Roll Threader Modernization with 1500TF Processor
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Introduction

Siemens Energy in Painted Post, NY, formerly Dresser Rand, is responsible for the production of large compressor systems for use in the energy sector. In the mid-1990s, they purchased a large Leistritz Thommen horizontal roll-threading machine to cold roll the threads for their compressor system connecting rods. The machine had a Faude control system in it that used a B&R industrial PC, Bosch RexRoth VFDs, motors and general purpose I/O.

Despite the large capital expense, Siemens Energy was unable to get the desired performance out of the machine. The biggest source of production rejects was thread lead error. The machine's supplier did their best to support the machine, but they eventually split into two companies and neither of the new entities was able to continue providing support. Without support, machine down-time events became prolonged, ad hoc solutions were put into place and band-aid remedies implemented in order to maintain production schedules. The end result was long lead times for product and well as diminished product quality. Siemens knew they needed help, but they had incredible difficulty finding integrators who were willing to tackle a very complex machine and process.

In late 2016, Siemens invited Digitronik Labs to visit the location to see if we could provide an upgrade path that unified the controls architecture, integrated current technology, and improved the resulting product quality. And this would need to be done while keeping downtime to a maximum of two weeks.

In this paper, we will provide an overview of the initial state of the machine, our engineering approach for the upgrade, the resulting hardware architecture, and the overall results of the upgrade process.
Methodology

In order to achieve a viable upgrade path, we had three major decision points to consider:

First, we had to determine which hardware components would be upgraded, and which could be reused or repurposed. Doing this required a comprehensive review of the machine components as well as the production process itself.

Second, a new controls platform had to be chosen and validated. There were three choices: a replacement industrial PC, a CNC platform to handle the complex motion control, or a PLC with built-in motion control.

Finally, we had to develop an upgrade path that would limit machine downtime during the upgrade so as to minimize the impact on Siemens’ production schedule.

1. **Design the Upgrade Path**
   - New controller: PC, CNC, or PLC?
   - Plan the full upgrade process
     - Determine hardware to reuse
     - Find replacement components for the rest
     - Strategy to minimize production downtime

2. **Achieving Required Performance**
   - Understanding of specifications
     - Thread lead error elimination
     - Thread matching routine
   - Design of closed-loop feedback systems
     - Hydraulics high-side/low-side monitoring
     - Hydraulic servo control
   - Absolute positioning control with multiple axes
     - Hydraulic axis
     - Roll spindles
     - Feed table

3. **Commissioning and Factory Acceptance**
   - Executing the downtime mitigation strategy
   - Unforeseen challenges
Design the Upgrade Path

Siemens Energy had three major requirements that had to be met in order to move forward with the machine upgrade. In order of priority:

1. Improve the performance of the roll-threading process by minimizing lead error on the rolled thread
2. Limit production downtime to two weeks for install and commissioning
3. Improve the operator interface for the machine operators

Improve Performance

Digitronik proposed a specifications development phase of the project during which we identified controls components that could be reused, and which components would need to be replaced in order to achieve the desired performance specification.

The existing system was designed with a B&R industrial PC, RexRoth Sercos-enabled VFDs for the spindle motors and feed table motion, a Beckhoff BK7500 Sercos-enabled slice I/O rack, Rexroth Profibus-enabled remote I/O, Rexroth hydraulic servo valves for each hydraulic axis, and Sony magnetic linear encoders for hydraulic axis positioning. All existing encoder signals were routed to the Beckhoff BK7500 and converted to Sercos packets to be sent to the industrial PC. The system also utilized a Kistler CoMo strain gauge to measure the hydraulic pressure applied via the die head.

This system architecture was not optimal to today’s standards. One major cause of degraded performance was the Sony encoders; they were not absolute encoders, thus the system would lose hydraulic axis positioning on power-down events, rendering existing recipes useless. The industrial PC also had issues with log files filling up the hard drive, causing the PC to crash. The Kistler CoMo unit was determined to be non-functional as it’s back-up battery had failed and the programs that were on it were gone. To compound these issues, the customer was not able to get the latest code file, did not have a CodeSys license for the code, and did not employ any engineers or technicians with the required expertise to use these tools.

It was determined that, while a CNC controller would meet the performance requirements, there would still be a knowledge gap that would inhibit Siemens’ ability to maintain the machine with in-house resources. Consultation with Siemens applications engineers lead to the proposal of using a Siemens 1500TF processor with TIA Portal v15 to access the motion control features of the PLC. It was also determined that all closed-loop feedback devices should be IRT capable in order to maximize system performance.
The proposed hardware upgrade path consisted of the following:

- Siemens 1500TF processor
- Siemens 15.4” Comfort panel
- Siemens S120 VFD's (IRT capable)
- Siemens ET200sp IRT-capable I/O rack
- MTS Series V, Profinet IRT-capable absolute linear encoders for hydraulic axis positioning
- Siemens 1PH series vertical mount motors with absolute rotary encoders for spindle motion (spindle motor encoders are IRT capable)
- Omega PX319 pressure sensors for high/low-side hydraulic pressure differential feedback (analog signal goes to analog card on ET200sp IRT rack)
- New controls enclosure to piggyback on existing controls enclosures

**Minimize Production Downtime**

With an appropriate set of hardware selected, the remaining challenge for the upgrade path was to limit the install and commissioning schedule to two weeks of downtime. In order to achieve this, Digitronik had the new controls panel built off-site and shipped to the plant for installation in parallel with the existing controls enclosures. This enabled us to install the new controls enclosure while production remained running. We then ran new cables alongside existing cables to all areas where we were replacing controls components. This methodology allowed us to change over the control system in less than a day, and also allowed us to revert back to the old control system in the event that some unforeseen hurdle should arise. We were certainly glad that this methodology was employed as we did have to revert back for several months due to delivery of incorrect components during the initial commissioning activities.

**Improve Operator Interface**

The original machine operator interface was designed for a general purpose roll-threading application. As such, the operators had to navigate between five different screens in order to complete the machine set-up and perform the roll-threading operation. We reviewed the required setup operations with the machine operators and we were able to use the recipe tools provided by WinCC to reduce the number of setup screens to two, including the recipe screen. After selecting a recipe, all required setup operations can be accessed from a single screen. For additional convenience, we included the on-screen calculator from the WinCC toolbox library. By restructuring the user interface, machine operator's workflow was improved substantially.
Recipe Selection Screen

Material Handling Screen (Main Operations Screen)
Material Handling Screen (with Pop-up Calculator)

Hydraulics Control Parameters Screen (Maintenance Screen)
Achieving Performance Specification

In order to improve the thread lead error and produce threads that are within specified tolerances, we needed the following:

- **Real-time (IRT) communications for all closed-loop control systems**, including:
  - Hydraulic axis positioning (MTS Series V, Profinet IRT absolute encoders)
  - Hydraulic servo valve control (analog output card on ET200sp, IRT)
  - Pressure monitoring high-side/low-side of each hydraulic axis (Omega PX319 pressure transducers, Analog input, ET200SP, IRT)
  - Spindle Motor Positioning and control, IRT
- **Complete code rewrite**
  - Hardware layout to include all existing I/O and safety guarding
  - Virtual gearing of spindle motors to ensure synchronous operation throughout the rolling process
  - Siemens hydraulic control blocks to control position and force
  - Thread matching routine
- **New user interface via Siemens Comfort Panel**
  - Workflow design improvements
  - Recipe management
  - Maintenance screens
  - Homing routines
  - Machine alarming

By using the integrated motion control and virtual gearing provided by TIA portal for the 1500TF processor, we were certain that once we had all axis in position, we could synchronize the process and achieve the desired thread roll. One of the critical aspects of getting all the axes in position is the thread-matching of both roll thread dies. This parameter is referred to as the track angle offset and is critical to achieving thread match between both die heads. Our approach to calculating the track angle involved a track angle routine, wherein:

- Both hydraulic axis are positioned to just barely touch the rod blank
- Rotate or inscribe the die head track lines onto the blank using the single-step degree parameter as our angular rotation value
- Measure the thread to thread deviation and use that value to calculate the relative track angle offset for the right side die head
- We then rotate the right side die head to a calculated absolute angle offset and store this value into the existing recipe

This approach allows for quick set-up for a new recipe, and ensures all parameters are saved so that the recipe can be loaded and new connecting rods can be produced with a high degree of repeatability.
Commissioning and Factory Acceptance

Commissioning activities were comprised of changing the system over to the new controls scheme, wiring up new controls components, and performing I/O checks. Once the system was determined to be wired correctly, commissioning activities commenced. These activities included extensive hydraulics system testing and characterization. Maintenance activities on the RexRoth hydraulic servo valves included breakdown and cleaning, replacement of old O-Rings and development of a “valve zero set” procedure required to maintain optimal machine performance by minimizing hydraulic axis drift.
Final Results

1: Scribing Sequence
In this application we were interested in controlling position and not force. The traces below show that we were able to maintain the tracking position to within 0.0001”. Trace 1 represents the move to the tracking position, which is just at the touch point of the rod blank. A move of 0.0005” is then issued, which causes the tooling to make a scribe mark on the rod blank.
Trace 2 and Trace 3 show hydraulic cylinders A and B movement from the track position to the scribe position. Movement is controlled well within the specification of 0.0001".
2: Automatic Sequence:
Again, in this sequence we were interested in controlling position and not force. The traces below show that we were able to maintain movement positioning to the 0.0001” specification. Trace 4 shows the automatic sequence where the cylinders move from the fully-retracted position, to the pre-cut position, to the cut position, then back to the pre-cut position and finally back to the fully-retracted position.
Trace 5 shows that hydraulic cylinder ‘A’ moved through the sequence while maintaining the 0.0001” specification. The trace also shows that cylinder ‘A’ was the last to reach the setpoint position of 7.25” as seen by the auto cut position not being triggered, but the retract to pre-cut position was being triggered. The requirement for automatic mode is that both cylinders reach the setpoint position before being retracted.
Here we zoom in on Trace 6 to view the time discrepancy of 1 ms delay between cylinder ‘A’ and cylinder ‘B’ reaching their setpoint positions.
Trace 7 show that hydraulic cylinder ‘B’ also moved through the sequence maintaining the 0.0001” specification. It also shows that cylinder ‘B’ reached the setpoint position and waited for cylinder ‘A’ to be in position before retracting.

Comments on results:
Prior to machine upgrade, three full rolls were required to achieve the desired result. The first roll was used to make an initial cut that was short of the final thread depth. The second cut was to the final thread depth, but not for the desired thread length. The third roll was required to complete the roll over the entire thread length. The second and third rolls were performed separately in order to prevent damage to the tooling resulting from poor die head position. Without using two operations, the dies would slip off the end of the rod and collide with each other at full force.

After the upgrade, the operators are now able to complete the full roll threading process with only two rolls at full thread depth and length. We were able to achieve this because we were able to control the hydraulic cylinder positions with a much higher accuracy. This improvement in accuracy is the result of using the Isochronous Real-Time controls architecture of the 1500TF processor and closed-loop feedback components.
Conclusion

Since completion of the upgrade, operators are now able to complete the full roll threading process with only two rolls at full thread depth and length. This is almost entirely a function of the control system, as only minimal mechanical changes were required in order to achieve this enhanced performance.

In addition to performance, the machine operator’s job has been simplified thanks to the redesigned machine interface. Operators must no longer memorize a series of arcane procedures to configure and run the machine, and the risk of downtime due to erased recipes has been eliminated.

There are many applications of the modernization process that have the potential to mitigate expensive machine replacement via targeted machine upgrades. This is especially true in the machine tool market as there are many aging machines, which in many cases are no longer manufactured, making them difficult to support and maintain due to obsolete or under-performing control systems. This project proves the viability of modern PLCs as replacements for aging CNC systems.

Thank You

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