Friction Stir Welding Control: Feasibility Study

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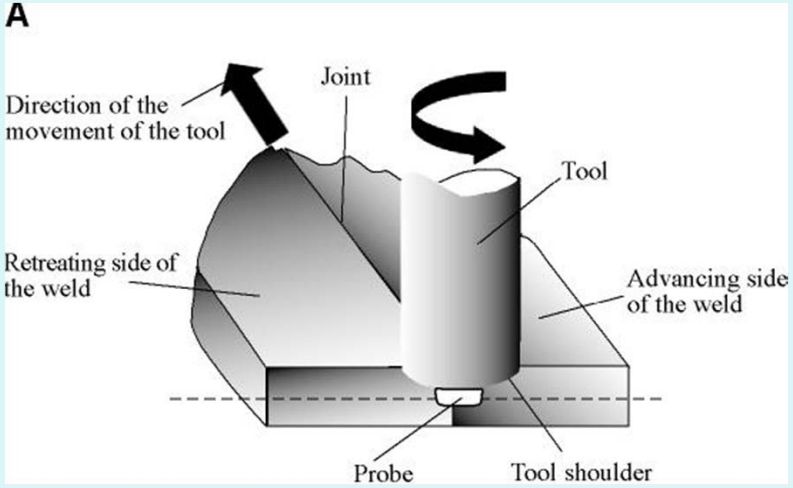
Friction Stir Welding Control Overview

- Friction Stir welding is a solid state metal joining process
- A rotating tool creates heat and plasticizes the metal. This allows the metal to be “stirred” around.



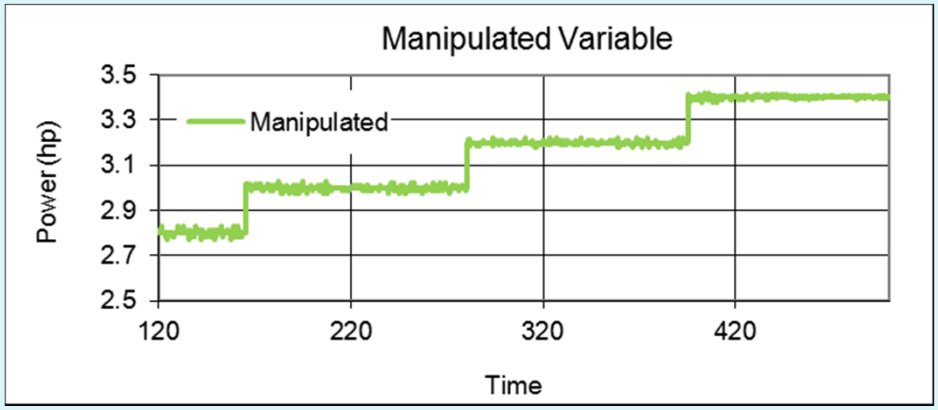
Friction Stir Welding Applications

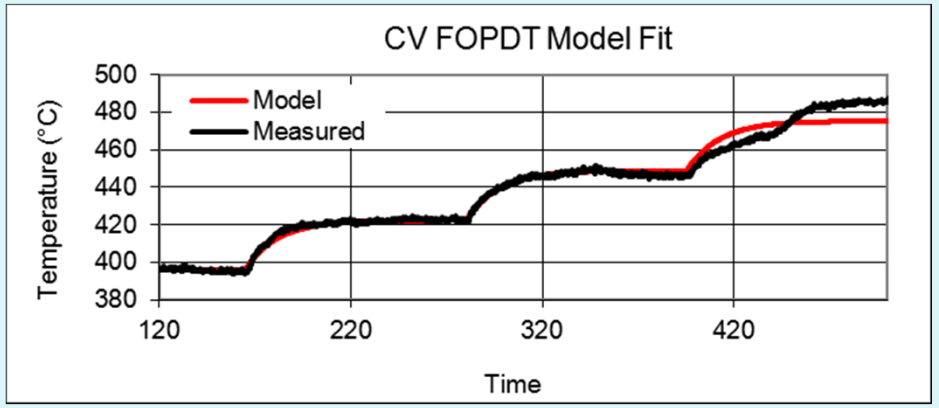
Feasibility Study Objectives

- Develop Simplified Model of FSW Process
  - PDE of Tool Heat Transfer
- Investigate feasibility of FSW model-based control
  - 2-3 weeks of effort
  - Explore feasibility through simulation
  - Compare model to run data
  - Demonstrate in simulation
    - PID (Proportional Integral Derivative Control)
    - MPC (Model Predictive Control)
  - Detail projected effort / costs to implement MPC
  - Develop implementation plan

FSW Process Model - FOPDT

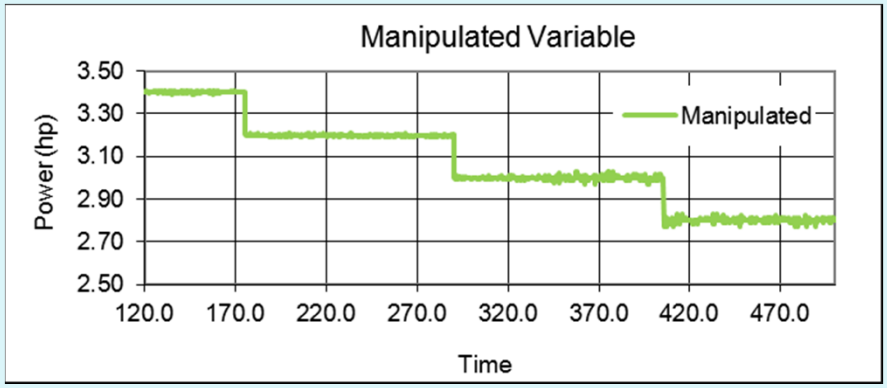
- Model #1 of FSW Process – Step Up in Power
  - First Order Plus Dead-Time (FOPDT) Model
  - Model predictions on same Aluminum data
  - Gain (K_p): 131.7 °C/hp
  - Time Constant (tau_p): 16.5 sec
  - Dead-time ($theta_p$): 1 sec

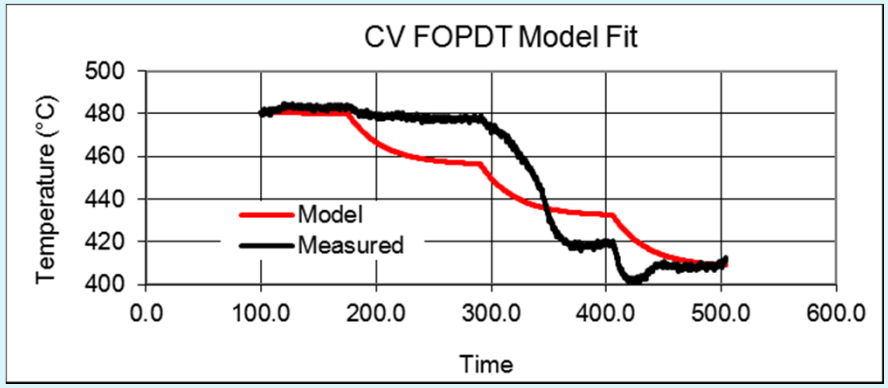




FSW Process Model - FOPDT

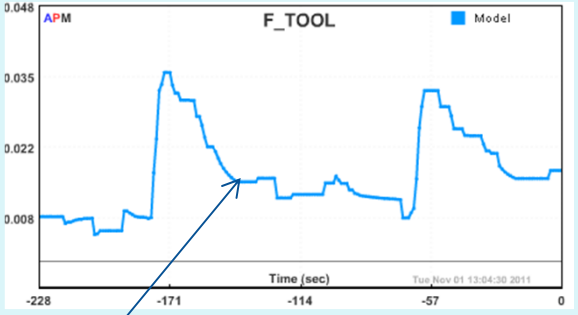
- Model #1 of FSW Process – Step Down in Power
  - First Order Plus Dead-Time (FOPDT) Model
  - Model predictions on same Aluminum data
  - Gain (K_p): 120 °C/hp
  - Time Constant (tau_p): 20-30 sec
  - Dead-time ($theta_p$): 1 sec

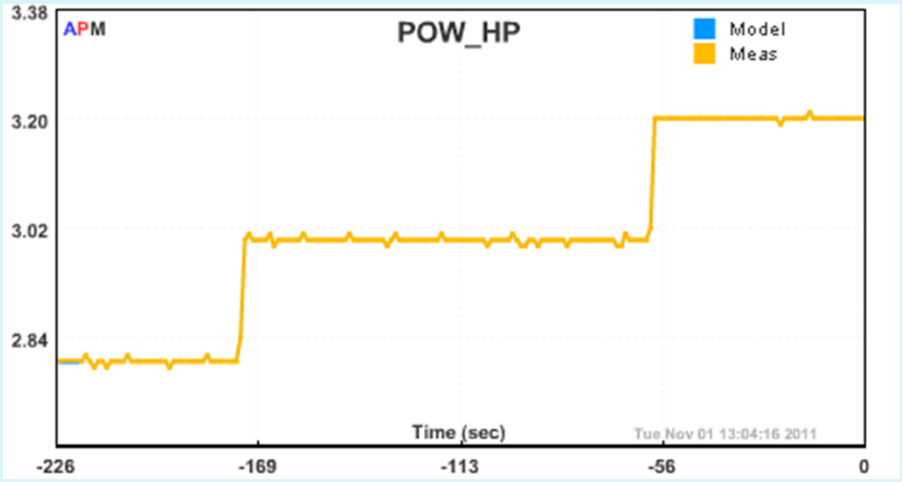


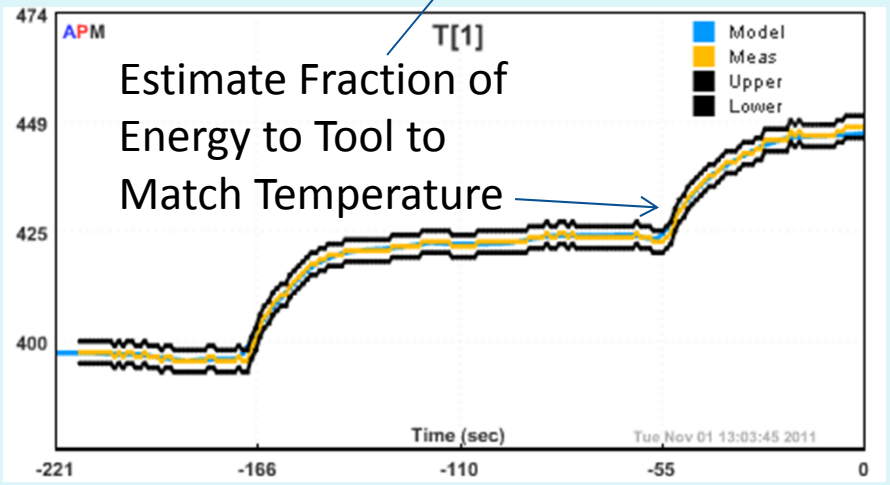


FSW Process Model – PDE Model

- Model #2 of FSW Process
  - PDE of Tool Heat Transfer
  - Demonstrate model predictions on Aluminum
  - Fit PDE model to process data





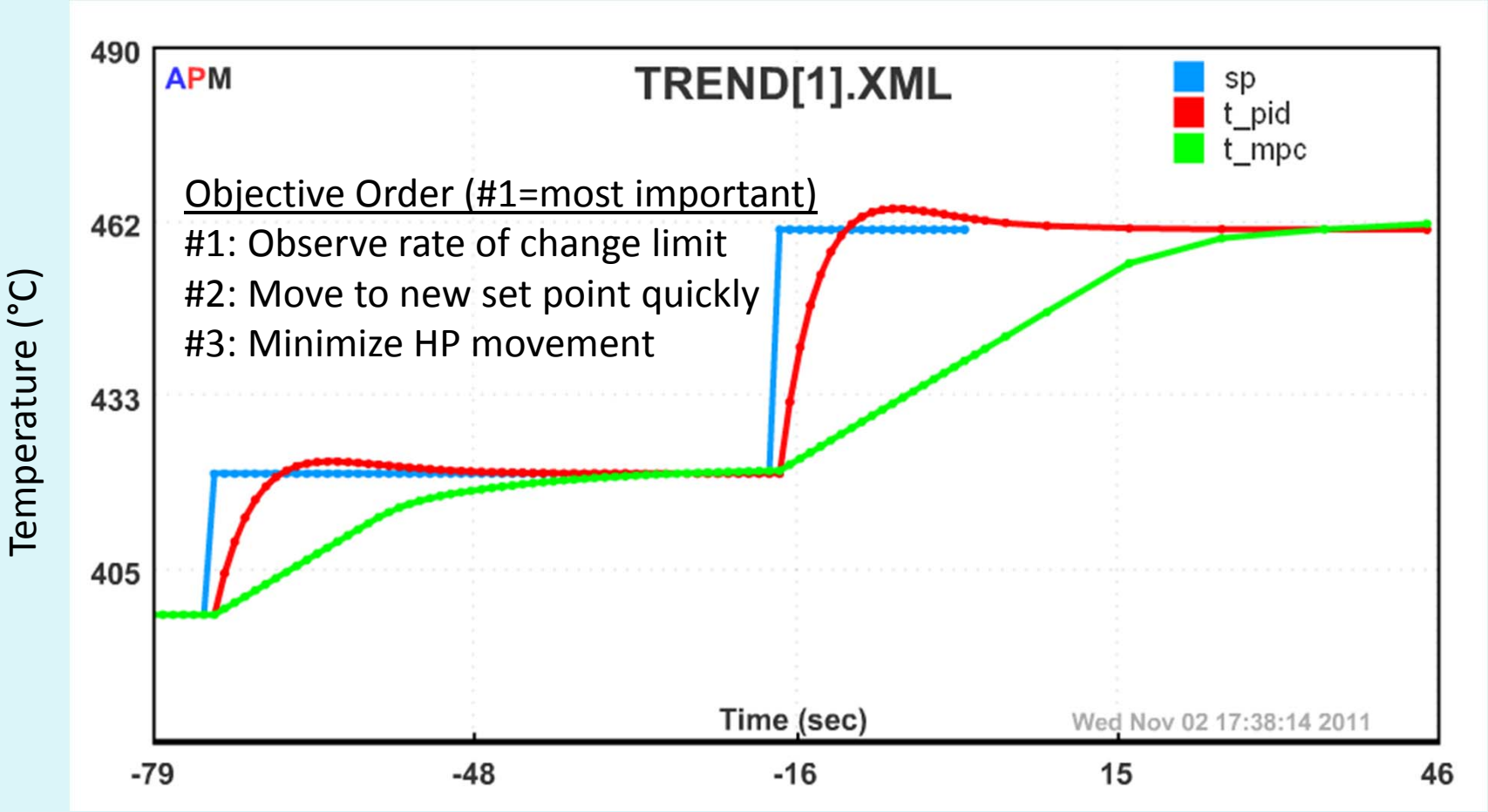


Estimate Fraction of Energy to Tool to Match Temperature

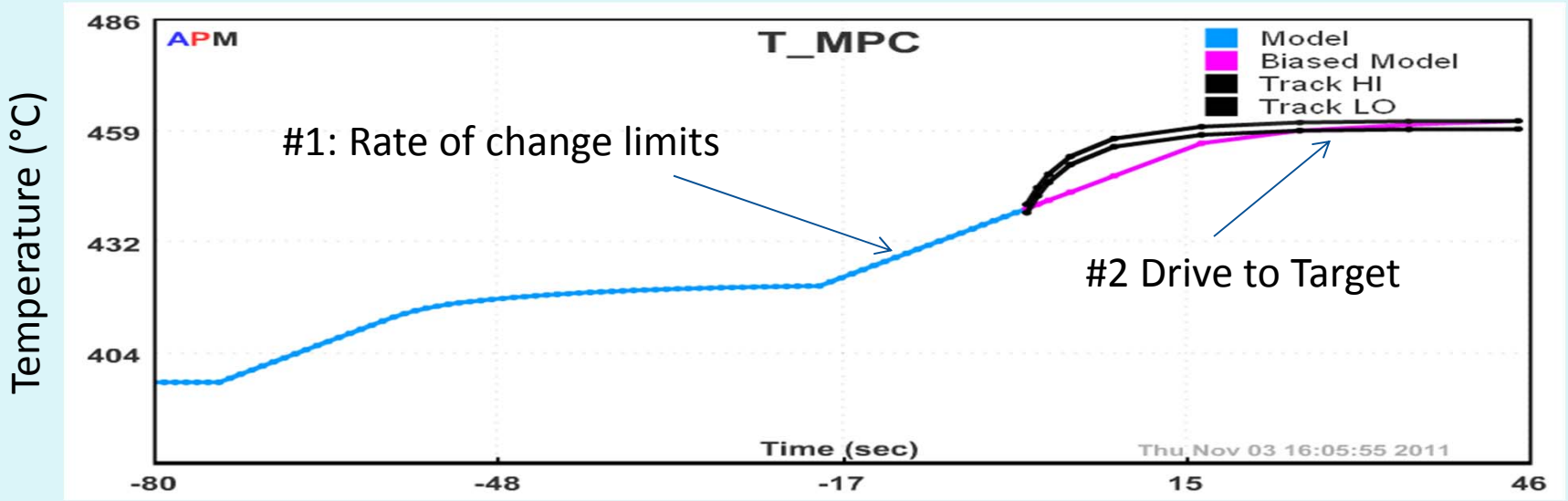
FSW Temperature Control

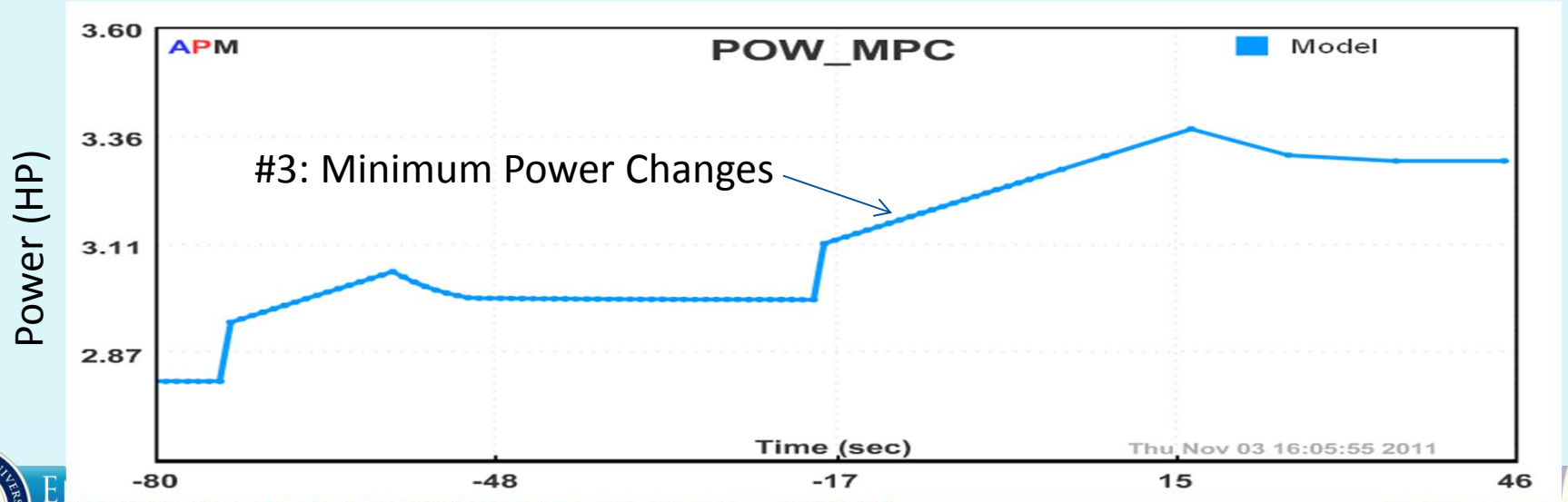
- Current Practice
  - PID Control
  - Start-up procedure
    - Constant rotational speed
    - Manual adjustments to guide temperature
      - Z Axis Force
- Proposed Control Strategy
  - Model based control
  - Automatic control through start-up
    - Limit overshoot
    - Keep process within constraints
      - Rate of change limits for motor power (HP)
      - Rate of change limits for tip temperature

Comparing PID and MPC

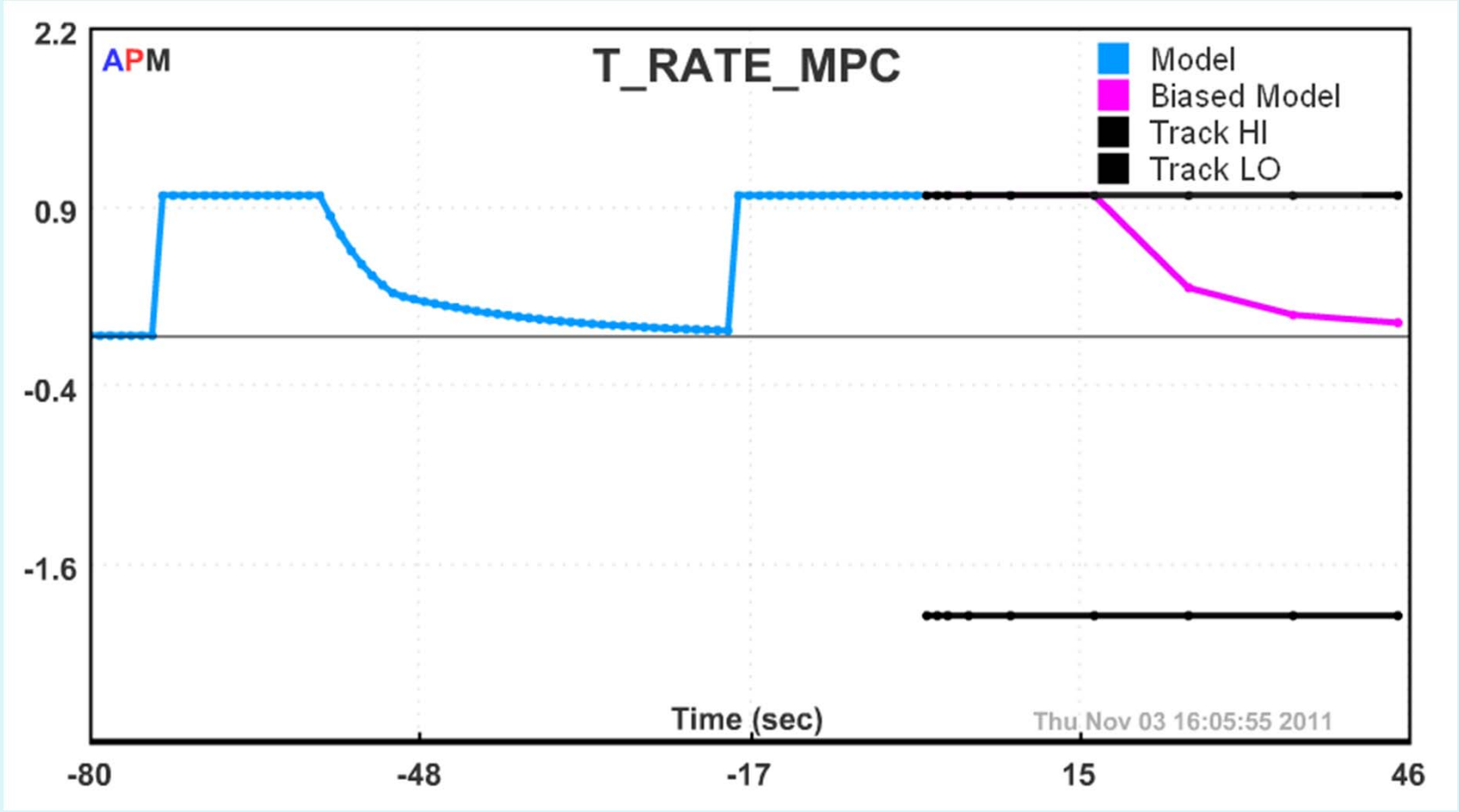


Model Predictive Control

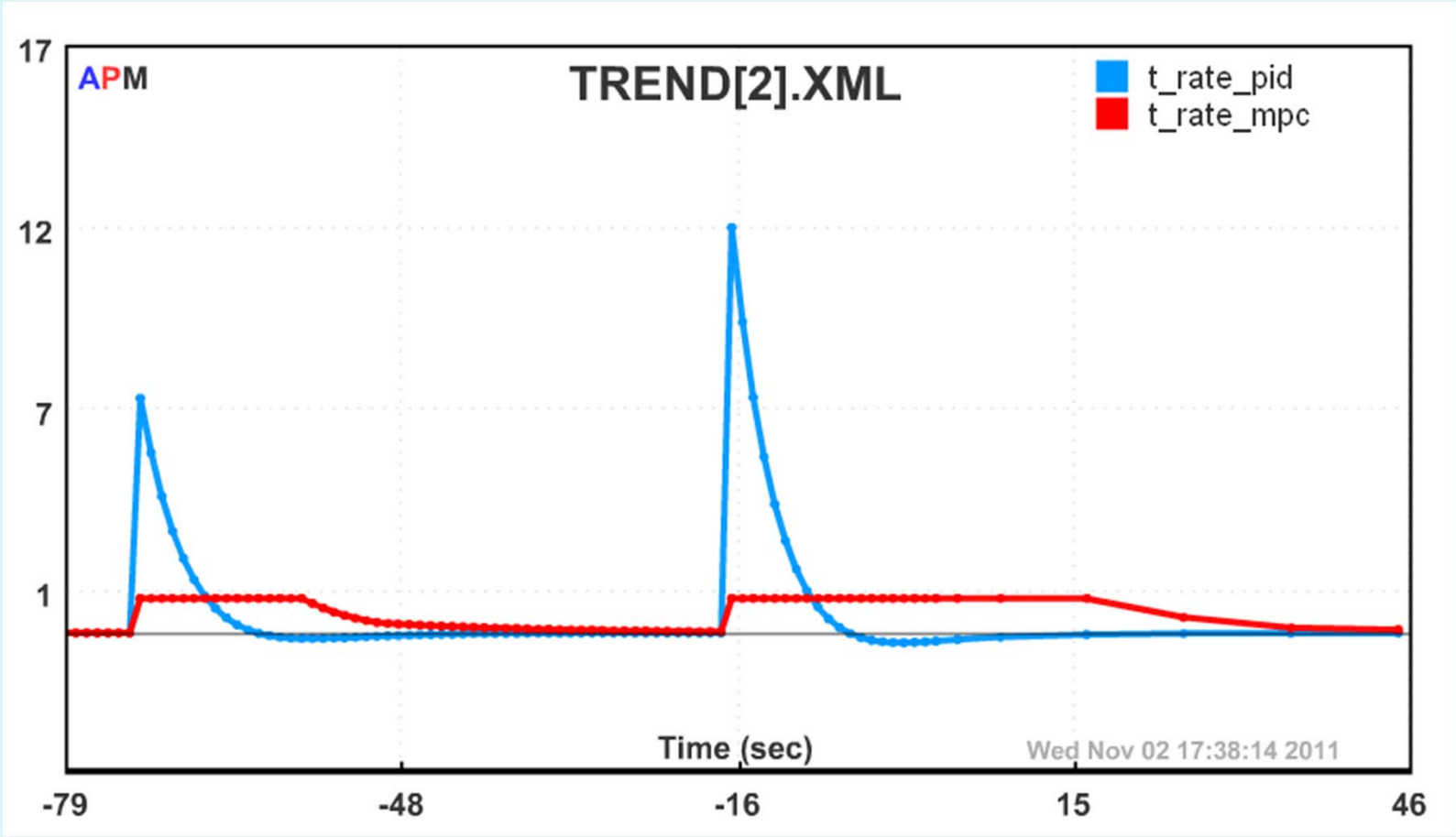




Operate Within Constraints



Rate of Change for PID and MPC



Recommendations

- Model Predictive Control has advantages for:
  - Start-up
  - Large load changes
  - Constrained control - MV or CV tuning
- Start control studies now with FOPDT model
  - Interface with PLC through OPC connection to RS Linx
  - Existing equipment sufficient
- Address complex modeling / control issues
  - Seek funding for a graduate student
  - Investigate multi-variable control