MATLAB Controller Linked to an ANSYS Structural Model for Directional Drilling

Controller Development

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Outline

- Introduction
  - Directional drilling
  - Slide drilling & associated challenges
- Control algorithm development strategy
  - Complexities of plant (drill string) model
  - MATLAB controller linked to external plant model
- Steps to execute MATLAB to ANSYS linkage
- Example Problem
- Summary

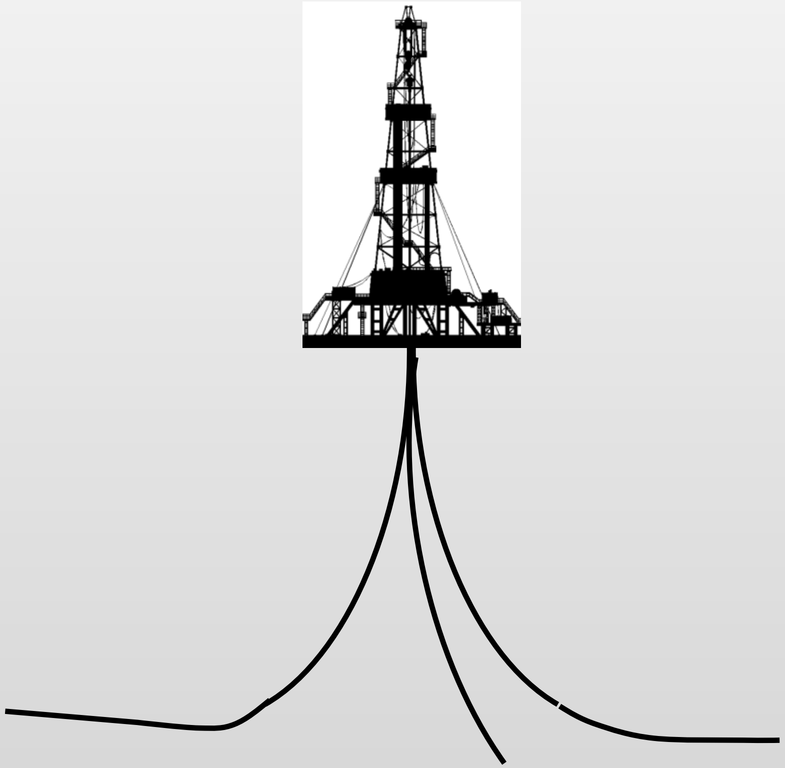
Introduction

- Directional drilling involves creating non-vertical wellbores, benefits include:
  - Multiple holes from same location
  - Reach otherwise inaccessible locations
  - Increase exposure to formation

- Directional drilling can be done in sliding mode using downhole mud motors and bent housing

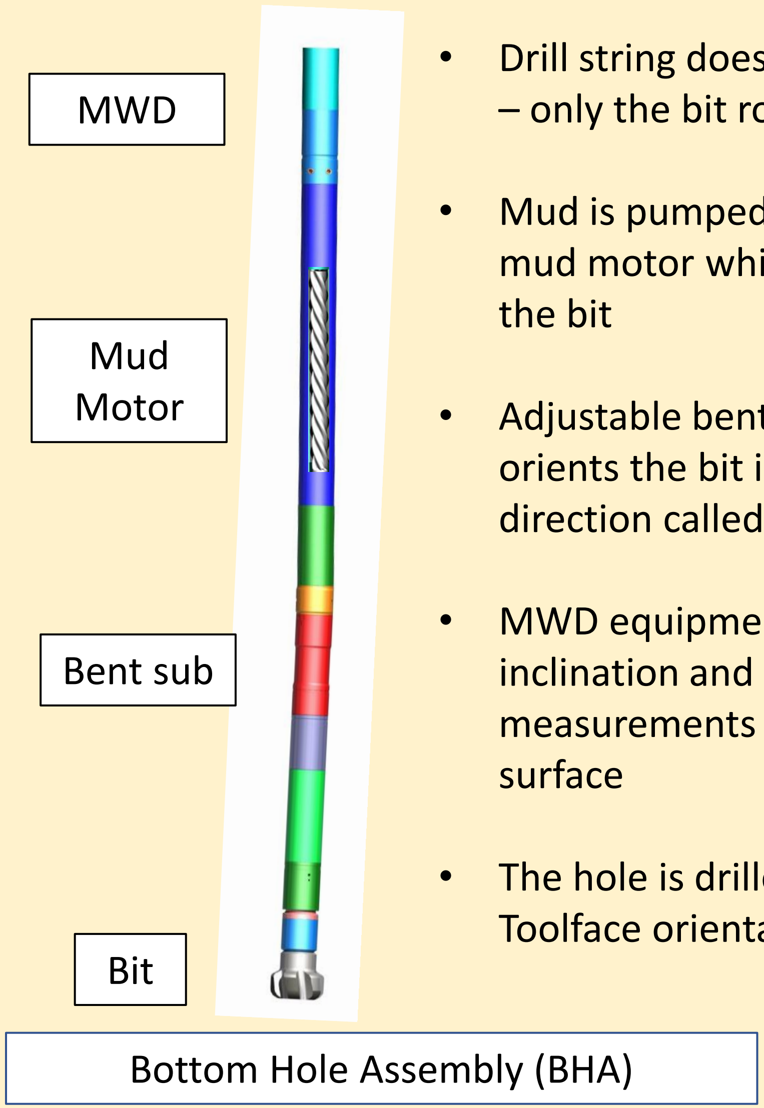
- During slide drilling, maintaining orientation and sustaining desired Rate of Penetration (ROP) is challenging

- Incorporation of automation in the slide drilling process could lead to significant advantages including:
  - Increased ROP
  - Improved wellbore quality

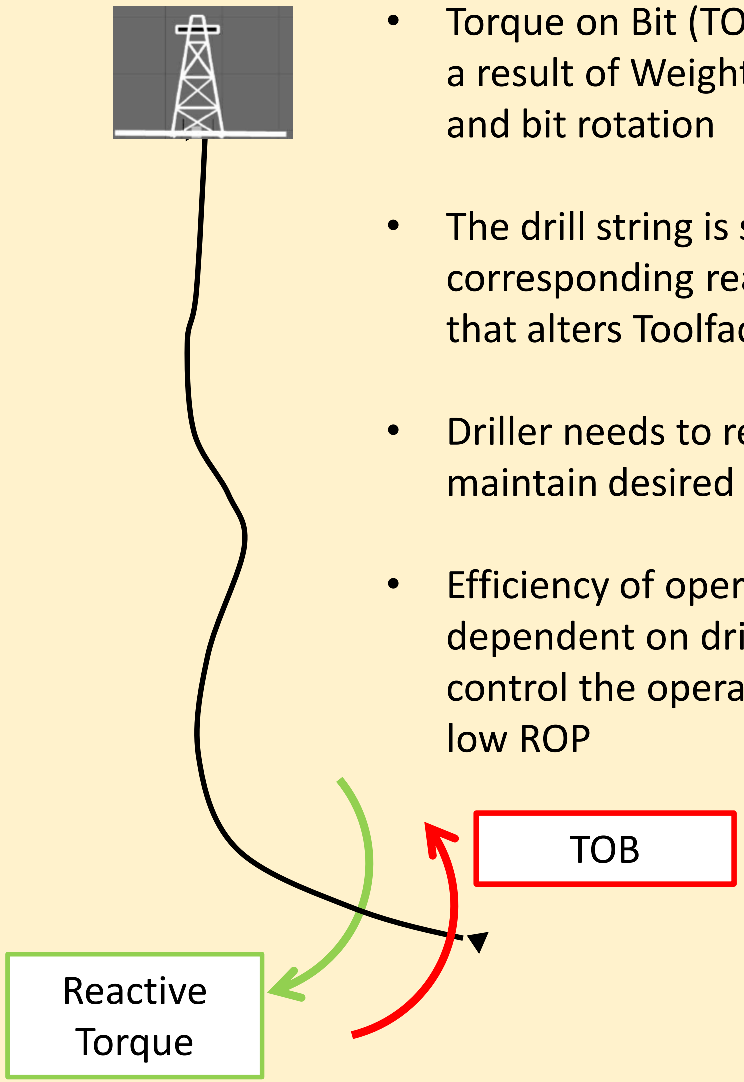


Directional Drilling

Sliding Operation



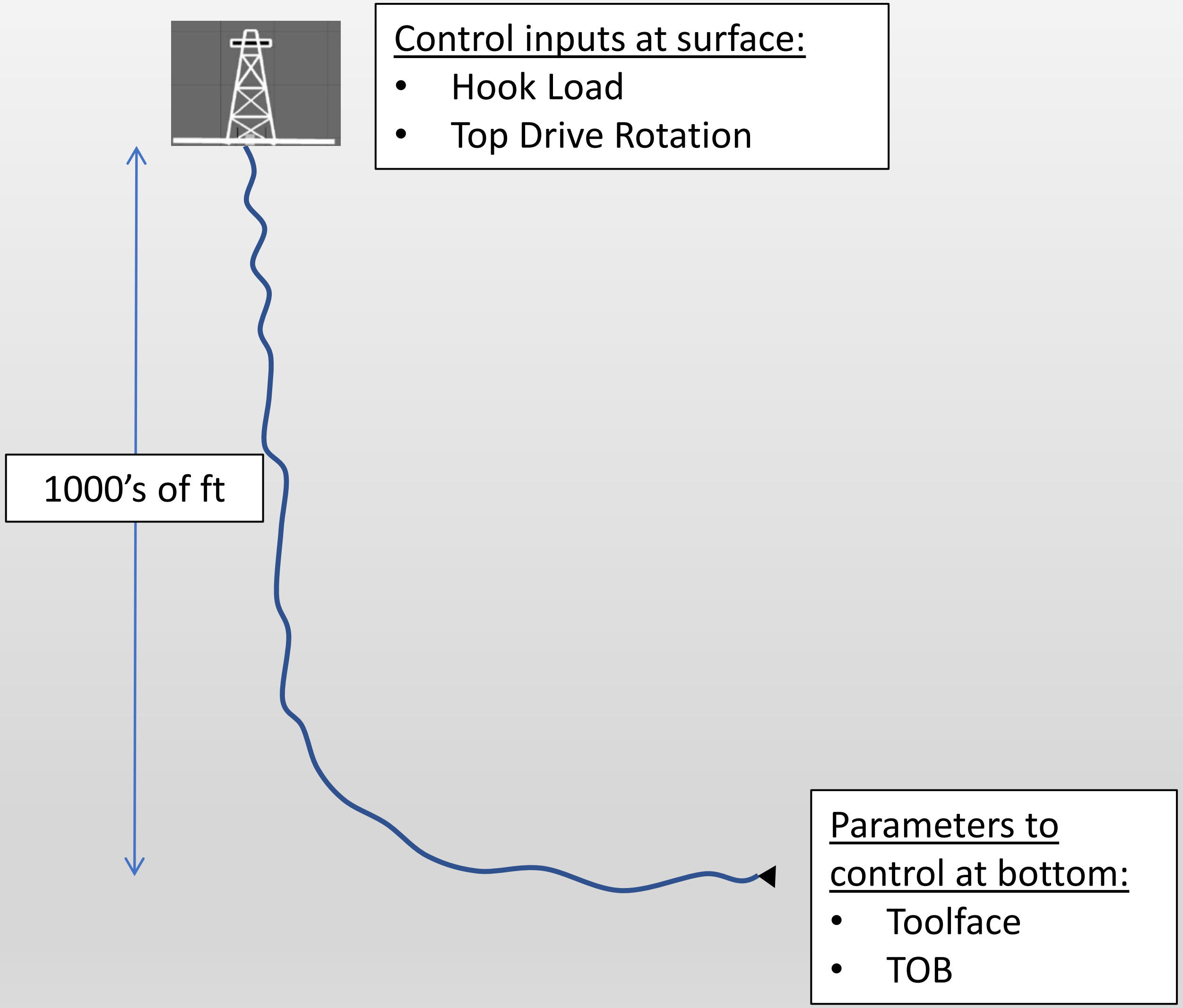
- Drill string does not rotate – only the bit rotates
- Mud is pumped to the mud motor which rotates the bit
- Adjustable bent sub orients the bit in a specific direction called Toolface
- MWD equipment sends inclination and azimuth measurements to the surface
- The hole is drilled along Toolface orientation



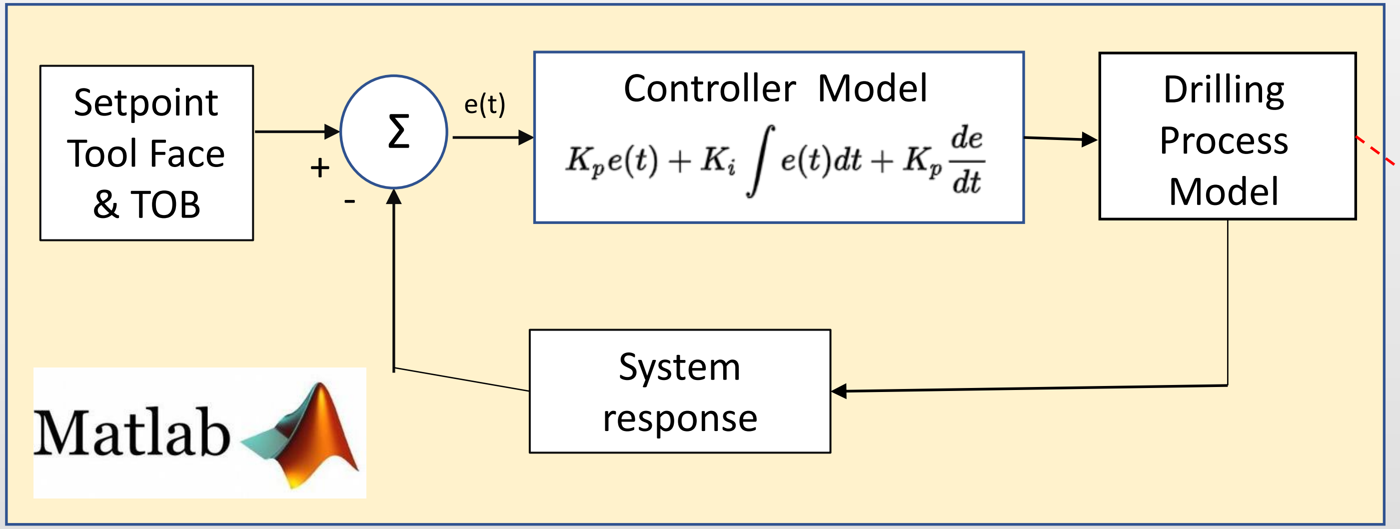
- Torque on Bit (TOB) is generated as a result of Weight on Bit (WOB) and bit rotation
- The drill string is subject to a corresponding reaction torque that alters Toolface
- Driller needs to reorient the bit to maintain desired trajectory
- Efficiency of operation is dependent on driller abilities to control the operation resulting in low ROP

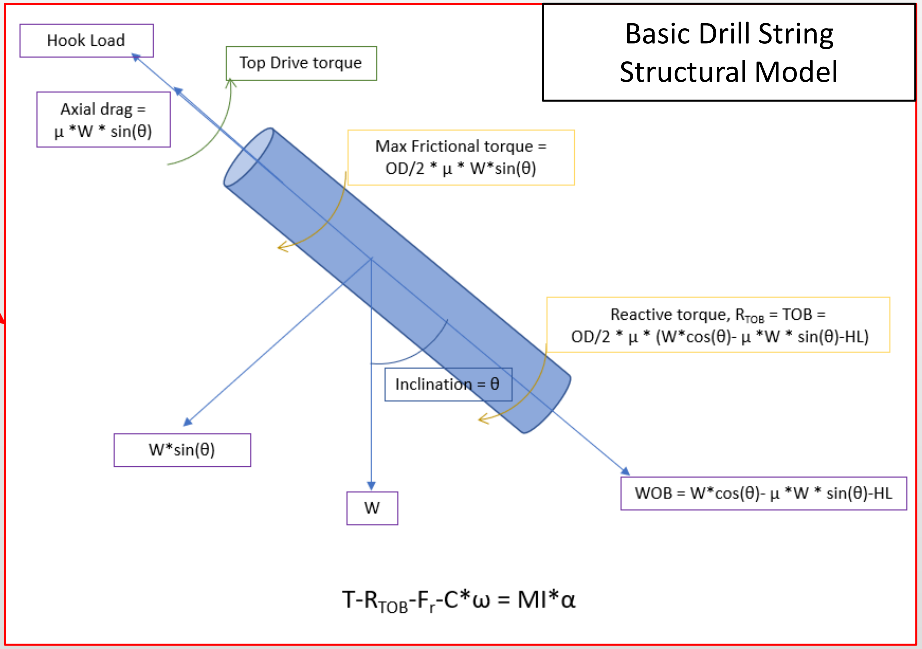
Sliding Operation Automation Challenges

- Drill string behavior is complex:
  - Length & flexibility of drill string
  - Wellbore friction
- Constantly changing conditions:
  - Geological formations
  - Wellbore geometry as drilling progresses
  - Forces like WOB, drag etc.
  - Every well is different
- Limited and sometimes missing measurement information
- Time delays in information transfer from downhole



Sliding Operation Control Algorithm Development

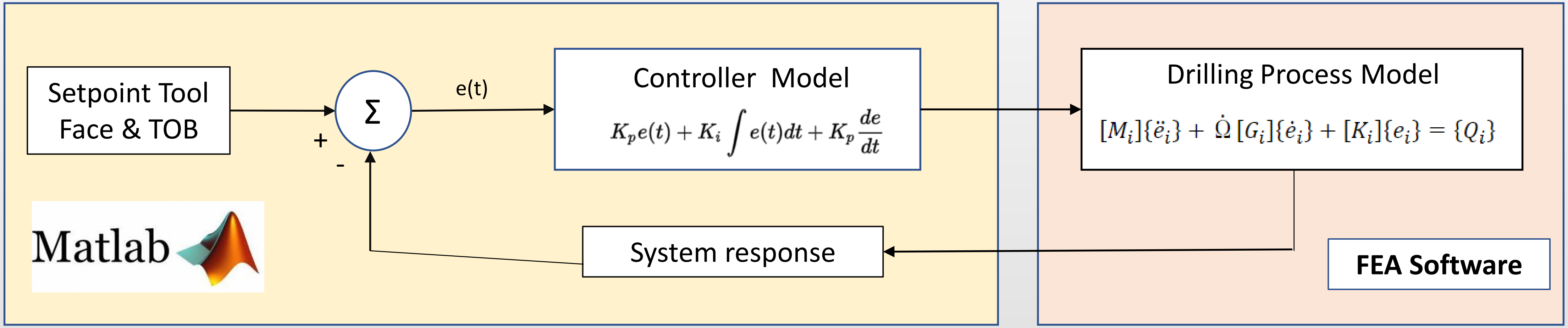




- Traditional control is one of the methods evaluated for sliding automation, linking controller model to a drill string structural model in a feedback loop
- Entire loop including the controller and drilling process model is developed in the MATLAB environment

- Drilling process is highly nonlinear - realistic representation requires sophisticated models
- Physics underlying the drill string model increases in complexity for large and more realistic models
- Difficult to develop, maintain & upgrade

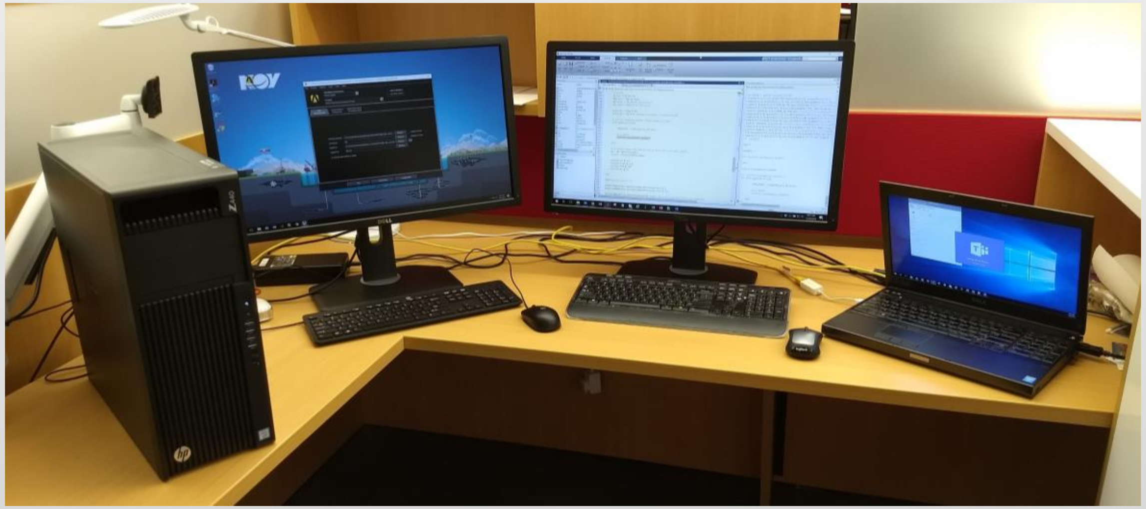
Sliding Operation Control Algorithm Development - MATLAB Linked to FEA Software



- Complexities associated with developing and maintaining the physics underlying of the drill string behavior can be reduced by using a Finite Element Analysis (FEA) Software like ANSYS
- Controller and rest of the loop can be maintained in the MATLAB environment
- Hybrid technique allows users to leverage the strengths of both software – MATLAB for the Control algorithm & commercial FEA software for structural model development

MATLAB & ANSYS Co-simulation

- ANSYS Mechanical APDL as a server (-aas mode) lets client applications connect and control running Ansys simulations
- ‘ANSYS aas MATLAB toolbox’ can be installed in MATLAB and used to execute the connection
- Commands in MATLAB script allows for:
    - Generation and execution of ANSYS commands
    - Transfer of results from ANSYS to MATLAB
- Using a separate computer as a server for running ANSYS also speeds up simulation time
- Same technique can be employed for other software like Fluent for simulating fluid systems

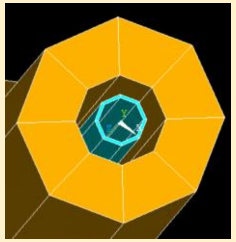


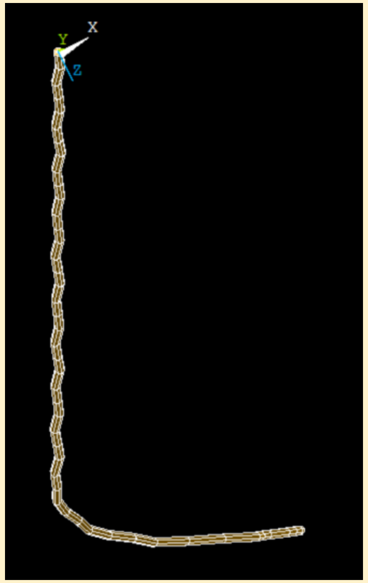
Example Problem

Ansys

ANSYS - Drilling String Model

Drill string within wellbore

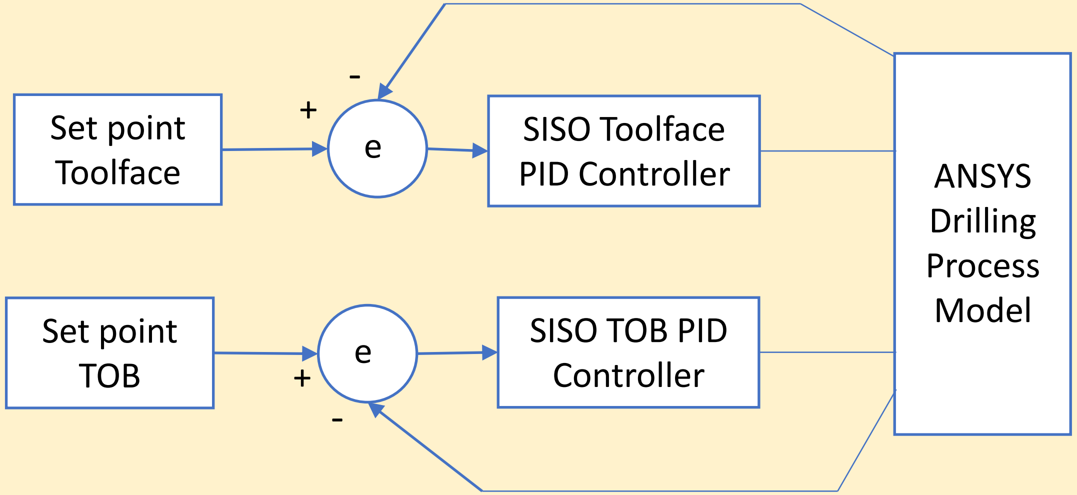




- The ANSYS drilling model is non-linear and dynamic in nature
- Key aspects of the model includes realistic representation of:
  - Wellbore friction
  - Wellbore tortuosity
  - Fluid interaction forces
  - Drilling progression
- MATLAB script used to generate ANSYS input file that creates the structural model by specifying parameters such as TVD, KOP, DLS, BHA configuration etc.

Matlab

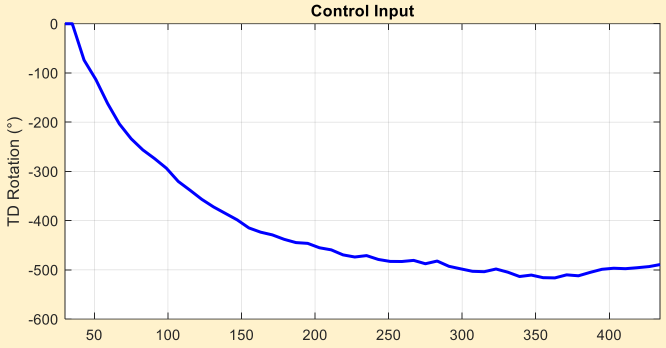
MATLAB - Basic Controller Model

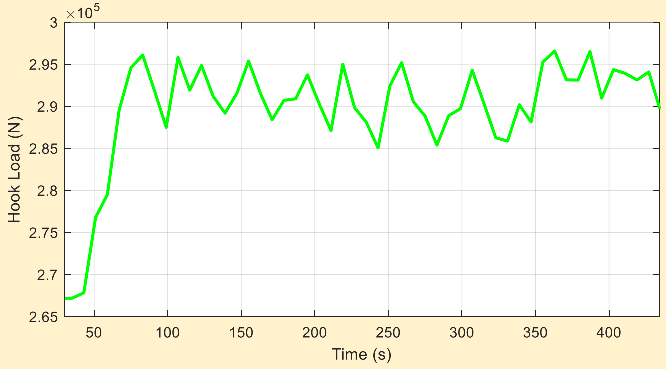


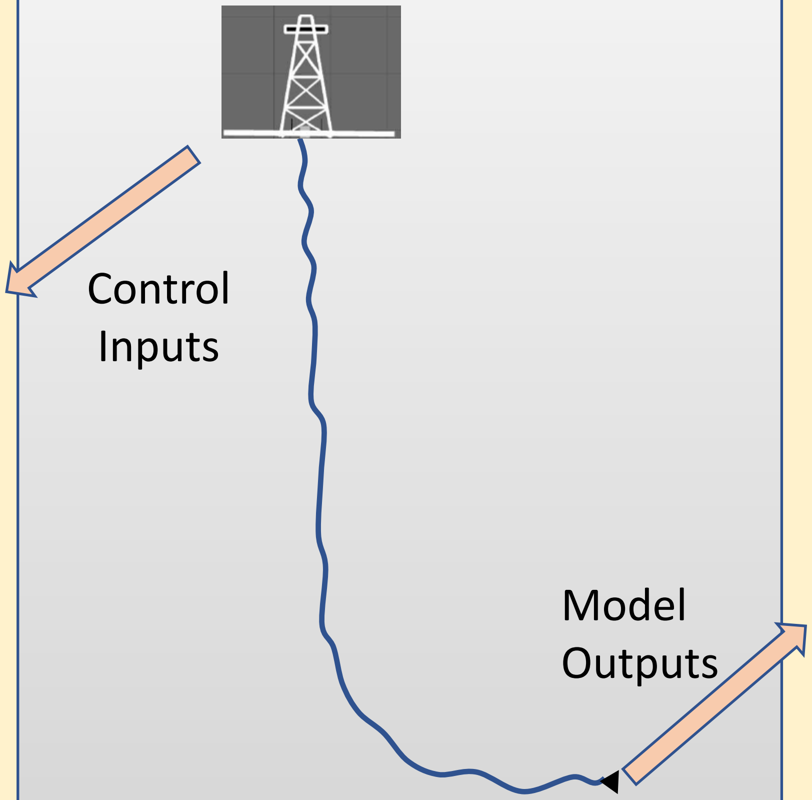
- Two separate SISO PID controllers were employed for TOB and Toolface control
- Time delay introduced into the loop to represent latency in downhole information transfer
- Multiple simulations performed to tune controller

Example Problem Results

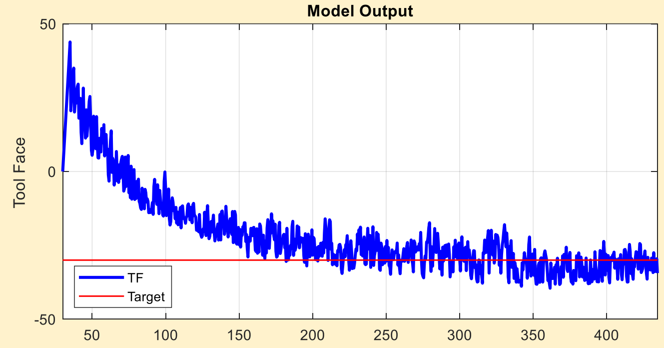
Top drive rotation and hook load adjusted by control algorithm

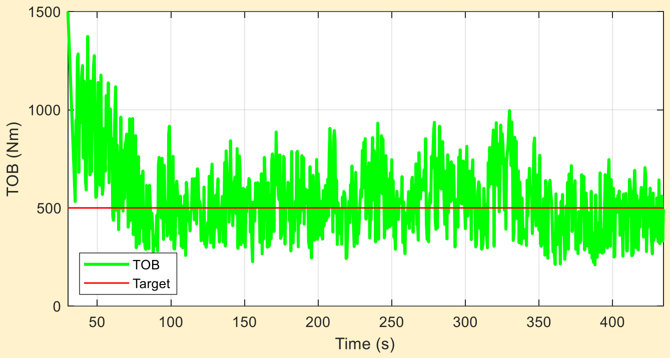






Toolface and TOB reaching and maintaining setpoint values





Example problem meant for demonstrating successful implementation of the discussed technique and may not represent a realistic scenario

Summary

- Powerful tools and sophisticated techniques are required to solve challenging drilling related control problems
- One approach to develop control algorithms requires realistic modeling of complex mechanical processes such as the drilling
- MATLAB controller was linked a realistic ANSYS FEA drilling process structural model
- MATLAB/ANSYS co-simulation technique was explored for slide drilling control algorithm development
- Hybrid technique allows users to leverage the strengths of both software and reduce computational times