Master’s Thesis Engineering Technology

2019-2020

Comparison of PI/PID and model predictive control applied to a Simscape Multibody model of a DC-powered conveyor belt

Berden Ruben

Master of Energy Engineering Technology

Olaerts Tristan

Master of Energy Engineering Technology

Setting

This project was commissioned by the Electrical and Automation Engineering Department of **HAMK Häme University of Applied Sciences** in Finland. In the university's laboratory, there is a simple **conveyor belt**, shown in Figure 1, which will be **modelled and controlled**. The conveyor belt is straight and horizontal and is equipped with a 24V DC motor that can be controlled in speed by using PWM control.

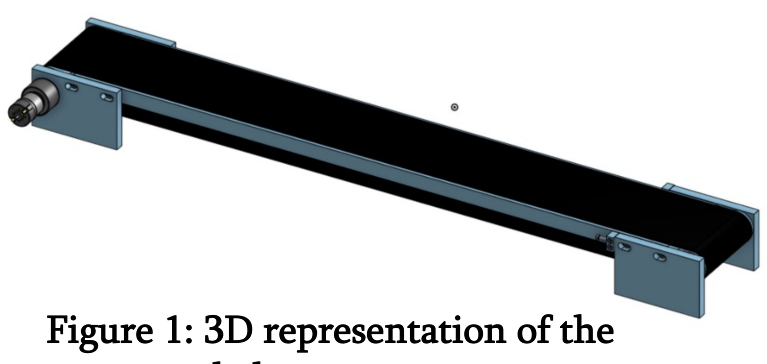

Figure 1: 3D representation of the conveyor belt

Objectives

This study is set out to investigate three main aspects of the modelling and control of a conveyor belt.

1. Investigate the **toolchain** from CAD to Simulink Multibody to real-time control
2. Examine complexity to identify the **parameters** of a Simulink model
3. Analyse and compare **PI/PID and model predictive control** applied to the conveyor belt

Method

The 3D model of the conveyor belt is drawn using the free online tool **Onshape**. This tool is used because Onshape is compatible with **Simulink Multibody** which makes it possible to implement an Onshape drawing with a few simple commands. Once the 3D model is implemented in Simulink Multibody a **friction model** is added. This model is then applied to the Simulink model to become a realistic conveyor model.

The added friction model follows the **Stribeck model**. The friction force is simulated as a function of relative velocity and is assumed to be the sum of Stribeck, Coulomb, and viscous components, as shown in figure 2. This model has for a certain velocity regime a decreasing friction force with increasing velocity. This is called the Stribeck effect. This representation proves accurate for real friction.

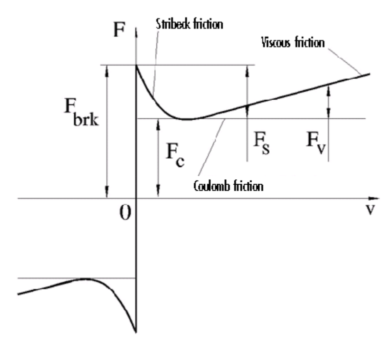

Figure 2: Stribeck friction [1]

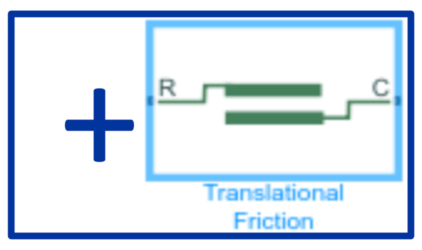

Figure 3: Onshape logo [2]
Figure 4: Simscape Multibody logo [3]
Figure 5: Translational Friction block [1]

Results

PI/PID control

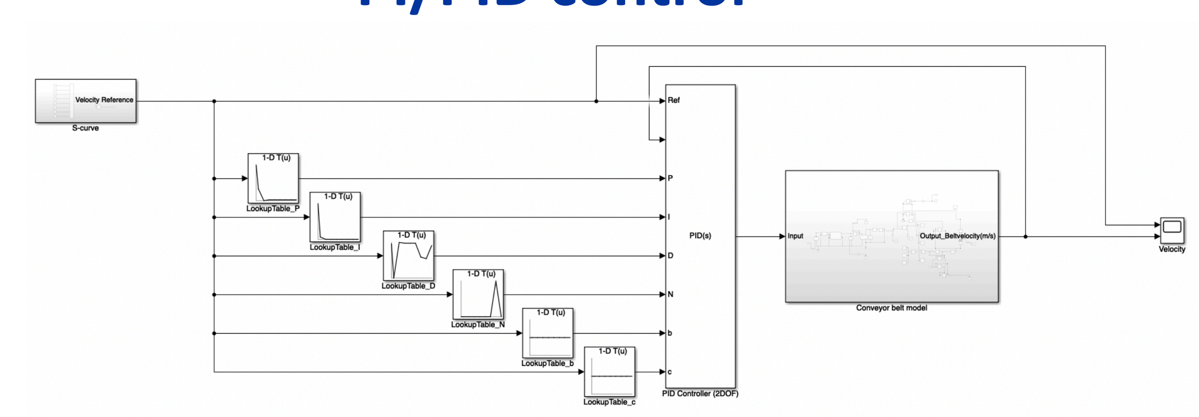

Figure 6: Gain scheduled PID Simulink model with belt speed as measured variable

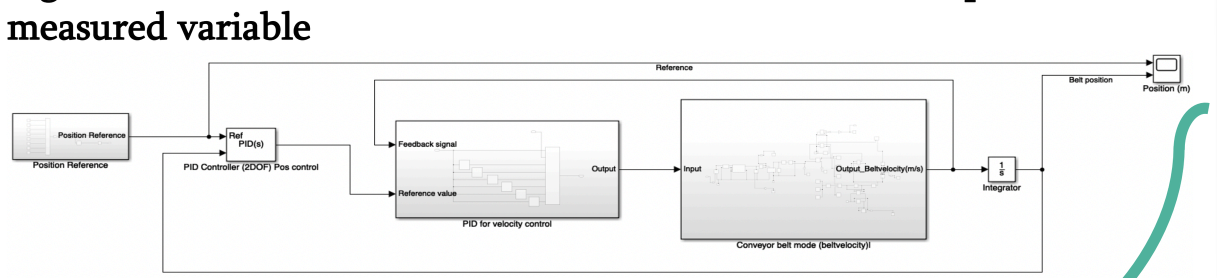

Figure 7: Cascade PID Simulink model with belt position as measured variable

For the conveyor application with **speed control** it can be concluded that gain scheduled PID performs better than a single MPC. The main advantage of the gain scheduled PID is that there are different linearizations at different operating points. This results in an overall accurate response. The MPC is designed for a linearized conveyor belt model at 10V, resulting in deviations at low voltages.

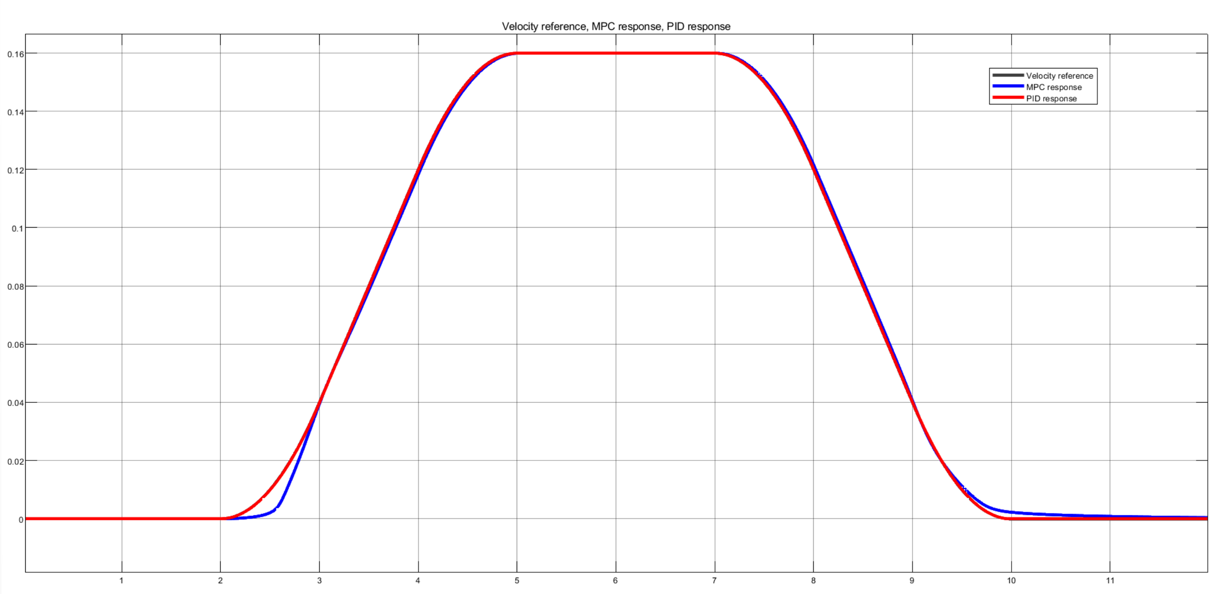

Figure 10: Comparison of MPC response and PID response with belt speed as measured variable

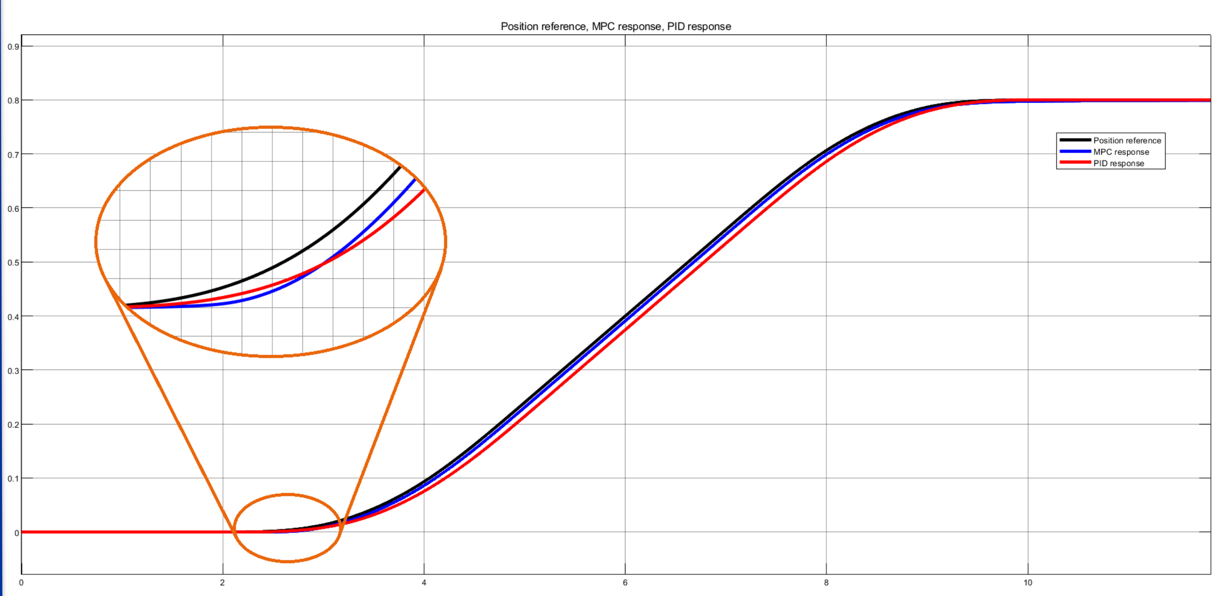

Figure 11: Comparison of MPC response and PID response with belt position as measured variable

Model predictive control

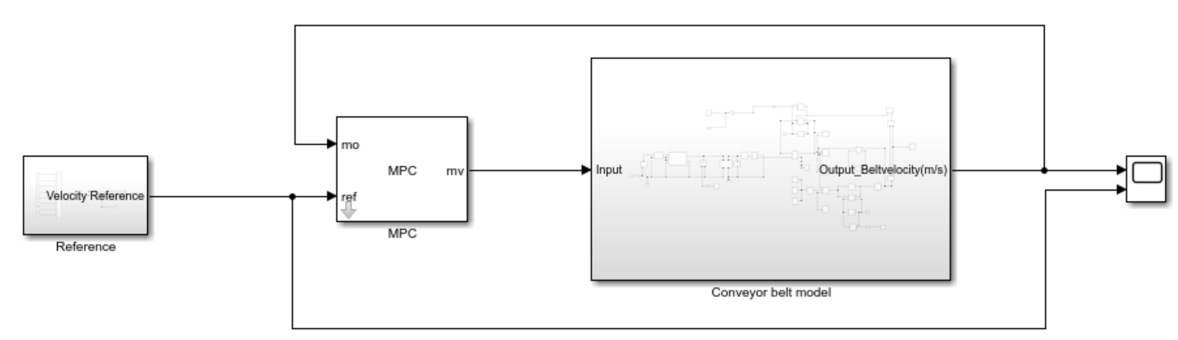

Figure 8: MPC Simulink model with belt speed as measured variable

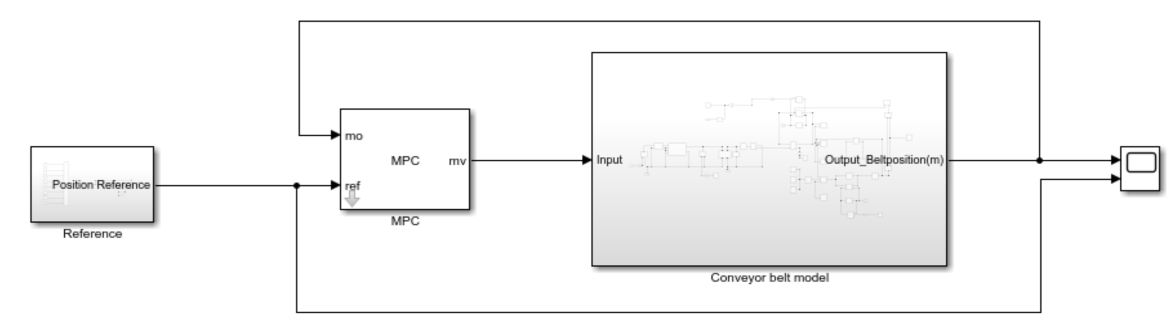

Figure 9: MPC Simulink model with belt position as measured variable

For the conveyor application with **position control** it can be concluded that both PID and MPC perform equally good. The PID starts faster than the MPC and reaches the final position first. The MPC on the other hand is overall closer to the reference position. The deviation on the final position is for both controllers acceptable.

Conclusion

1. The **conversion** from an Onshape model to a Simulink Multibody model is **straightforward**. The design process is accelerated by building the graphical model in a familiar CAD environment.
2. Practical tests on the conveyor belt were not carried out. This made it impossible to match the parameters with test values.
3. Simulations have shown that for the conveyor application a **gain scheduled PID controller performs better** than a single MPC controller at **speed** control. In **position** control, the PID and the MPC are **equivalent**.

[1] MathWorks, ‘Friction in contact between moving bodies - MATLAB - MathWorks Nordic’, MathWorks Documentation, 2016. [Online]. Available: https://se.mathworks.com/help/physmod/simscape/ref/translationalfriction.html. [Accessed: 11-May-2020].
[2] Onshape, ‘Onshape | Product Development Platform’. [Online]. Available: https://www.onshape.com/. [Accessed: 11-May-2020].
[3] ‘Simscape Multibody - MATLAB’. [Online]. Available: https://se.mathworks.com/products/simmechanics.html. [Accessed: 11-May-2020].

Supervisors / Cosupervisors: Prof. dr. ir. Juhani Henttonen
Prof. dr. ir. Johan Baeten

HAMK HÄMEEN AMMATTIKORKEAKOULU HÄME UNIVERSITY OF APPLIED SCIENCES

UHASSELT

KU LEUVEN