 in a 13 ½'' open hole and into 13 5/8 csg, 1160 ft long
  - Required plug length?
  - Maximum cement volume?

Flow rate 420, RPM 120



DP size	Transport efficiency criteria	Annular velocity criteria, flow rates < 170 – 420> gpm
6 5/8''	OK for > 120 rpm	Approach criteria for 420 gpm
5 7/8''	OK for > 120 rpm	Below criteria
5''	OK for > 120 rpm	Significantly below criteria
3 ½''	OK for > 120 rpm	Significantly below criteria

Time in:

- What can we do?

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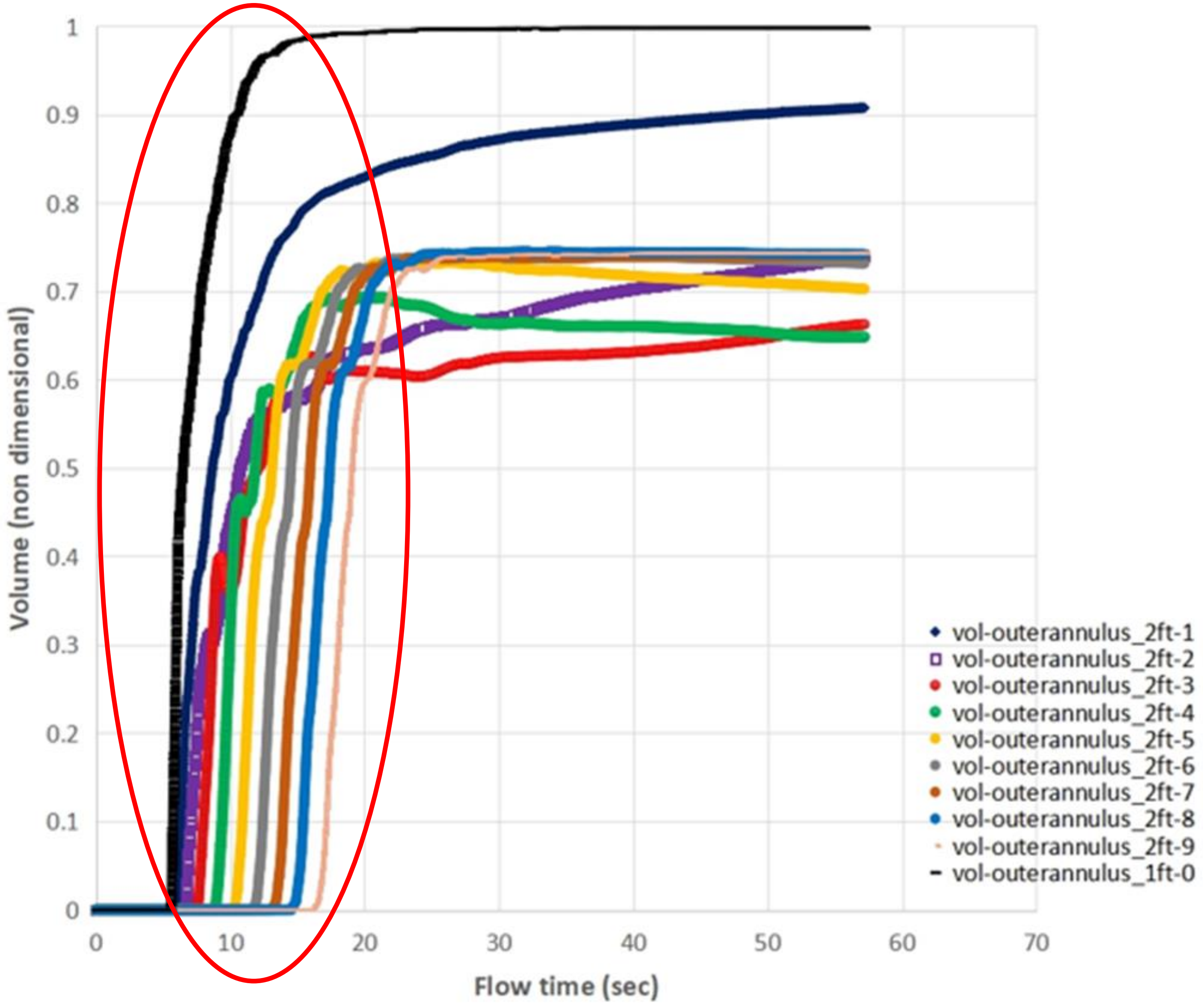
Potential field routine

- Pump, pull and rotate
- Parametric optimization ongoing
  - Fluids
    - WBM case
    - OBM case
  - Pump rates
  - String rotation
  - Cmt volume/translation speed
  - String size
  - Use of string mill/centralizer/similar
- Need displacement rate in the outlet region to be > pulling rate for this to be successful
- Hope to try this sometime 2020



Need

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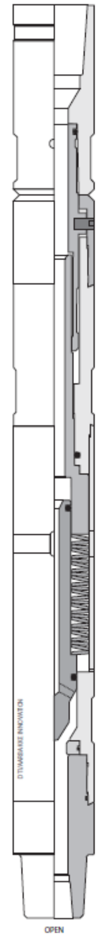
Need

- BHA
  - Bull nose
  - Spring loaded float (anti U-tube)
  - Float
  - Stabilizer/centralizer/scrape

- Practical
  - BHA is plug and play and will go offshore in 1 basket
  - Most likely assembled from existing components
  - Standard DP connection
  - On stand by, or stored offshore
  - Sturdy
  - Re-dress routine/service

- Suggested reading
  - Published Best Practice for balanced plug (google it)
  - SPE 184702 (cmt displacement and CFD work)
  - COP 2014/2017 presentation (P/W/C)
  - Halliburton/Baroid 2018 PAF presentation (cmt vs WBM)



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Q&A