Minimizing Rolling Mill Gap Control Engineering Time Using Commercially Available Motion Control Modules

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Introduction

We recently upgraded and modernized a Temper Mill (in-line with a Pickle Line). The old Roll Force Cylinder controls were 'black box', so the code could not be readily converted, and was created and commissioned from scratch. The new Temper Mill control platform had very good built-in Motion Control functionality. In this paper we will present how we misused the commercially available 2-Axis Analog Motion Control Module close both the Position Loop and the Velocity Loop on the Roll Force Cylinders, resulting in adequate responses (~26ms) for our needs, with very little engineering time.

History

The Temper Mill on their Pickle Line was originally installed in the mid-1990's with a VME Controller. Around 2000 the VME Controller was replaced by a GE 90-70 with a Third Party custom Hydraulic Gap Control Card.

Reason for Upgrade

The lack of availability for the Third Party custom Hydraulic Gap Control Card and the GE 90-70 PLC being 'designated as mature' drove the decision to upgrade the Temper Mill Controls.

Platform Choice

Rockwell's L75 ControlLogix was chosen for several reasons:

- The Pickle Line had previously been upgraded to a Rockwell ControlLogix platform.
- There were already several other machines in the plant running the Logix platform.
- The technical personnel were already familiar with the architecture.
- The large install base and use of standard off-the-shelf components should help delay any future obsolescence.

System Architecture

The Temper Mill PLC used Ethernet to communicate with the Pickle Line PLC and its own Field I/O. A standard commercially available 1756-M02AE 2-Axis Analog Motion Control Card was used to interface with the existing Roll Force Servo Valves and the existing Resolver-to-Quadrature position feedback converter.

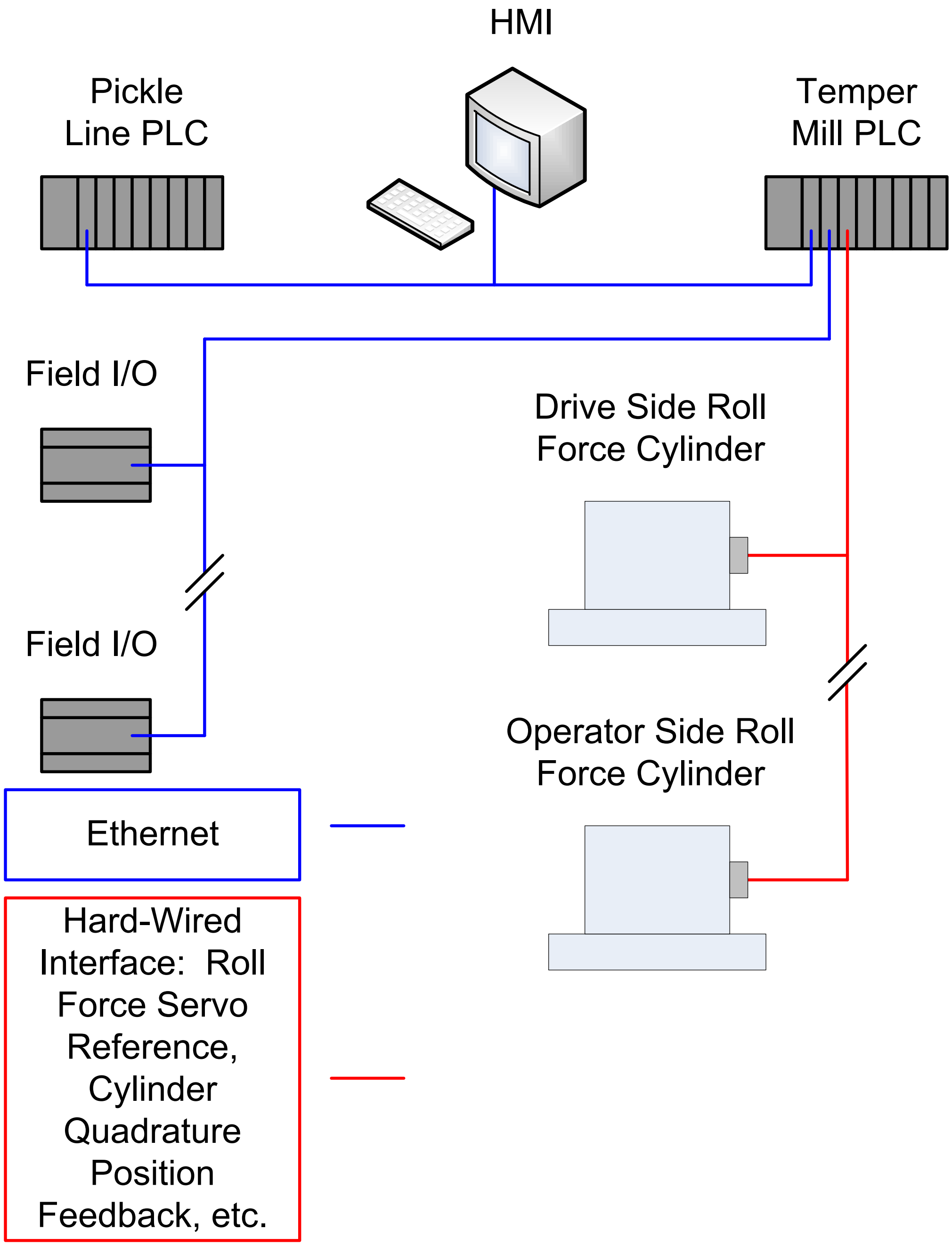

Figure 1. System Architecture

Analog Servo Drive Motion Module

Rockwell's ControlLogix platform 1756-M02AE is a 2-Axis Analog Motion Control Card. Its primary application is 'Analog servo interface drives with quadrature feedback'.

In these 'Analog servo interface drives with quadrature feedback' applications the M02AE will:

- Focus on Position Control,
- Close the Position Loop internally,
- Provide an Analog Velocity Reference to an Analog Servo Drive, and
- Expect the Analog Servo Drive to close the Velocity Loop.

This will not work for Roll Force Cylinder Control.

The M02AE can also be configured with its 'External Drive Configuration' as 'Hydraulic'. In 'Hydraulic' mode the M02AE will:

- Focus on Position Control,
- Close the Position Loop internally,
- Close the Velocity Loop internally, and
- Provide an Analog Reference to the Hydraulic Cylinder's Valve.

This will also not work for Roll Force Cylinder Control while rolling, but it is closer.

Our desire is not to Position the Roll Force Cylinders like a Single-Axis Robot, but to Regulate Roll Force via Hydraulic Cylinder Control.

The Logix programming environment has a 'Motion Axis Jog' (MAJ) command 'to move an axis at a constant speed until you tell it to stop'. The primary purpose of this command is to Home or position an Axis on a machine, but it will make an Axis run at a specific speed in a specific direction.

Force Control by Screw Velocity

When controlling Roll Force with Screw-downs the Roll Force is controlled by the Screw Velocity. The Mill Modulus can be used as a Transfer Function for the relationship between a Delta Position (Velocity) and Delta Force for Roll Force by Velocity Regulation.

Force Control by Motion Axis Jog Velocity

We used this concept to control the Roll Force via Axis Velocity Control with very little logic:

First, the System Gains are derived from the results of the Mill Modulus.

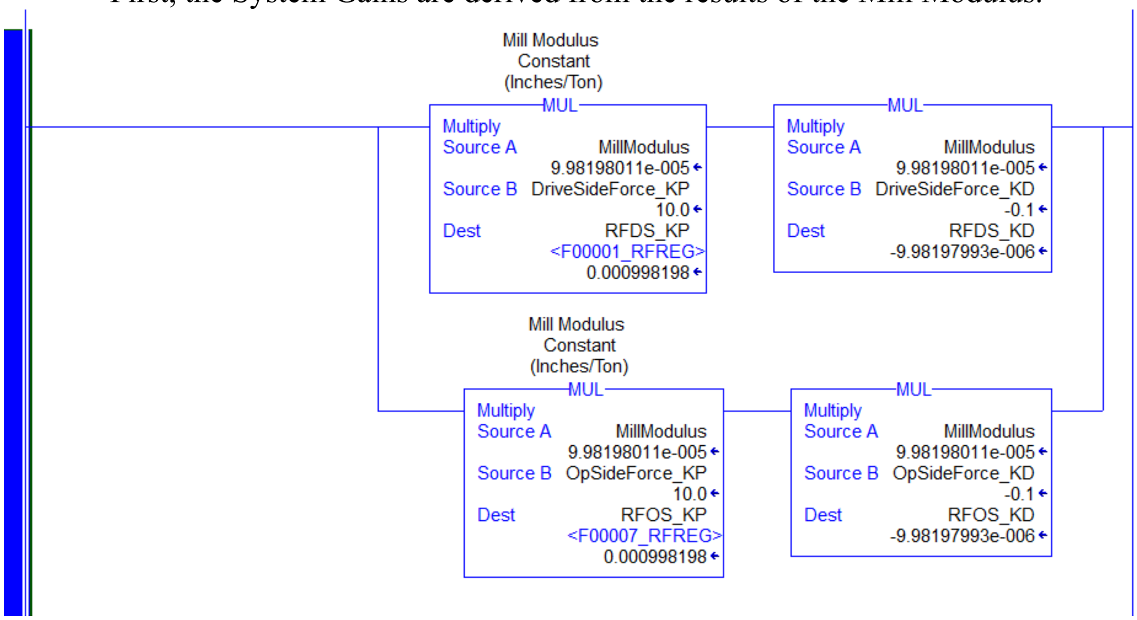

Figure 2. System Gains from Mill Modulus

Next, the Force Regulator.

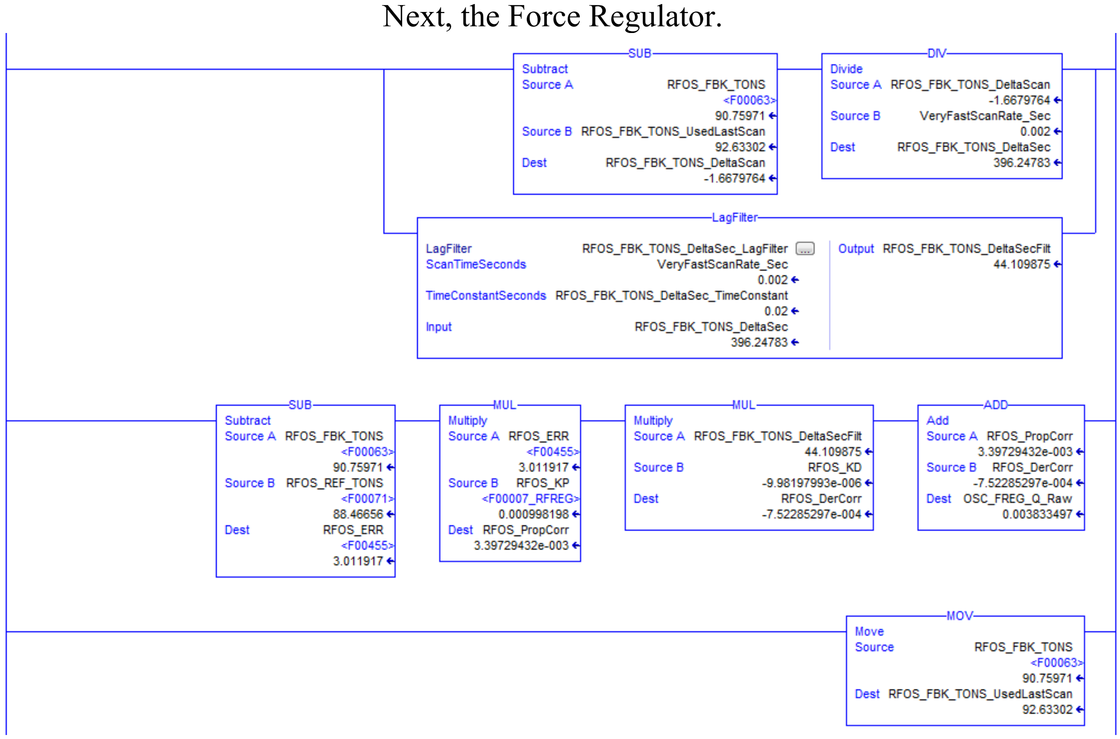

Figure 3. Force Regulator

Finally the Velocity Control.

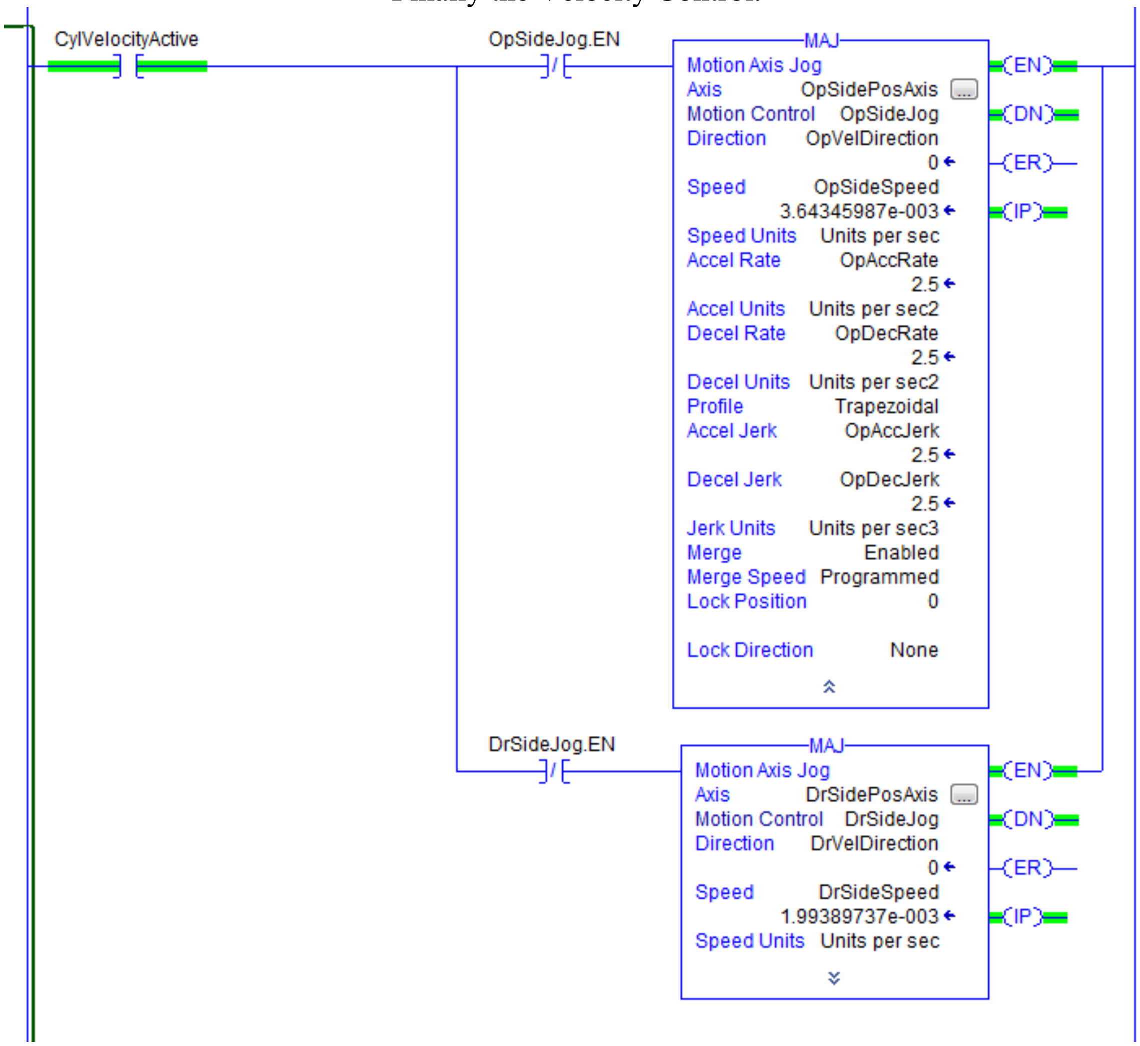

Figure 4.Velocity Control

Results

The Roll Force Regulator ended up having a Time Constant of 26ms (38 rad/s). The system response was completely adequate for this application.

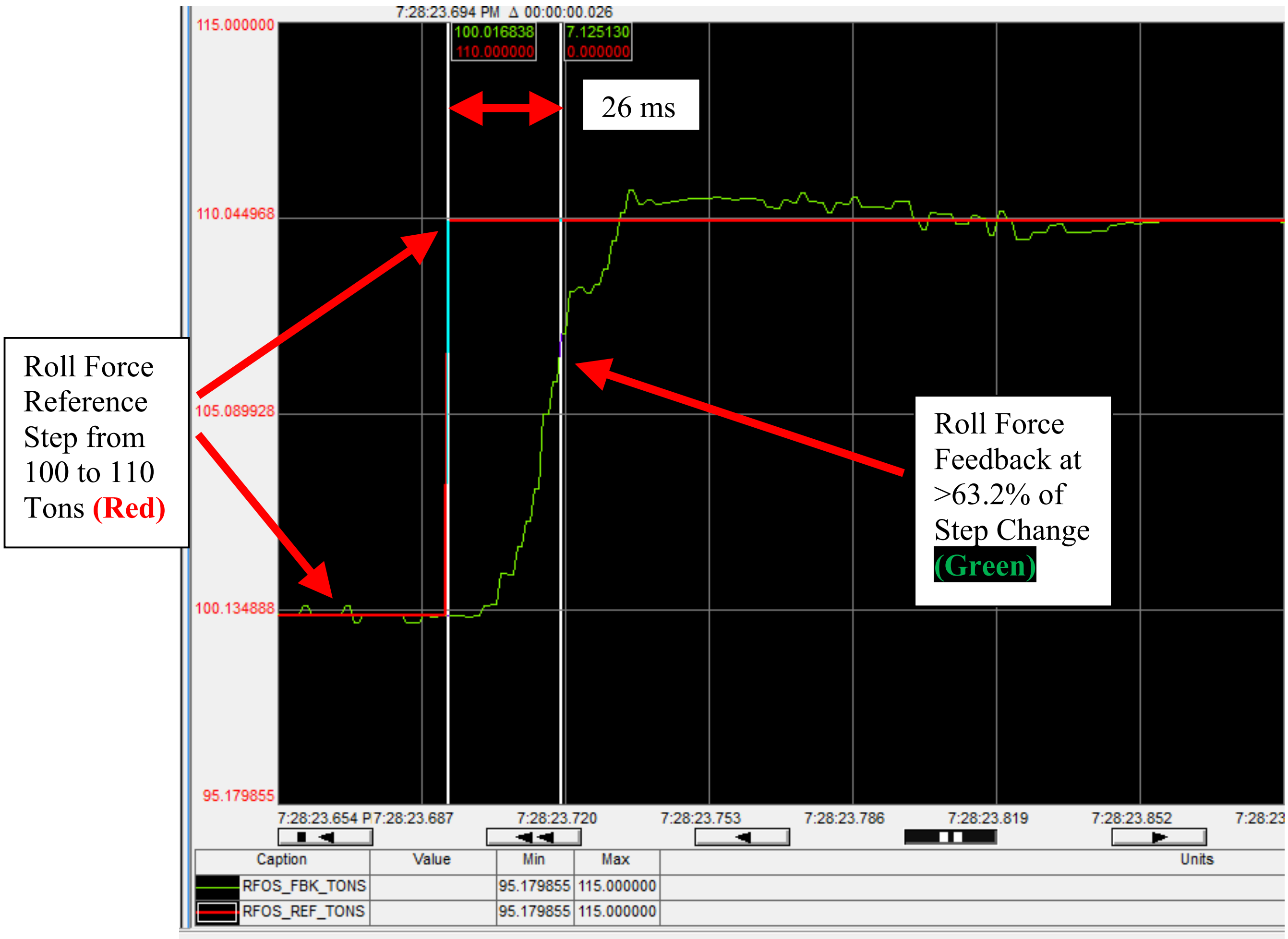

Figure 4.Step Response

Conclusions

The controlling of Roll Force by Cylinder or Screw Velocity is not a new concept. The system response was adequate for this application. What is of interest is how little engineering time it took using commercially-available off-the-shelf components with a very large install base and support structure.

Acknowledgements

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