Machine Controls Training

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Machine Controls Training Class Syllabus

Machine Controller Basics

- Hardware
- Configuring the Controller
- Navigating the Controller Software
- Scrap Handling
- Coil Changes

Encoder Tracking

- Basic Function
- Quadrature
- Differential Signals
- Resolution
- Tracking Variance
- Alignment
- Calibration and Variance
- Mounting Issues

Open Loop and Closed Loop Applications

Open Loop Feed-to-Stop

- Stopping Reaction Time
- 2-Speed Stopping
- Hydraulically Driven Equipment

Open Loop Flying Die

- Press Reaction Time
- Boosted Dies

Closed Loop Flying Die

- General PID Theory
- AMS-specific Closed Loop
- Servo Tuning
- Motion Profile

Closed Loop Feed-to-Stop

Troubleshooting

- Length Calibration
- Explaining the Part Queue
- Testing Inputs and Outputs

Part Punch Programming

- Punch Tooling Setup
- Gagged Dies
- Macro Punch Tools
- Pattern Programming
- Macro Patterns

About AMS Controls

With over 11,000 installations in place, and working for more than 3,000 clients, AMS Controls sets the standard for operational efficiency in the roll-forming industry. AMS Controls' extensive line of products includes a suite of production and management integration software and family of controller solutions, specifically tailored for a wide variety of applications. Our engineers have the expertise, intelligence and technology to evaluate all facets of your operation and then provide valuable information in addition to proven system products and software to enhance the productivity and profitability of your organization.

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Introduction

This document is designed to serve as a guide for the Machine Controls Training Class as well as a reference document.

Hardware

Introduction

This section is a simple introduction to the XL200 Controller. We will explore different parts of the controller and their functions.

External Ports

Mouse Port

Keyboard Port

VGA Port

DVI Port

RS232 Port

Sercos

Touch Screen

External Fuses

Inputs and Outputs

Encoder Circuits

Communication Ports (RS485)

Configuring the Controller

XL200 Series Options

There are several different XL200 series controller models available from AMS Controls. Each model may be configured to operate in different modes depending on the options available.

The basic controller model number indicates the base model of the controller without options (for example, XL200CL indicates a base controller for a closed-loop system). Additional optional features will change the controller model number by adding the associated letter or letters to the end of the basic model number. For example, an XL200CLB is a closed-loop controller with optional Bundle Tag printing.

Below is a list of options currently available for the XL200 series controllers. Please note that not all options are available with all base models. For questions regarding a specific system, contact AMS Controls.

XL200

Capable of operating two presses with no gags.

XL202

Capable of operating one press with one gag or two presses with no gags.

XL206

Capable of operating one press with five gags, six presses with no gags, or any combination of presses and gags totaling 6.

XL212

Capable of operating one press with eleven gags, twelve presses with no gags, or any combination of presses and gags totaling twelve.

XL266

Used primarily for Schlebach machines. Has a shear up complete input as well as press up complete inputs. Up to six presses including the shear.

XL270

Tile machine controller.

XL244CL

Capable of operating one press with four gags, five presses with no gags, or any combination of presses and gags totaling five. Two of the presses can be closed loop.

Closed Loop (CL)

Supports the use of a servo driven feeder or die accelerator systems. May be limited based on additional options.

Print on Part (P)

Supports direct-to-controller integrated ink jet printing for part marking systems and tag printers.

Bundle Print (B)

Supports direct-to-controller integrated bundle ticket printing.

Extended Macro (M)

A standard XL200 series controller can be programmed with as many as 25 macro patterns using pattern numbers 975-999. Those requiring more macro patterns add the M option, enabling the customer to access as many as 350 macro patterns. With this option, the range of extended macro patterns is 650-999.

Auxiliary/Slave Controller (S)

An auxiliary controller can be used when the S option is purchased. With this option, the XL200 series controller supports up to 8 downstream controllers.

Analog (AA)

This option allows the operator to vary line speeds automatically depending on the length of the part being produced. Analog output is proportional to part length for flying die lines. Allows full control of speed and direction for open loop feed-to-stop lines.

Alternating Press (L)

Allows two presses to be defined as one press. The controller will automatically distribute press targets between the two presses. Often used on stud lines that run at high speeds to avoid overlapping punches.

Brake and Hump (U)

Supports brake and hump lines.

Hydraulic (Y)

Closed loop hydraulic support.

Multi-Axis (X)

Support for Y/Z axis positioning.

Tube Mill (T)

Supports continuous operation machines such as tube mills and extrusion machines.

Continuous Press Option (C)

Continuous press support for a closed loop feed-to-stop.

SERCOS (O)

SERCOS II, Class C interface support for closed loop.

PLC Interface (I)

PLC integration using Modbus protocol. Most I/O can be memory mapped to PLC, high level data can be published from controller to PLC.

Flying Gags (F)

Supports multiple gags on a closed loop flying die.

Hole Detect (H)

Provides hole detect functionality. The controller will detect the leading edge of a piece of material, detect a single hole, or detect and count a series of holes.

Fleece Applicator (KMF)

Supports KMF fleece applicators.

Rotary (RE)

Rotary support for closed loop flying applications. The following press types are supported: rotary, crank, eccentric, and linear.

Multi-Hit Die Accelerator (MHA)

Supports a closed loop flying die line that can fire on multiple targets during die stroke without returning home between targets.

Dual Multi-Hit Multi-Press Die Accelerator (MHA2)

Supports two closed loop flying dies that can fire on multiple targets during die stroke without returning home between targets. Supports two closed loop flying die axes.

Dual Rotary/Crank/Flying Die (MRE2)

Dual rotary/crank/flying die software. Each axis can be configured with any of the three options. The following press types are supported: rotary, crank, eccentric, and linear.

Stick-Fed (SGF)

Supports a stick-fed line (servo grip feed or servo feed rolls).

Spiral Duct (SPD)

Supports a spiral duct machine. Open loop feed-to-stop only.

How to Find the Customizing Switches
Setting the Customizing Switches

Troubleshooting: Understanding the Part Queue

If there's one aspect of AMS machine controllers that generates the most confusion for Machine Operators, it is the Part Queue. This functionality leads to a great deal of misunderstanding in terms of why the machine controller does what it does, and subsequently, often leads to frustration among Machine Operators, as well as excessive scrap generation.

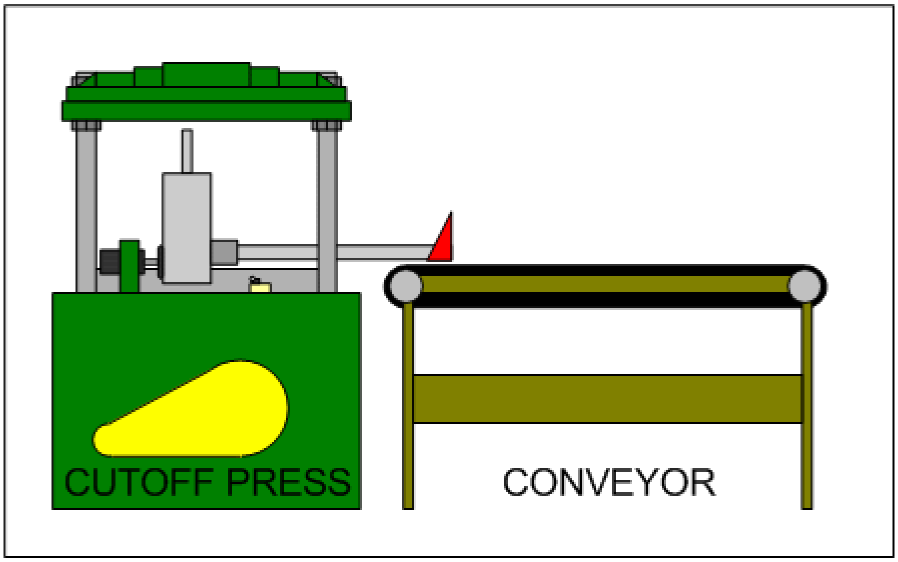
With understanding, production errors and scrap can both be minimized, thus eliminating frustration felt by Operators and Production Managers, alike. In order to understand what the Part Queue is, it is first important to understand *why* it exists at all.

Why do I have a Part Queue?

The Part Queue is a section of the machine controller's memory allocated to pre-calculating targets for punching, shearing, and printing (Ink Jet or Impact - Printing directly onto the part). The **purpose** of the Part Queue to allow the machine controller to change lengths, punch patterns, and print messages on-the-fly without requiring the production line to stop and without generating scrap.

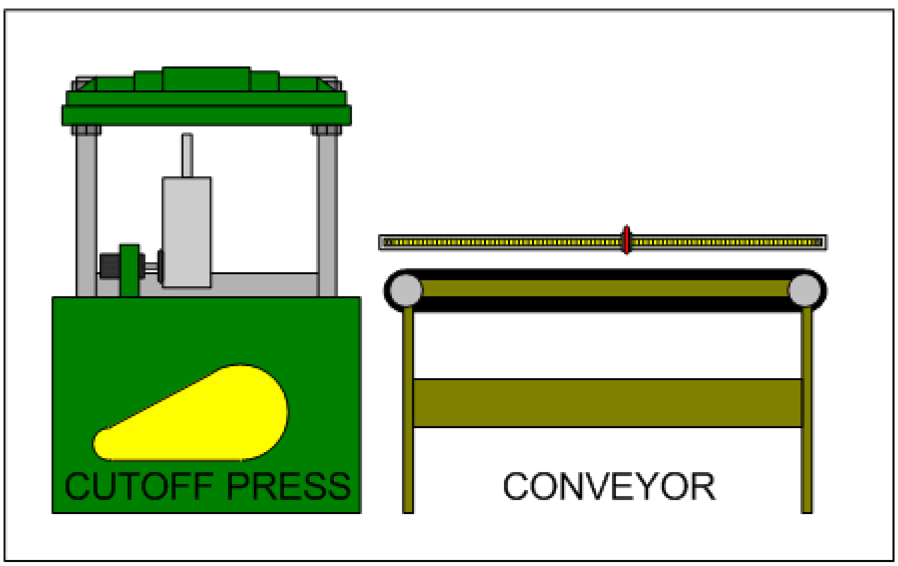
History

For decades, length control on flying die roll forming lines was accomplished through the use of gauge bars or a flag switch. A gauge bar was a bar pre-cut to the length desired for the finished product and mounted to the exit of the cutoff die. A stop (or flag) would be mounted to the end of the gauge bar. When the line was in motion, the leading edge of the material would catch on the flag, dragging the die forward. At some point in the travel the die would contact a switch that would fire the cutoff press. Springs or some kind of air actuated return cylinder would drag the die back to its home position between cuts. When a new length is desired, a new gauge bar is mounted in place of the old bar.



Gauge Bar Length Control

Similarly, a flag switch cutoff system used a flag tied directly to the switch that fired the cutoff press. In this case, when the leading edge of the material contacted the flag switch, the press would fire to cut off the finished part. The entire flag switch assembly is often mounted to a graduated tape measure, which in turn is mounted to a board or bar. This allows the operator to loosen the flag switch, slide it to a different position to cut a different length.



Flag Switch Length Control

The benefit of these types of length control is repeatability. Lengths controlled mechanically by physically tying part length to the press operation yields an extremely consistent result.

The costs often outweigh the benefit in these systems, because running the line too fast can damage the part or physically destroy the flag (ripping it off the switch of the end of the gauge bar). Worse, length changes require the line to stop, and when using a flag switch the operator must often trial several parts before getting the new length right. This generates scrap and downtime.

Physical Length Control

Benefits

- Accurate and consistent lengths

Problems

- Reduced throughput
- Increased downtime
- Increased scrap

The Solution (XL200 Series)

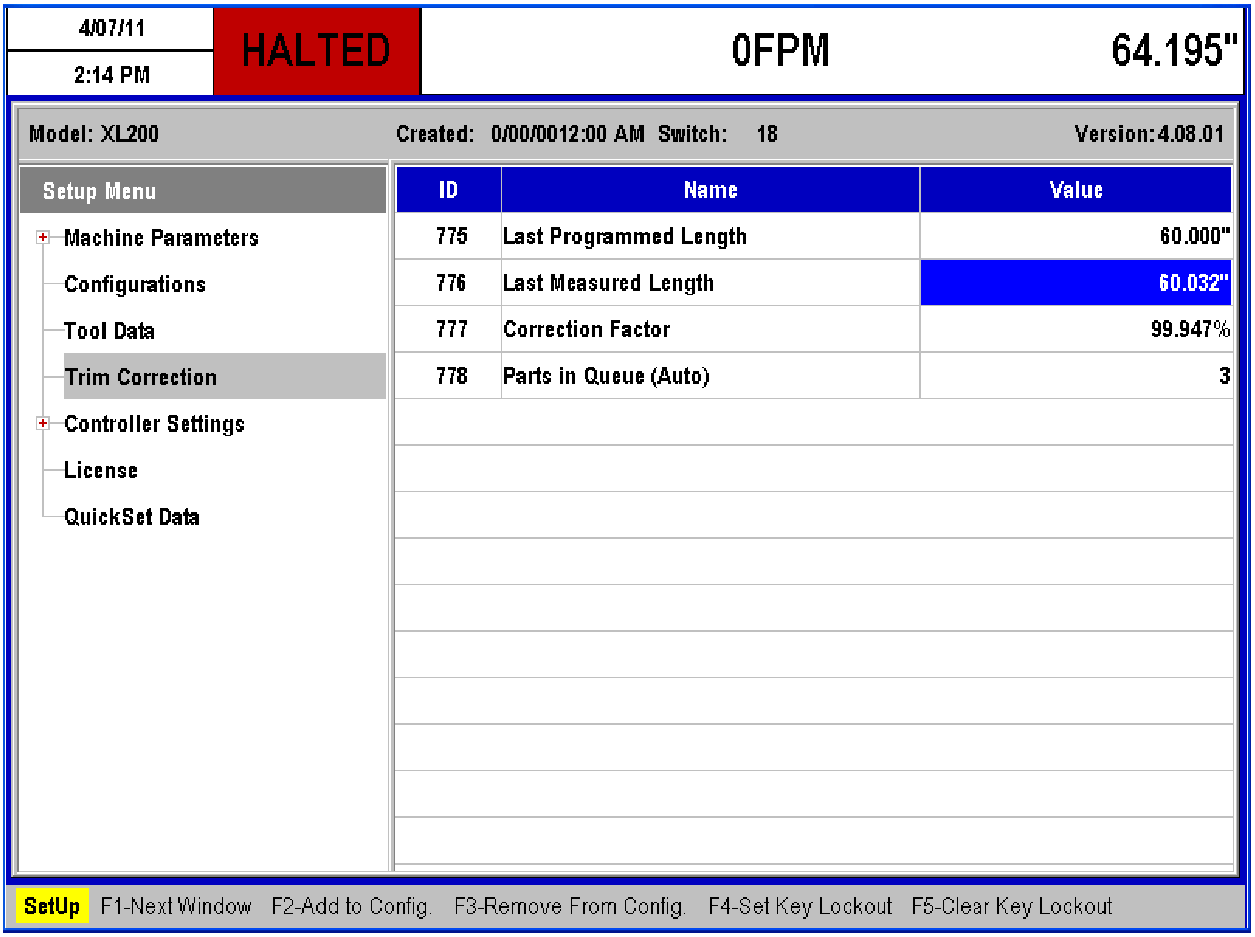
In order to handle changes on-the-fly and avoid generating scrap, AMS Controls created machine controls with a Part Queue (or Queue). The Queue allows the machine controller (or XL200) to cleanly transition between parts without stopping production or generating scrap between parts.

When the Operator puts the machine into Run, the XL200 calculates at least 2 parts worth of punch, print, and shear targets before putting the line into motion. This process takes fractions of a second.

The XL200 is programmed with the physical layout of the machine, including the real world distances between the cutoff and the punch tools. Information regarding the parts are keyed in by the operator or (preferably) downloaded from an upstream system. With all of this information, software has everything it needs to make part changes on-the-fly.

Parts in Queue

There are two distinct versions of Queue functionality – Shear Only machines and Punching/Printing machines. The specific machine application type dictates the size and operation of the Queue. The XL200 displays the number of Parts in Queue in the Trim Correction menu (Setup\Trim Correction). This is to alert the Operator to the fact that changes made in programming (Tool Distances, Punch Programming, Calibrations, etc.) will only take place ***after the Queued parts exit the machine***.



Screenshot of XL200 Calibration Menu

Shear-Only

For machines where the XL200 only controls a cutoff press (no punching, no printing), the Part Queue always consists of 2 parts. Thus, programming changes that are made on-the-fly (while the XL200 is in the Run mode) will only take place on parts as they enter the Queue. Parts that are already Queued will not reflect programming changes.

Since a shear-only machine performs no operations on the material that require the cut point to be referenced, each time the machine halts (exits Run mode), the XL200 dumps (or clears) the Queue. When the machine is put back into the Run mode by the Operator, the Queue is re-filled based on all current settings and changes made while the machine was halted. Those changes are immediately reflected on the first finished part.

Punching/Printing

For punching/printing machines, the Queue is maintained when the machine exits Run mode. XL200 controllers treat Ink Jet and Impact printers as if they were punch presses for the purpose of calculating targets on a finished part. For many end-users, the placement of a print message on the part is as critical as the placement of a punched hole for other users. For this reason, even if a machine only has a cutoff press and a printer, print targets must be maintained in the Part Queue when the line is halted.

For punching lines, the placement of holes on the part with reference to the cut point can be extremely critical. If the XL200 did not maintain targets in the Part Queue when the line halted, those targets would be lost and scrap would be created. The amount of scrap would always be equal to at least the distance from the cutoff to the farthest upstream punch tool.

Also, the number of parts in Queue will often be more than on a shear-only machine. The size of the Queue will fluctuate based on the real-world physical distance between the farthest tools controlled by the XL200, and the lengths of the parts being cut. For instance, if the physical distance between a punch press and a cutoff press was 800”, and the finished part lengths were 10” long, the Part Queue would have to be at least 80 parts. Since the controller always Queues at least 1 more parts than it needs, the Part Queue would be a minimum of 81 parts. Thus, changes applied to the XL200 would not show up on the parts until at least 81 parts exited the machine.

It is this functionality that allows the XL200 to seamlessly change punch patterns, print messages and lengths on-the-fly without stopping or generating any scrap. The Part Queue can expand and contract as needed and this happens automatically with no input required from the user other than the standard programming functions.

How can the Part Queue Cause Confusion?

For Machine Operators, the Part Queue can be the source of confusion and frustration if they don’t understand the relationship between what they are currently doing, and when they can expect their changes to be implemented by the XL200 controller.

For many Operators, especially in production facilities with multiple machine application types, one machine might seem to apply calibration changes immediately (shear-only line calibrated while halted), but another machine might cut several parts “before calibrations take effect”.

What many Operators learn is that “double cycling the shear” (firing the shear manually twice in a row while the line is halted) forces the XL200 to apply changes immediately. This often leads operators to force the Queue to be cleared for their own satisfaction and understanding when it isn’t necessary. On a punching line, forcing the Queue to clear will generate as much scrap as the distance from the shear to the farthest upstream punch tool.

Calibration

Length calibration is a key function where confusion regarding the Queue comes into play for Operators. Punching/Printing lines will always require the Operator to wait for a few parts before a calibration takes effect. Shear-only lines will require the Operator to wait, but only if he performs the calibration on-the-fly.

Regardless of the machine application type or the state of the machine, the XL200 always displays the Parts in Queue in the calibration screen to let the operator know how many parts he must produce before he sees his calibration take effect. As long as the parts produced are still within tolerance, this shouldn't create a need to generate scrap parts. If part lengths are out of tolerance, then the Operator might as well force a clear of the Part Queue, since any parts made would be scrapped, anyway.

Manual Shear Due to Material Buckling

Sometimes minor mechanical issues during the production process will cause a part to "hang up" in the cutoff press tooling. This situation might cause a complete jam up, or it might only deform the current part. If the issue is minor and the operator can clear the issue without scrapping all the parts in the entire machine, often he will do so by jogging the defective material past the shear and performing a Manual Shear operation.

During normal circumstances, a Manual Shear references the cutoff to the material and perhaps to a "home switch". This is true when threading a new coil of material for the first time. In this case the readout on the XL200 shows zero (0.000").

When dealing with a punching/printing machine, the distances of all the tooling could be quite large (300' or more). Performing a single Manual Shear on the material would be enough to cut out the bad material sticking out past the cutoff, yet maintaining all the rest of the punched material between the cutoff and the farthest upstream punch. In this case, should the operator perform a single Manual Shear operation on the material, the controller will continue to read the last known material length sticking out of the cutoff. This is intended to be a visual indication for the Operator that the XL200 "knows" is must complete the rest of the current part.

When the operator performed his single Manual Shear, the controller automatically counted the distance past the shear as scrap. When the Operator puts the line back into the Run mode, the XL200 will complete the current part at its original cut point and count the rest of the part as scrap at that time. After that, the XL200 will immediately begin producing good parts based on all the punched material still inside the machine.

Unfortunately, due to the lack of understanding regarding the Part Queue, many Operators assume the XL200 has a software problem, because it doesn't display zero after the single Manual Shear. The Operator will then perform a second Manual Shear operation, forcing the XL200 clear the Part Queue, and thus scrap out all good product in the machine. This is a common misunderstanding.

Switching Orders On-the-fly

In the XL200 series machine controller, the operator can change the sequence of orders produced through several different methods. He can actually re-sequence the orders from the Program menu, or he can use the "Set to Next" feature from the Status menu.

Sometimes, a situation will arise where the operator wants to skip the next order and produce an order farther down the sequence. Rather than re-sequence the order list, he'll wait till the machine produces the last parts of the current order, then he'll navigate down the list, find the desired order and set the first cutlist item to "**Next**" (F2 – Set to Next).

If his machine is a punching/printing machine, often he is confused and frustrated because the machine will immediately produce a few parts from the order that was immediately after the last order in the production sequence. This happens when multiple orders have the same Material Code and Product Code values. If the material and tooling don't change, there's no reason the controller shouldn't begin queuing the parts from the next order in the sequence. This prevents scrap between parts/orders, and potentially allows the machine to continue producing the next order without halting the line (depending on the automatic halt settings).

The XL200 actually displays the fact that it has begun to Queue up the parts in the next order by changing the status of the cutlist items to "**Fill**" – indicating *"I have filled some of these parts into my Queue"*.

When this happens, the controller produces the few parts in the Queue, counts them as "**Done**", and then moves into the next order as indicated by the Operator, however, many Operators are confused by this and assume the software is in error. Operators will often halt the machine and perform a double Manual Shear operation (clearing the Part Queue and generating scrap). They see that the XL200 immediately begins working the order they originally desired, but they don't make the connection that they just created several feet of scrap, and possibly wasted 2 or more parts that were perfectly good.

The correct reaction to this situation would have been to simply set the "in between" parts aside until the operator comes back to that order, and then re-insert the finished parts into his bundle.

Summary

The Part Queue is a section of the XL200 series controller memory used to pre-calculate punch, print, and shear targets for finished parts. It allows the controller to change part length, punch pattern, and print message on-the-fly.

Due to the physical distances on a roll forming line, and the desire to avoid unnecessary scrap and downtime, the relationship between the Part Queue and what's happening on the machine can be difficult for Machine Operators to comprehend without additional training. This leads to situations where the controller is perceived to be erratic or arbitrary in its functionality.

When the human Operators misperceive the XL200 controller functionality, the result is often unnecessary scrap and downtime. Appropriate training and understanding of the functions and why they are important avoids waste and production errors.

Navigating the Controller Software

Introduction to the Status Screen

Program an Order

1. Press [Program].
2. Press **[End]**.
3. Press **[F2]** to add an order.
4. Enter the **order number** and press **[Enter]**.
5. *(optional)* Enter the **material number** and press **[Enter]**.
6. *(optional)* Enter the **product code** and press **[Enter]**.
7. Enter the **bundle number** and press **[Enter]**.
8. Enter the **quantity** (Qty) and press **[Enter]**.
9. Enter the **part length** and press **[Enter]**.
10. *(Punching Only)* Enter the **pattern number** and press **[Enter]**.
11. Repeat steps 7 - 10 until the entire cut list is entered.
12. Press **[Status]** to return to the Status Screen.

Edit an Existing Order or Item

1. Press [Program].
2. Select the **order number** (if used) and press **[Enter]**.
3. Select the **order data** *or* **cut list item** to be edited.
4. Select the **specific data** to be edited.
5. Enter the **value** and press **[Enter]**.
6. Press **[Status]** to return to the Status Screen.

Change the Sequence of Items Within an Order

1. Press [Program].
2. Select the **order number** to be re-sequenced.
3. Select the bundle item to be moved.
4. Press **[Move Up]** or **[Move Down]** to move the item.
5. Repeat for any other items.
6. Press **[Status]** to return to the Status Screen.

Remake an Item

1. Halt the line.
2. Press [Status].

3. Select the desired done or partially-done **bundle item**.
4. Press **[F4]** to re-make the order. The *Remake Item/Order pop-up window* displays
5. In the **Number of Pieces Field**, enter the quantity of pieces you want to remake (the field pre-fills with the quantity of the selected item already done).
6. Press **[OK]** to save the remake
   or
   press **[Cancel]** to stop the remake.

Delete a New or Done Order or Item

1. Press [Program].
2. Select any **order** or **bundle item** with a status of READY.
3. Press **[F3]**. The selected order or item is deleted.

Note: All DONE orders/items are erased automatically after the number of days set in Auto-Delete Done Orders have elapsed.

Set the Next Line to Run

1. Halt the machine.
2. Press [Status].
3. *(Punching Only)* Cycle the shear twice to clear the target queue.
4. Select the desired **bundle item** to run (the item must have a status of READY or SKIP).
5. Press **[F2]**. The selected bundle item is set to be next.

Create a Pattern *(Punching Only)*

1. Press [Program].
2. Press **[F6]**. The *Pattern Editing screen* displays.
3. Press **[F2]**. Enter the **pattern number** and press **[Enter]**.
4. Press **[F1]** to toggle from menu window to detail window.
5. In the Tool ID field, enter the **tool number** and press **[Enter]**.
6. From the Reference drop-down, select the **reference** for the tool and press **[Enter]**.
7. Enter the **offset** and press **[Enter]**.
8. Enter the **Y-Reference** and **Y-Offset**, if applicable.
9. Repeat steps 5 - 8 until the pattern is complete.
10. Press **[F1]** to toggle to the main window to enter more patterns.
11. Press **[Status]** to return to order programming.

Edit a Pattern *(Punching Only)*

1. Press [Program].
2. Press **[F6]**. The *Pattern Editing screen* displays.

3. Select the **pattern** to edit.
4. Select the **data** to edit.
5. Enter the **new value** and press **[Enter]**.
6. Press **[Status]** to return to the Status Screen.

Delete a Partially Completed Order or Item

1. Halt the machine
2. Press [Status].
3. *(Punching Only)* Cycle the shear twice to clear the target queue.
4. Select the **bundle Item** to produce next and press **[F2]**. Its status changes to NEXT.
5. Press [Program]
6. Select the partially completed order *or* item.
7. Press **[F3]**. The line is deleted.

Note: Deleting partially completed orders or Items causes them to show as UNSCHEDULED in Eclipse.

Increment Quantity During Run Mode

1. Select the bundle Item currently running.
2. Press **[Inc. Qty.]** (Increment Quantity).
3. (*Eclipse users only)* Select **scrap code** from the pop-up menu.
4. Select **[OK]** to accept the scrap code.
5. Press **[Inc. Qty.]** as many times are needed to make the required number of additional parts.

Decrement Quantity
(Identifying Scrapped Parts as Good Parts)

1. Halt the line.
2. Highlight the **bundle item** to be decremented.
3. Press **[F5]**. The Decrease Quantity pop-up window displays.
4. In the **Number of Pieces** field, enter the number of pieces to decrement. Press **[Enter]**.
5. In the **Coil to Adjust Footage** field, enter the number of the coil you're adjusting footage for and press **[Enter]**.
6. Press **[OK]**. The pop-up closes and the quantity displayed in the Done field for the selected item is increased.

Skip an Item to be Run

1. Press [Status].
2. Select an **order** or **item** with a status of READY.

3. Press **[F3]**. The item's status changes to SKIP.

Load a Coil

1. Press [Production Data].
2. Select **Coil Inventory** from the main menu (left pane).
3. Press **[F2]**.
   - *If a coil is currently loaded,* the *Unload Current Coil pop-up window* displays.
     - Select **Return Coil to Inventory** if material is left on the coil.
       or
     - Select **Coil was Completed** if the coil was completely used.
     The *Load New Coil pop-up window* displays.
   - *If no coil is currently loaded,* the *Load New Coil pop-up window* displays.
4. In the **Coil** field, enter the ID of the coil to load.
5. Press **[OK]**. The coil inventory is updated to reflect the changes.

Note: If the controller features a sheet detect switch, the pop-up window displays automatically, without proceeding through steps 1-2.

View Coil Inventory

1. Press [Production Data].
2. Select **Coil Inventory** from the main menu (left pane). Coil information displays in the detail window (right pane).
3. Press **[Status]** to return to the Status Screen.

Perform a Calibration Trim

1. Press **[Setup]**.
2. From the main menu (left pane), select **Trim Correction**.
3. In the **Last Measured Length** field (right pane), enter the last measured length and press **[Enter]**. The *Update Correction pop-up window* displays.
4. Select **[Yes]** to update the correction, or **[No]** to cancel the correction update.
5. Allow 2-3 parts to run before the change occurs.
   or
   (Punching Only) Halt and cycle the shear twice for the correction factor to take effect immediately.

Note: Perform this procedure only when part lengths are consistently short or long; otherwise, contact maintenance.

View Inputs and Outputs

1. Press [Diagnostics].
2. From the main menu (left pane), select **Input/Output**.
3. Press **[F1]** to toggle the view to the I/O information in the right pane.
   - Use **[Page Down]** and **[Page Up]** to scroll through the list.
4. Press **[Status]** to return to the Status Screen.

Set the Time Clock

1. Press **[Setup]**.
2. From the main menu (left pane), select **Controller Settings**.
3. Press **[→]** (right arrow) to expand the left pane's view.
4. Select **Clock/Calendar**. The right pane displays only the clock and calendar parameter fields.
5. Select a parameter to edit, enter its new value, and press **[Enter]**.
   - Repeat for each parameter until all are set as required.
6. Press **[Status]** to return to the Status Screen.

Note: If connected to an Eclipse PC, the controller time is updated to match the Eclipse PC's time.

Tailout Sensor

Understanding the Tailout Sensor

This document details the usage of the Tailout input to the XL200 Series machine controller. Proper use of this input keeps scrap tracking accurate when loading and unloading coils on a roll former. It minimizes the amount of paperwork required by the Machine Operator for the purpose of recording scrap material. The Tailout input is also a critical component in the Coil Verification functionality in Eclipse.

Tailout is an input to the XL200 controller. This input is designed to come from a material sensing device located on the roll former, near the material encoder. The input serves four functions in the controller:

- Reference of New Coil to Avoid Erroneous Reporting of Startup Scrap
- Automatic Prompt of Load/Unload Coil
- Automatic Halt at End of Coil
- Proper Reporting of Scrap at End of Coil

Reference of New Coil

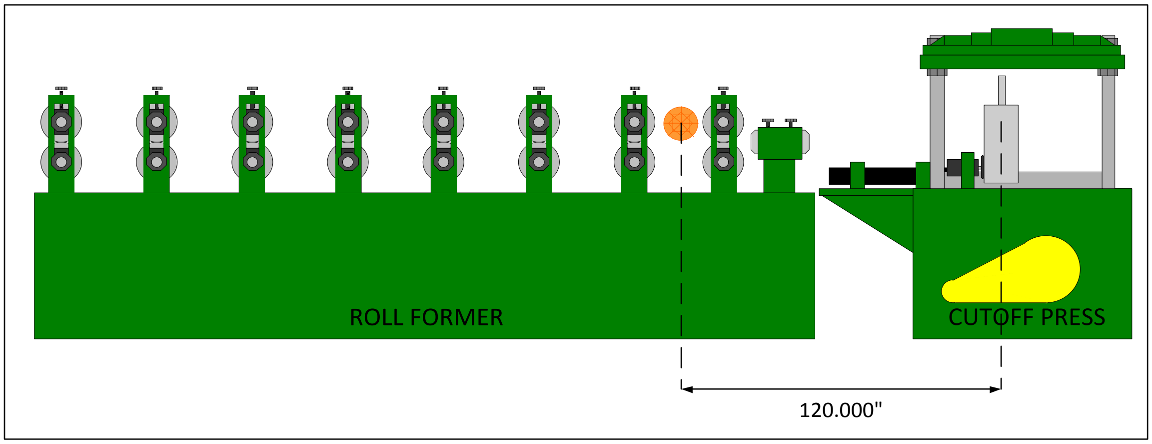
Tracking startup and end-of-coil scrap on each coil is important from the perspective of Purchasing and Production efficiency tracking. For many companies, the scrap generated at coil change is usually accounts for the highest percentage of scrap from the entire process. When using the XL200 and Eclipse production management system, the equipment must be setup properly with a Tailout sensor and the machine controller must have accurate settings. Otherwise, the scrap reports generated for Production and Purchasing can be wildly inaccurate.

In most applications, when the Operator loads a new coil he must jog some amount of material past the cutoff and perform a standing cut. The outer wrap of the coil might be damaged due to shipping and handling, or the leading edge of the material must be squared to the cutoff tooling to produce the first good part. This function also serves to reference the cutoff to the material for the length control system.

Let’s examine what happens when the operator loads a new coil onto a post cut roll forming line:

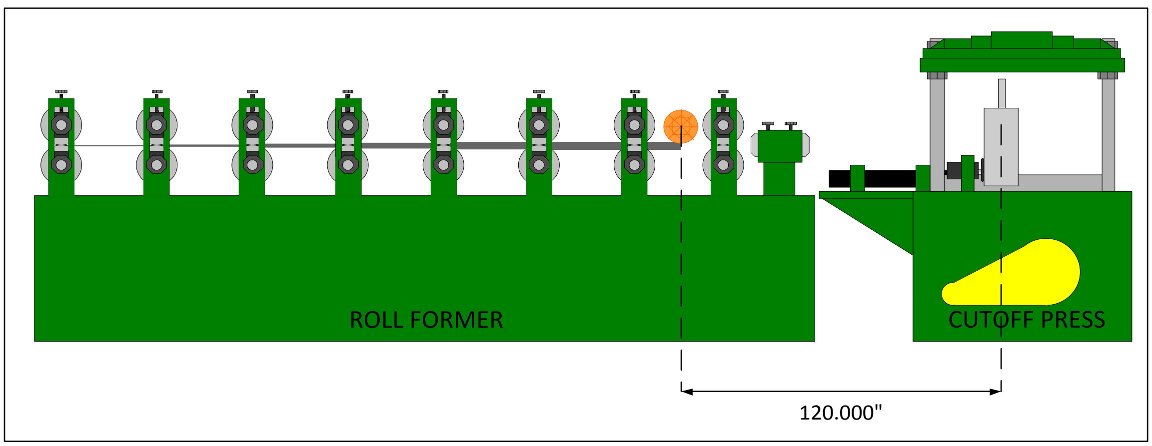
Example 1

> For the purpose of this example, we’ll assume the coil is in pristine condition and that the Operator simply needs to square up the leading edge of the coil. The amount of startup scrap should be minimal. We’ll begin by examining what happens on a machine that does *not* have a Tailout sensor mounted. The machine is empty (no material loaded), and the XL200 currently reports 0.000” past the shear. Note the physical distance from the encoder (the device that measures material) to the cutoff at home position (120” or 10’).



Post Cut Roll Former Ready for New Coil

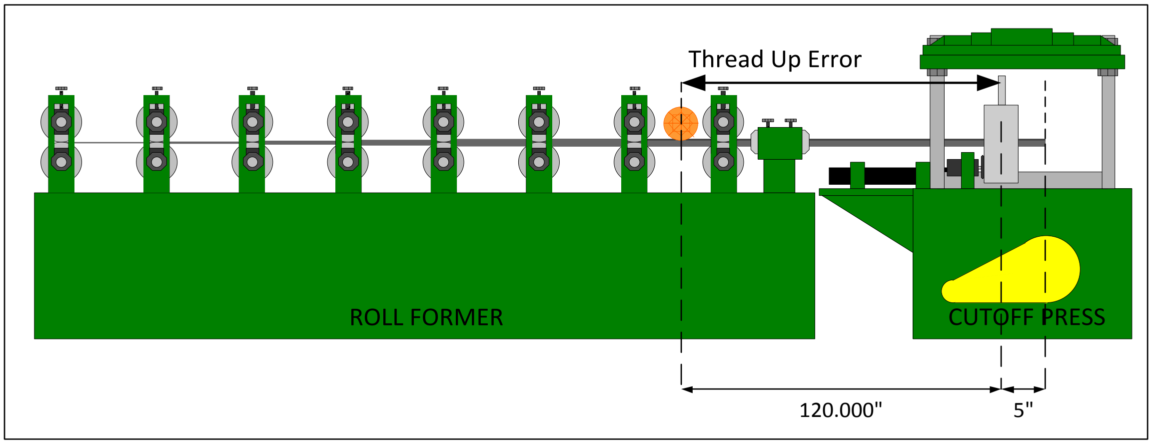
The Operator begins by loading a new coil. He threads the leading edge of the coil into the first set of rolls on the roll former, and then he jogs the material through the machine. This is often called "thread up".



New Coil Partially Threaded Through Roll Former

As previously stated, this coil was in excellent condition, so the Operator only needs to thread a few inches of material past the cutoff blade in order to square up the leading edge. In this case, he'll jog 5" past the cutoff.

The problem in this scenario is when the Operator was threading material into the roll former the control system was powered ON along with the rest of the machine. As the material flowed under the encoder wheel (measuring device), the wheel was turning. So, by the time the operator jogs 5" past the cutoff, the XL200 controller has seen 125" of material pass the encoder, and it reports that amount on the screen.



Reporting Error Due to Encoder Placement Distance

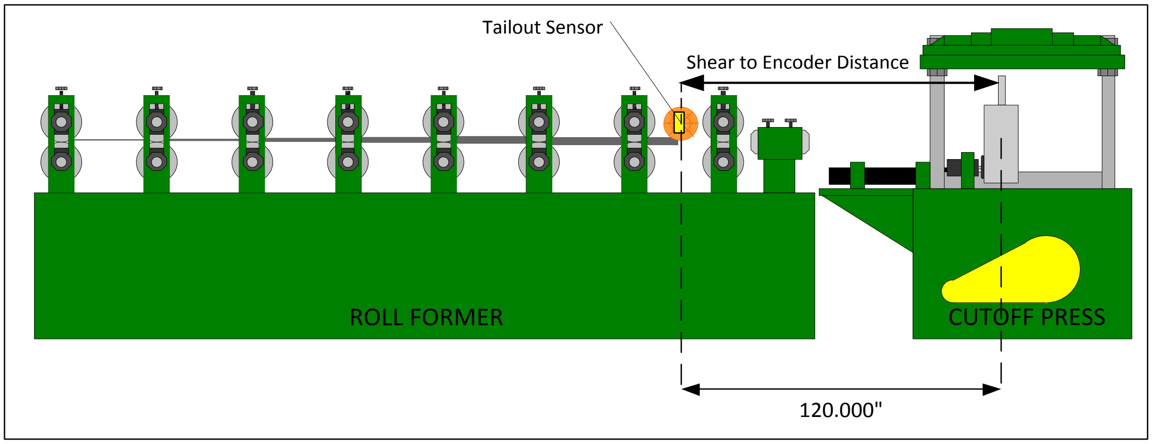
> When the Operator performs a Manual Shear operation on the material, the XL200 automatically reports any material past the cutoff as scrap to Eclipse. - in this case, 125” of scrap. Since this machine did not have a sensor to detect the presence of the material, the XL200 had no way of knowing how much material was actually scrapped. It erroneously reports 10’ more scrap than was actually produced from the beginning of the coil.

The situation described in *Example 1* is precisely the reason the XL200 has a Tailout input, as well as a parameter called **Shear to Encoder Distance**. Many users mistakenly believe the **Shear to Encoder Distance** is somehow used to calculate good part distances. This is unnecessary. The physical distance from the encoder to the shear (cutoff) should be a straight line, usually consisting of formed material. Once the Operator performs a Manual Shear, the XL200 references the cutoff to the material. Any amount of material that passes the cutoff tooling at a given point in time will be exactly the same amount of material that passes the encoder at the same point in time.

The only purpose of the **Shear to Encoder Distance** is so the XL200 can *accurately* report scrap to Eclipse during coil changes. Now, let’s examine what happens during a coil change when a Tailout sensor is properly mounted and the **Shear to Encoder Distance** configured:

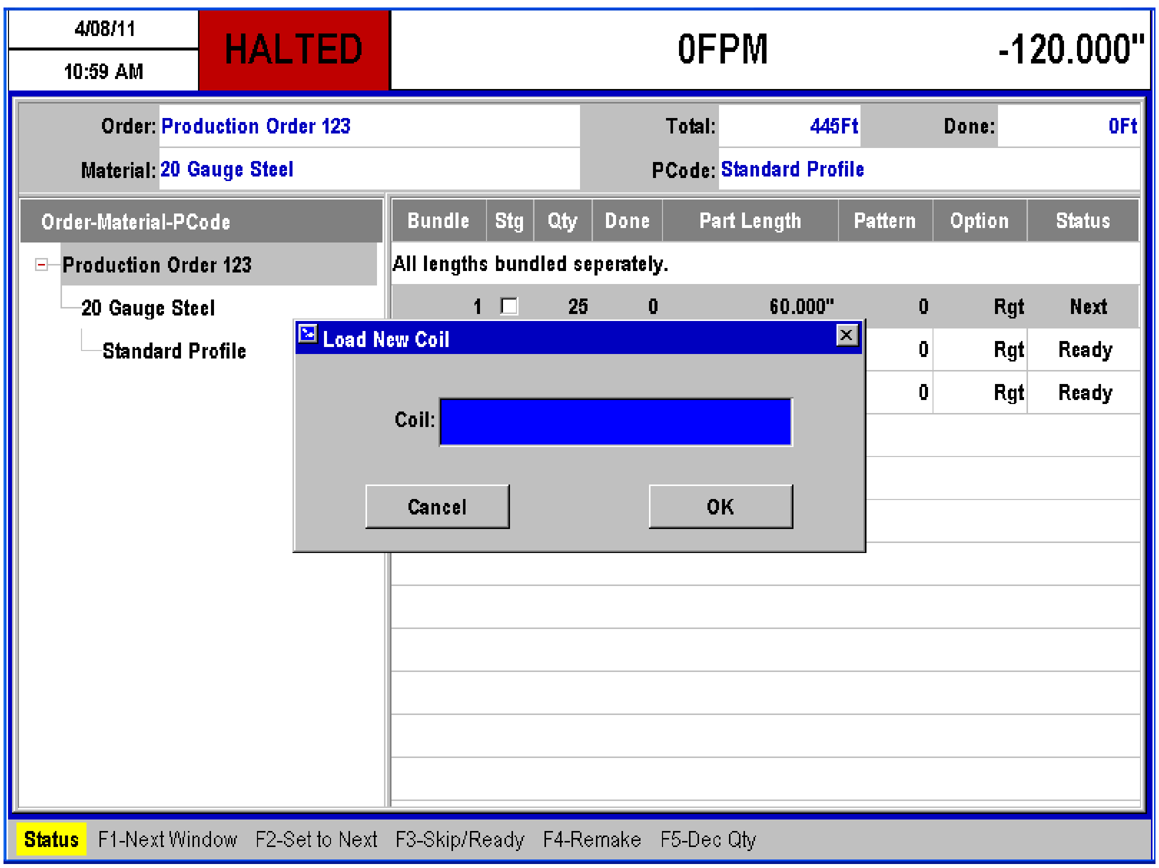
Example 2

> As in Example 1, the Operator has partially threaded a new coil through the roll former. This time, as soon as the leading edge of the coil reaches the encoder, it also triggers a Tailout sensor mounted at the vertical centerline of the encoder wheel. The placement of the sensor with regard to the vertical centerline of the encoder wheel is critical for accurate scrap reporting.



Tailout Sensor Triggered as Material is Threaded

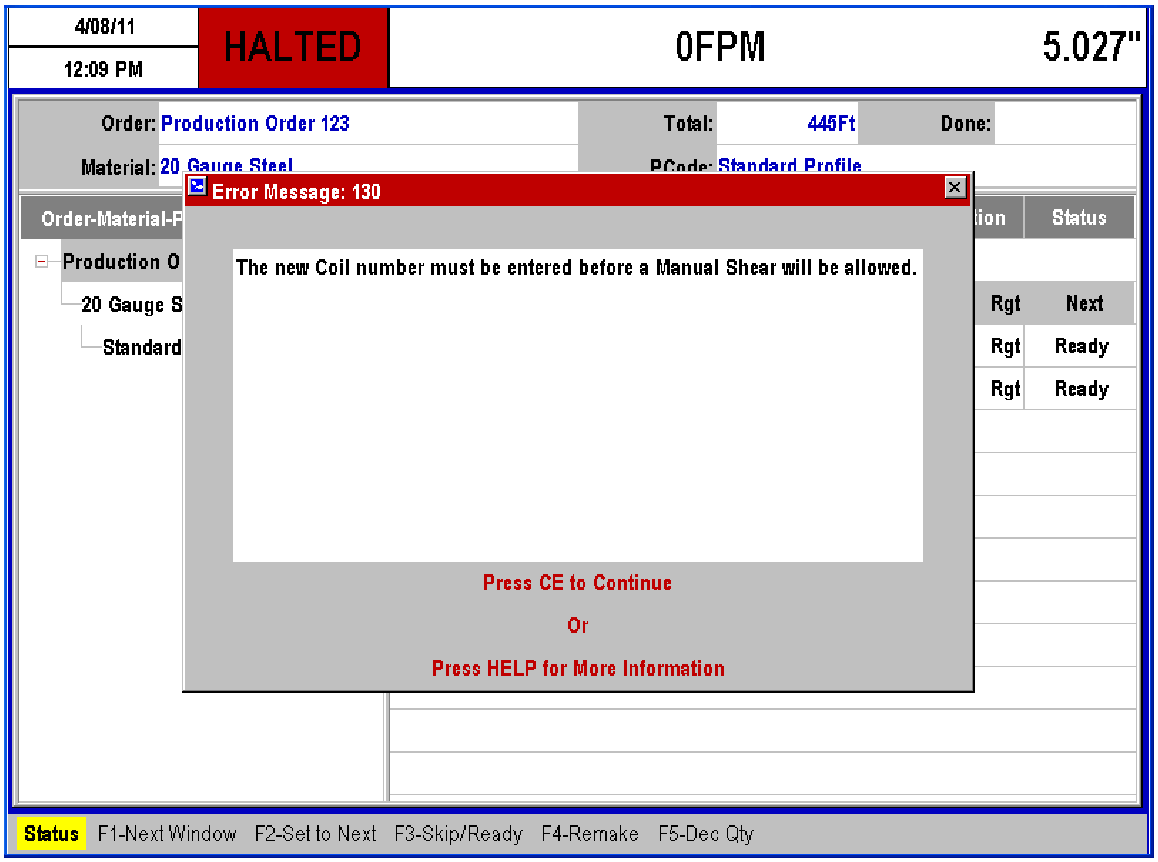
As soon as the sensor detects the leading edge of the material, two things happen at the XL200 controller; the length past the shear references to a negative distance equal to the **Shear to Encoder Distance**, and the controller automatically prompts the Operator for the new coil number.



Controller Referenced to Encoder Distance and Operator Prompted for New Coil

As the Operator continues to jog material forward through the roll former, the count on the controller screen should become more positive as the leading edge approaches the cutoff. When he jogs the leading edge 5” past the cutoff tool, the controller will accurately report 5”.

After threading the roll former, the Operator will stand before the XL200 to perform the Manual Shear operation to trim the leading edge of the coil. This time, he has a visual prompt on the screen requesting the new coil inventory number. If the Operator ignores the prompt, the XL200 software enforces the procedure and will not allow a Manual Shear until the new coil’s number is entered. This prevents scrap from a new coil from being counted against the last coil.



Software Enforcement of Procedure

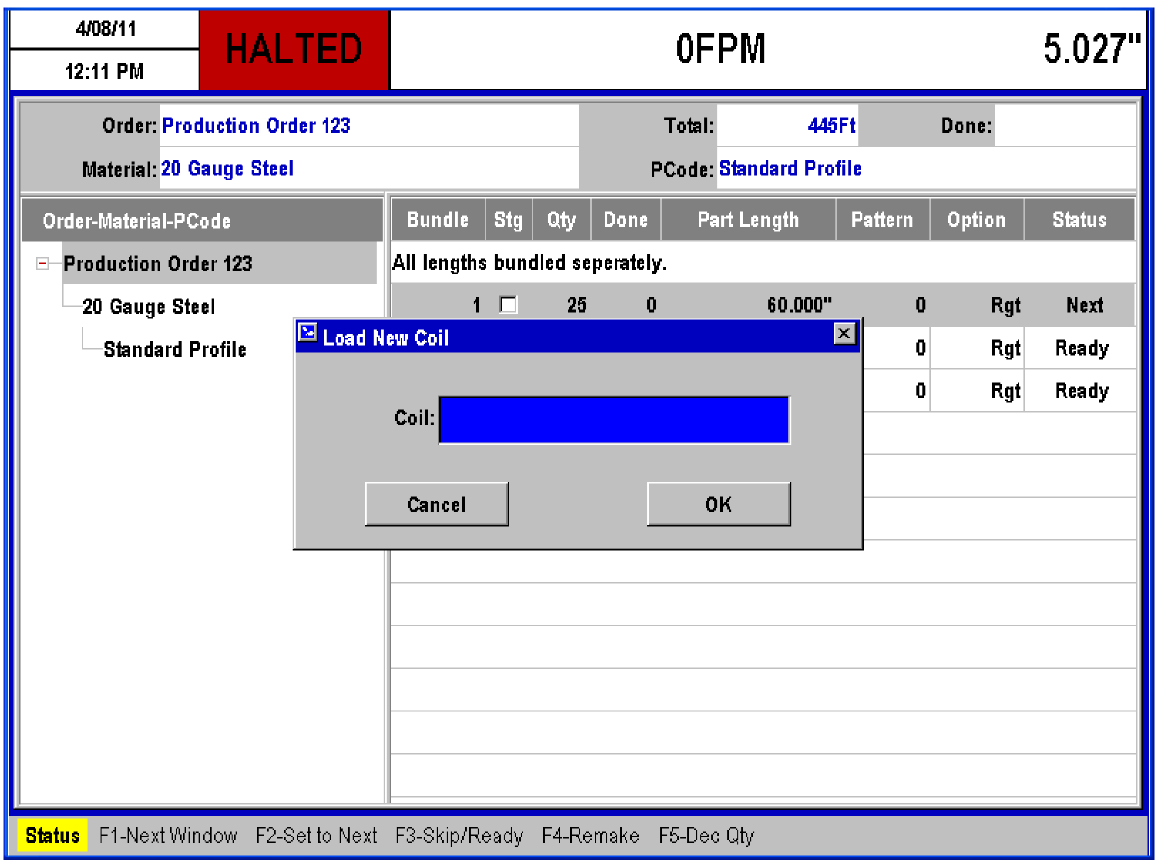
The Tailout input, in conjunction with the **Shear to Encoder Distance**, is used to correct the starting scrap on a new coil. The more accurate the distance measured from the point where the encoder wheel contacts the material to the back of the cutoff (shear blade), the more accurate the system will be when reporting scrap. Thus, the Tailout sensor should be mounted at the same vertical centerline as the encoder wheel.

Automatic Prompt of Load/Unload Coil

As seen in a preceding example (*Example 2*), one of the functions of the Tailout sensor is to automatically prompt a Machine Operator for a coil inventory number when loading a new coil. This allows Eclipse to accurately report raw material usage with regards to Coil Numbers, Order Numbers, Operator and machine performance, vendor performance, etc.

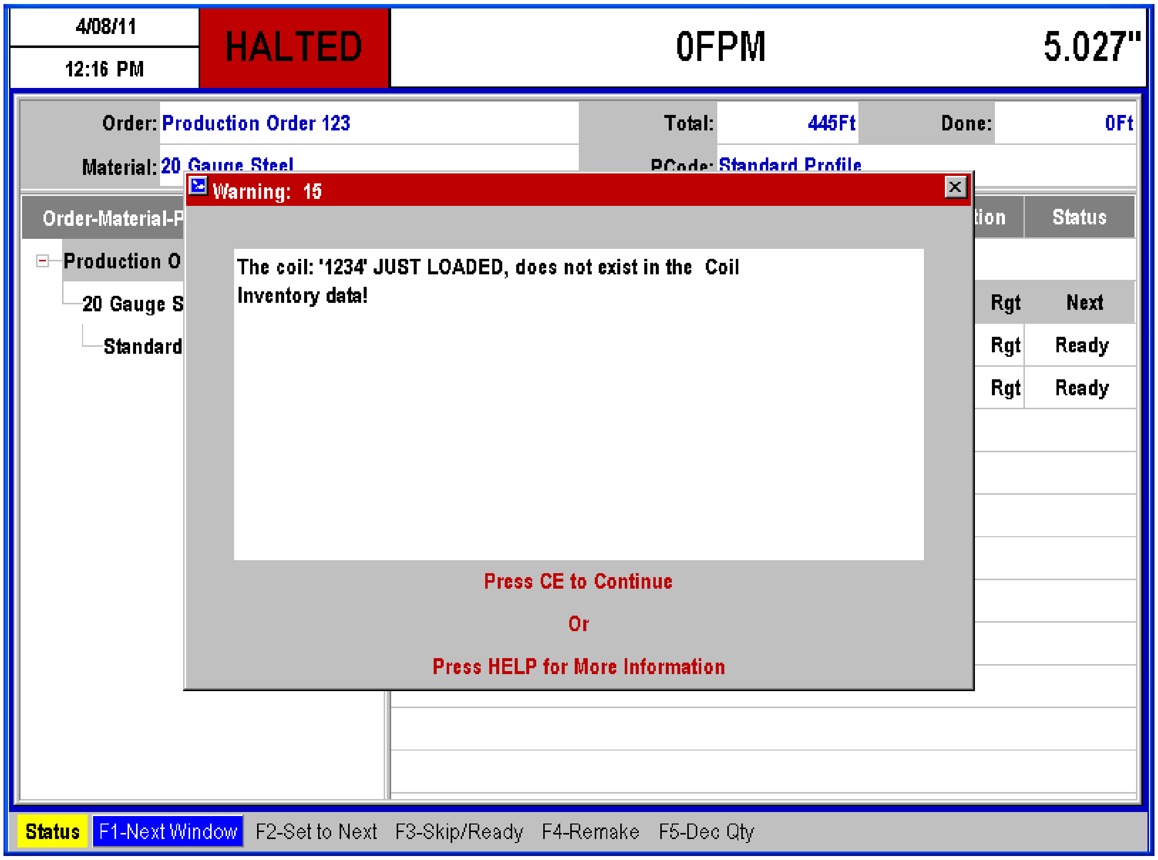
It also supports the Coil Verification feature within the Eclipse\XL200 system. When this feature is implemented, the system reports back to the operator on the current footage remaining on coils loaded, so the Operator can quickly decide if he has enough material on-hand for a batch of production. Software rules also allow management to enforce policies ensuring the correct raw material is used for every order.

The first time a XL200 controller receives the Tailout input (after a new startup, as a replacement unit, after memory clear), the machine Operator is presented with the Load New Coil window the first time he loads a coil onto the roll former:



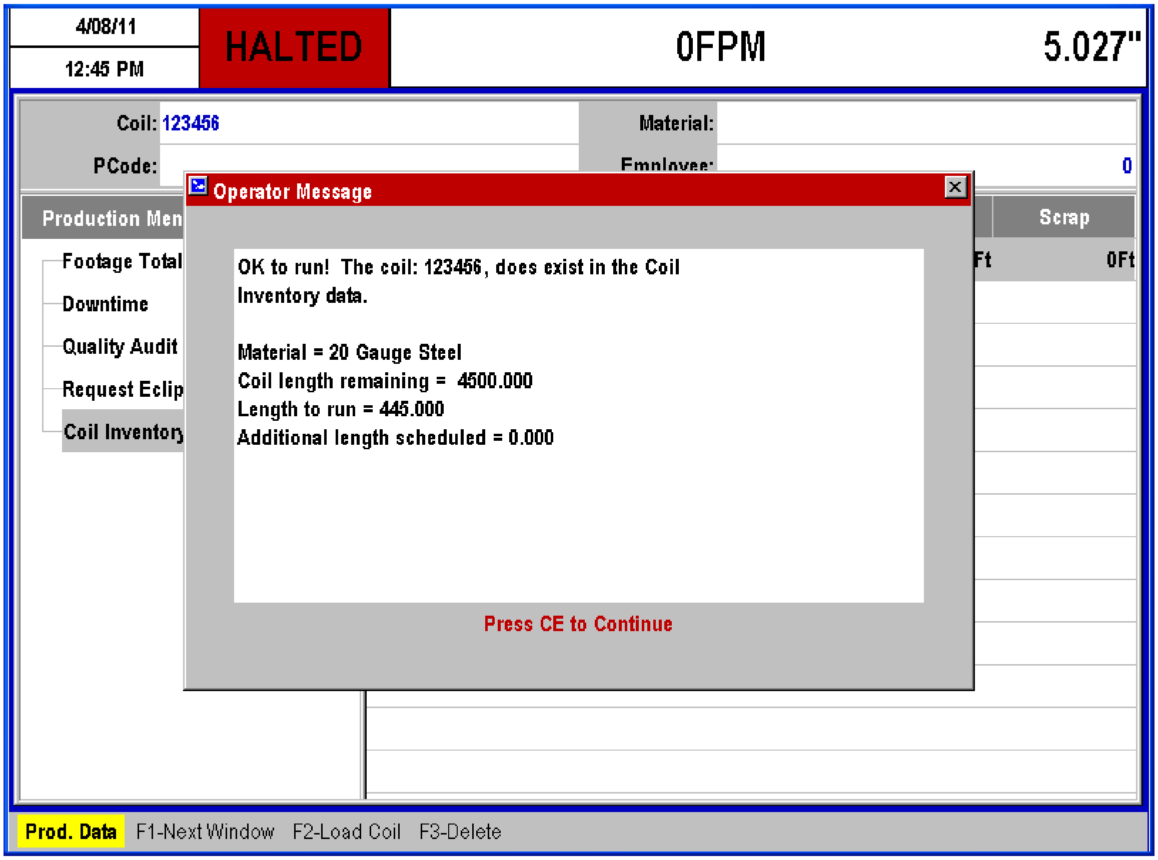
Automatic Prompt to Load New Coil

Once the operator enters the inventory Coil Number, the XL200 passes the number up to Eclipse to verify the coil exists in the system records. If not, the operator is presented with a warning message, indicating something must be done to correct the accounting error, or that the Coil Number was improperly entered:



Coil Number Entered Does Not Match Inventory

Once the inventory is corrected, or the correct coil number is entered, the system provides feedback to the Operator regarding the current coil's raw material, as well as the raw material needs of the production schedule:

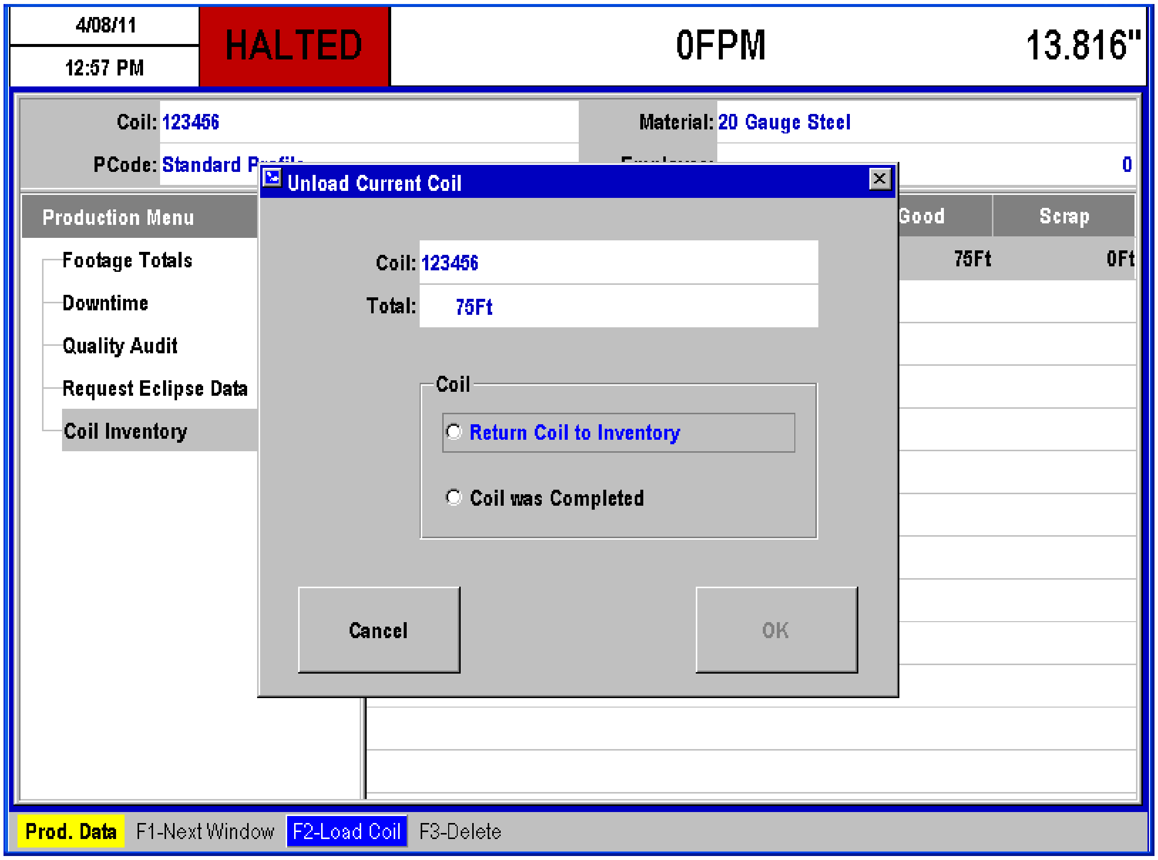


Operator Feedback from Eclipse Regarding Production Needs/Availability

In the example above, the Operator is presented with a message that indeed, the coil loaded exists in the company inventory. Additionally, he's notified that the amount of material remaining on the coil is more than sufficient to meet the needs of scheduled production.

If the *Length to run* or the *Additional length scheduled* exceeds the *Coil length remaining* someone could be notified to stage additional coils of the same material type, or other decisions could be made regarding the practicality of trying to complete the scheduled production with what's on-hand at the time.

So far, we've examined the process from the perspective of a first-time coil load. When a coil change is required, subsequent prompts from the XL200 first require the Operator to notify the system whether the last coil loaded was returned to inventory, or if it was completely consumed:



Unload Current Coil

Once the Operator tells the system the state of the last coil, he's re-presented with the Load New Coil prompt. Depending on the Operator's selection, Eclipse will update coil totals (and print a new coil ticket if this feature is used), or it will tabulate the final totals for the coil, zero its remaining footage, and tally any differences between the estimated length and the actual length consumed.

There are additional menus and options connected to the Coil Verification feature, but those are better described elsewhere in a separate, more focused document.

Automatic Halt

The XL200 controller can only cut or punch in automatic if the material is currently moving under the encoder wheel. Once the last inch of material has flowed passed the encoder wheel, the XL200 can no longer track punch or shear targets.

At the end of a coil (or at the **Coil Endpoint**) when the trailing edge of the material passes the Tailout sensor, the sensor toggles to its "On" position and the controller automatically exists of the Run mode. At this point, no more encoder motion is accepted by the controller - if the machine has "tailed out", then there's no material to track. This is another reason why the mounting location of the Tailout sensor is critical. The more material left in the machine, the more hand manipulation of the last portion of the coil is required by the Operator.

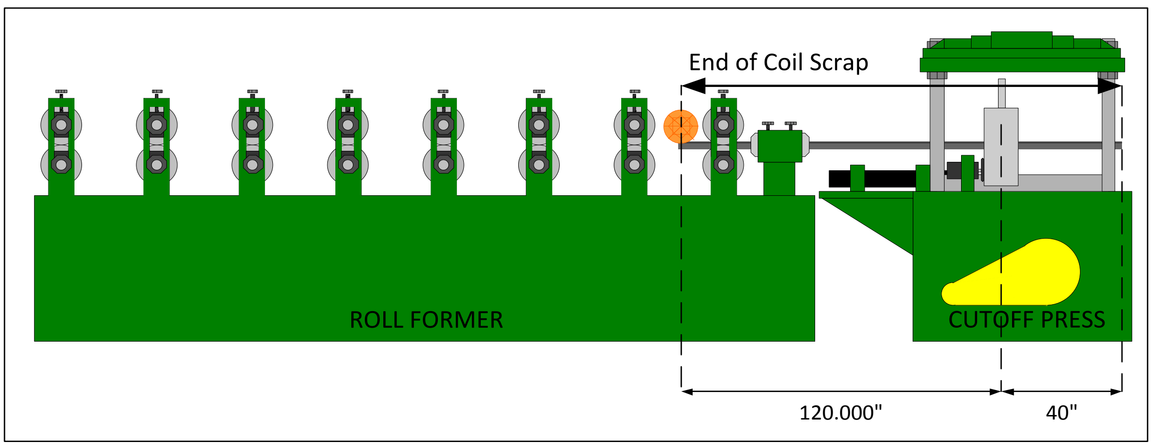
Reporting Scrap at End of Coil

At the end of a coil, some amount of scrap is typically unavoidable; material might be of poor quality, the controller cannot automatically cut the final length, etc. Because of these issues, when the XL200 controller receives the Tailout input, it automatically reports any material past the shear plus the **Shear to Encoder Distance** as scrap to Eclipse. This happens without operator intervention.

Let's examine a coil Tailout condition using the same machine as in *Example 2*:

Example 3

When the tail end of the material is pulled through the roll former and passes the Tailout sensor, the XL200 halts the line, and immediately reports the remaining material in the machine as scrap to Eclipse. In this case, the machine stopped with exactly 40" past the cutoff. Additionally, it also had the 120" of material from the encoder to the entry side of the cutoff.



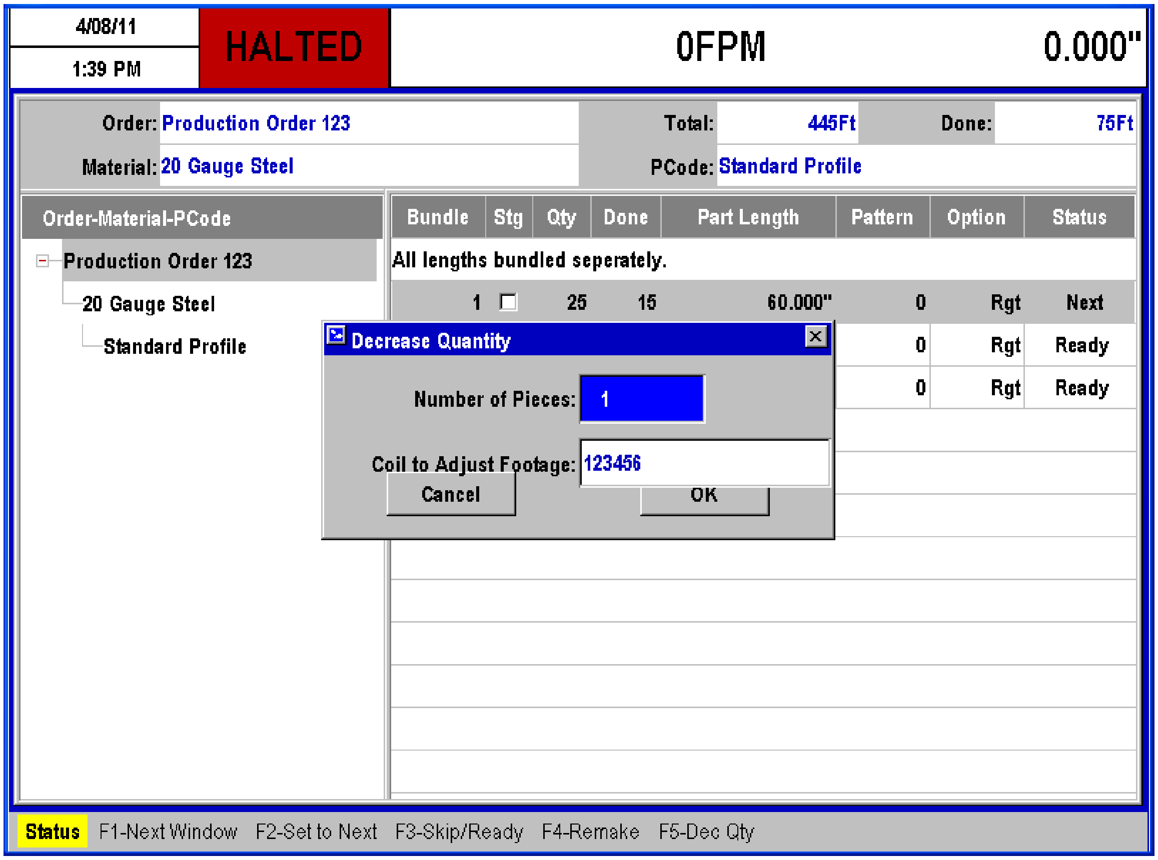
Coil Tailout

At the moment of Tailout, the XL200 automatically reports 160" inches of scrap to Eclipse on the current coil. If the remaining material is truly unusable, then the Operator merely empties the machine, and threads the next coil. All accounting has already been handled by the Eclipse/XL200 system.

Often, the remaining footage on a roll former can be hand-manipulated by the Operator in order to recover at least one last, good part from the coil. If this is the case, the operator simply hand-positions the remaining material so he can perform a Manual Shear operation to manually cut the last good piece(s).

Once this is complete, the operator should use the *F5 - Decrease Quantity* feature on the Status menu to alert the XL200 as to the number of good pieces he was able to recover from scrap.

Decrease Quantity not only corrects the current "Done" part quantity, but it automatically alerts Eclipse to take that length x quantity out of scrap for the current coil and add it back to "good footage".



Whatever unusable length remains has already been accounted in the scrap total. All accounting is handled within Eclipse, without the need to collect paperwork from the Operator.

Summary

Coil changes in roll forming processes are typically the most scrap intensive part of the operation. Accurate tracking of scrap and coil inventory are import to Purchasing/Accounting and Production.

A Tailout sensor, coupled with the XL200 and Eclipse production management system can provide a powerful tool to automate coil data entry, as well as accurate scrap tracking.

The Tailout input on the XL200 machine controller performs several critical functions pertaining to coil changes, and is integral to the Coil Verification feature within the Eclipse\XL200 system.

Diligent Operator training combined with software enforcement of policies leads to accurate accounting and greater automation within the system. This leads to the elimination of wasted time for the Operator and paperwork for the Production floor, as well as the office.

Tool Setup

Tooling Terms

The following terms are used frequently by AMS Controls. We've included our definitions to clarify what we mean when we use these words.

Press

A press is a device that closes a die set that is to punch, notch, or shear a given material. Air, hydraulics, or a mechanical flywheel may power the press. The Cutoff Press (Shear) is always considered press "0".

Tool

A tool is the smallest section of a die set that can be engaged with one cycle of the press. A tool may produce a single hole, notch, or shear, or a group of holes, notches, or shears. A tool is defined by a press number, an optional gag number (or multiple gag numbers), and an offset distance from the front of the press. A "Y-Axis" reference may also be necessary for some machines.

Die Set

A die set is a mechanical assembly containing any number of tools that punch, notch, or shear.

Gag

A gag is a device that can select or deselect specific tools in a die set. This is most often a sliding block that is moved by an air cylinder prior to activation of the press.

Pattern

A pattern is a set of tool operations that define most of the details of a finished part. Each entry has a tool number, a reference designation, and a dimension. For "Y-Axis" machines, a Y-reference and Y-offset will also be necessary.

Batch Item

A batch item in the controller is used to actually produce parts. Each batch item defines a batch number, quantity, length, pattern number, and production option.

Press & Gag Configuration

The XL200 Series feed controller can be adapted to several kinds of machines.

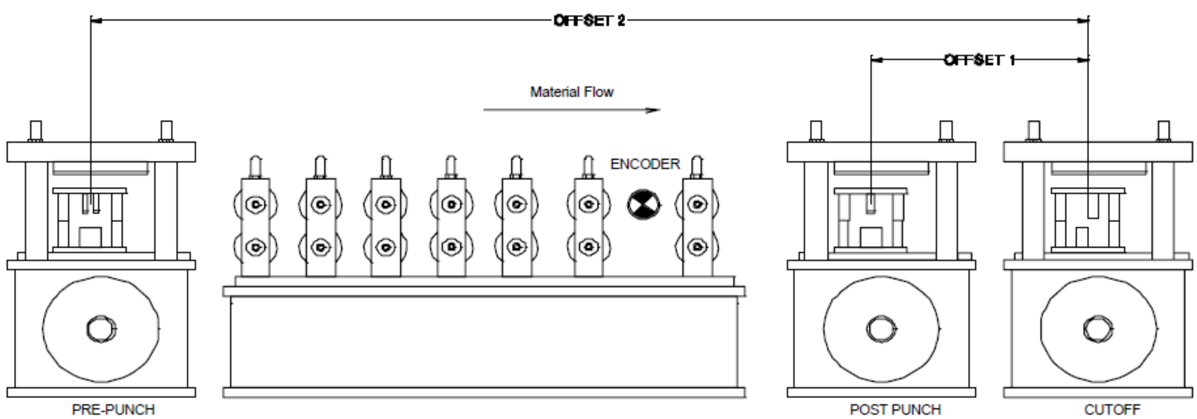
- The XL202CL can control a machine with two individual presses or with a single press and one gag.
- The XL206CL can control a machine with six individual presses, a machine with a single press and five gags, or any combination of presses and gags that add up to six.

- The XL212CL can control a machine with twelve individual presses, a machine with a single press and eleven gages, or any combination of presses and gags that add up to twelve.

Once the configuration of the machine is determined, the controller can be set to match that configuration.

Determining the Machine Zero Reference Point

For each application, a Machine Zero Reference Point is required. From this point, an offset to each die can be measured. The only requirement for this point is that it must be downstream from any tool location to avoid a negative reference.



1 - Press Reference Distance

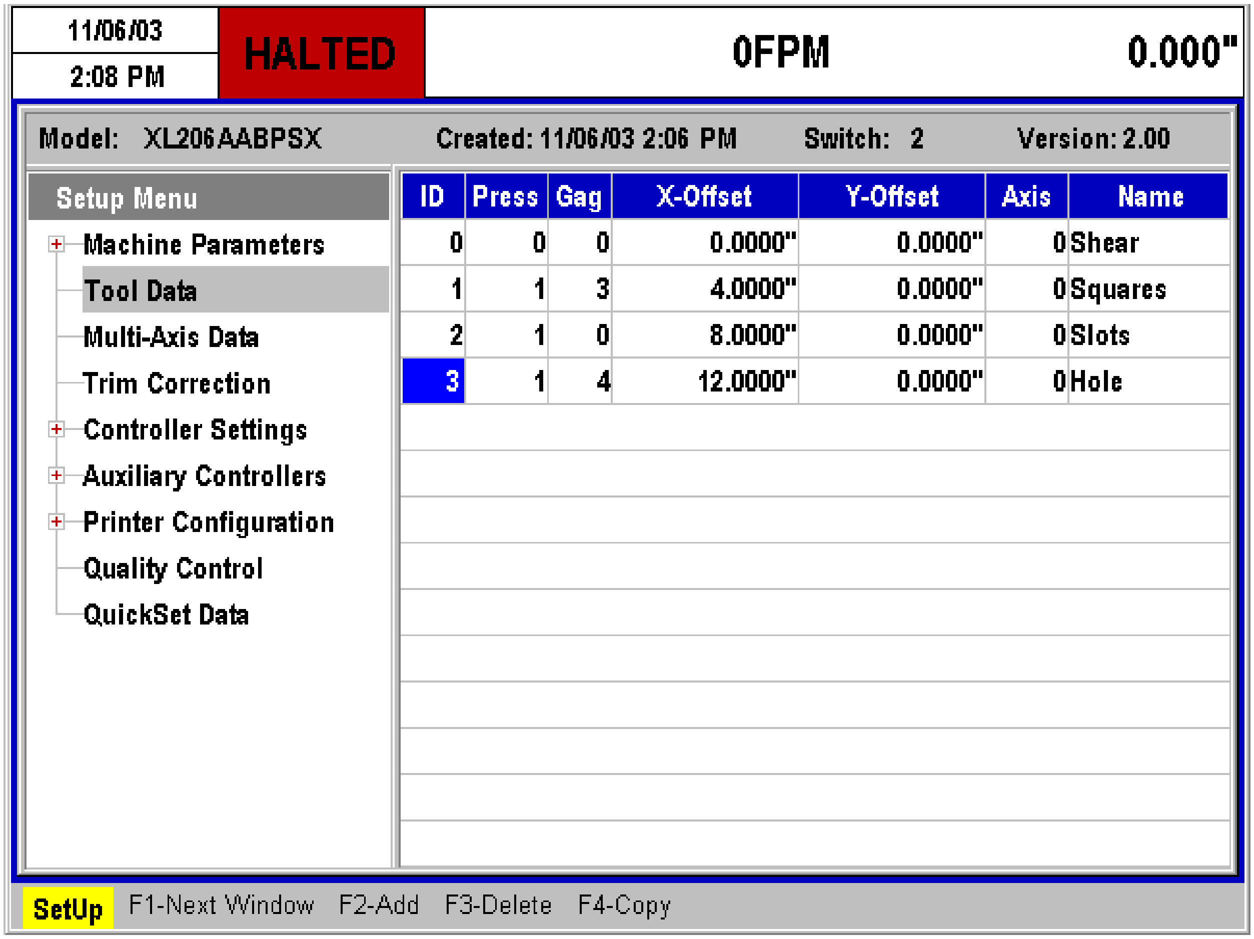
In most cases, the easiest point to use for a reference point is the back edge of the shear die. Tool offsets are then determined by activating all dies, including the shear, with material loaded and clamped in a stationary position. The strip is then fed forward past the shear. The distance from the leading edge to the reference point on each die tool is measured. These dimensions become the tool offsets.

Some dies may have tools that are downstream of the shear. In these cases, the back edge of the shear cannot be used as the reference point. An arbitrary reference point must be chosen that is located past the tool that is downstream. In this case, the tool for the shear will have a positive offset from the arbitrary reference point.

Note: All offsets must be positive numbers in respect to the common reference point.

1. Press the [SETUP] key to display the Setup Menu selection list.
2. Highlight “Tool Data,” displaying the tool definitions in the right-hand window.
3. Press the [F1] function key to tab over to Settings.
4. Pressing [F2] will open a new tool entry.

The Tool Data screen is used to enter tool offset data. A typical tool data display is shown below. Each entry contains an "ID," "Press," "Gag," "X-Offset," "Y-Offset," "Axis," and "Name."



2 - Typical Edit Tool Data Screen

Defining a Tool

ID (Tool Number)

The Tool ID Number is any numeric number from 0 to 974. Tools can be entered in any order and numbers can be skipped. Tool 0 is reserved for the shear and must always be programmed accordingly as Press 0. Tools 975 to 999 can also be programmed, but these are considered macro pattern tools.

Press

The Press Number refers to the "Press Output" associated with that tool. The Press Number must be from 1 to the number of presses programmed into the configuration switches. If any other number is entered, an error will be displayed. Press 0 is always assigned to the cutoff press.

Gag

The Gag Number corresponds to the Press/Gag Output that is energized when this tool is to be activated. The number must be greater than the number of presses programmed into the configuration switches and not greater than the number of maximum presses/gags allowed (ex. XL102=two, XL106=six, XL112=twelve). If no gag is to be energized for a specific tool, the Gag should be set to "0." This designates that no gag is connected.

X-Offset

The X-Offset is a distance measured from the designated machine zero point to a reference point on the tool. The "X" means that this measurement is in the same plane as the material is moving, the "X-Axis."

This point may be the center point of a single hole or may be the reference point cluster of holes or a die pattern. In others, it may be the leading or trailing edge of a hole die or notching die.

Y-Offset

The Y-Offset is the distance measured in the "Y" plane, or across the material motion plane. This provides an offset distance across the breadth of the part to create a reference location for a Y-Axis tool. This offset is provided by the drive when a tool is positioned in a specific location.

Axis

The Axis refers to the drive axis that a particular tool is attached to. Each individual positioning device will have its own "Axis" definition.

Name

The Name is any 8-character name that helps the operator identify a particular tool. Programming the Name is optional.

General Tool Information

More than one Tool ID can be defined for the same die tool. For example, a notching die that removes a piece from the corner of both the leading and trailing edges can have a tool defined for both corners. They would have the same press and gag data but different offsets. This allows for dimensions to be programmed directly from the part drawing.

Another use for multiple Tool ID entries is instances where a die tool may be changed to run different parts. Different Tool IDs and Offsets for both die tools would be available. Patterns using each die contain the corresponding tool reference. This means that no change in tool data is required when dies are changed; simply use the corresponding Tool ID for the selected tool.

Encoder Tracking & Mounting

Accurate and consistent part lengths are crucial to quality control in roll forming processes. Even if parts are produced in tolerance, a batch of parts that are inconsistent in length will be more rigorously scrutinized by the end-user than a stack where the ends of all the parts line up.

Encoder and material tracking problems account for most product length variations on computer controlled roll forming lines. From the perspective of a length control system, all information regarding the material - direction, speed, distance traveled - comes from a single point, where the encoder measuring wheel contacts the material. Proper tracking of the encoder measuring wheel is therefore critical to machine performance.

Variance can come from sources other than the measuring system. However, these sources are less likely, and tend to be specific to the machine application type. They are more appropriately addressed *by machine application* in a separate article, rather as a comprehensive article on length control. Also, since encoders are present on most computer controlled roll forming machines, and because the problems associated with encoder tracking and mounting are similar in each application, the encoder system should always be examined first when troubleshooting length variance.

For technicians, maintenance and engineering, locating the source of a length variance can be a daunting task. This article will help educate the troubleshooter and describe methodologies for correctly implementing the encoder system for a roll former, as well as ‘best practices’ for encoder systems on computer controlled roll forming lines.

Basic Encoder Function

A rotary encoder is a device that transmits digital pulses as a shaft is turned. A wheel is coupled to the end of the shaft, and that wheel rides on the surface to be measured. As material flows under the wheel, the wheel turns the shaft, and the electronics inside the encoder transmit pulses to a control system. A typical encoder and its associated measuring wheel are depicted in Figure 1-1.

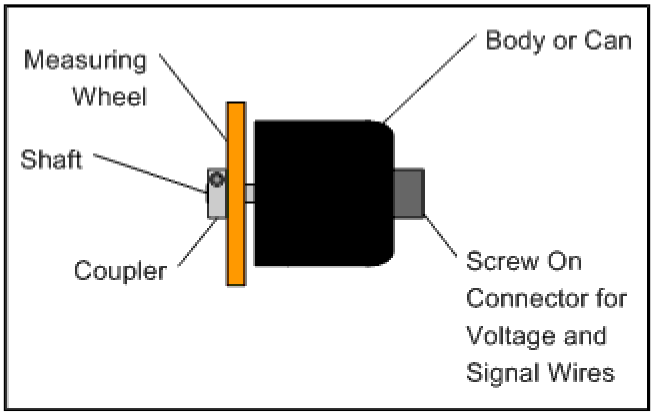


Figure 1-1

Inside the encoder there is a small disc typically made of plastic or glass. This disc might have hundreds, or even thousands, of slits cut in the outside diameter (see Figure 1-2). As the measuring wheel turns, it spins the shaft of the encoder. The disc is housed so the outside edge moves through an infra-red beam. As the slits in the disc move through the beam, the light is chopped into pulses that are picked up by a sensor located behind the disc.

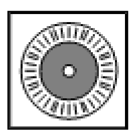


Figure 1-2

The light pulses are converted electronically into digital pulses and sent to the length control system (Figure 1-3).

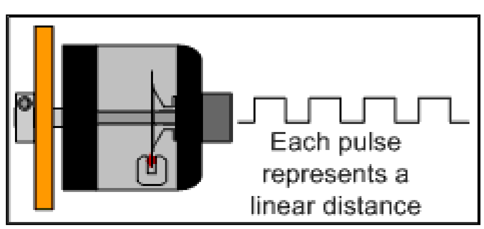


Figure 1-3

The control system must be programmed with the distance that is passing for each pulse. This is the linear distance measured by the wheel per pulse from the encoder, or resolution.

Quadrature

Quadrature is a method of looking at a bi-directional encoder signal and counting 4 pulses for every 1 pulse received, allowing higher resolution and greater accuracy from a lower resolution encoder. It is the directionality of the encoder signals that allows quadrature counting to be implemented.

With quadrature, there are two signal channels, normally called A and B. The encoder's disc and read head are arranged so the square wave signal from the A and B channels are 90 degrees out of phase. In Figure 1-4 time flows from left to right. The A signal (blue) turns on before the B signal (green), indicating forward motion.

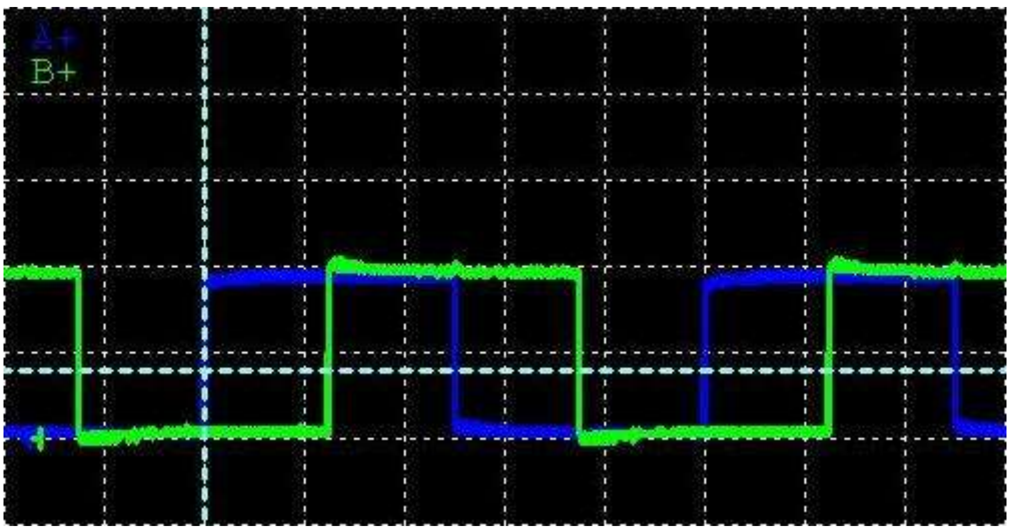


Figure 1-4

When B leads A (Figure 1-5), reverse direction is indicated. These signals can be seen using an oscilloscope.

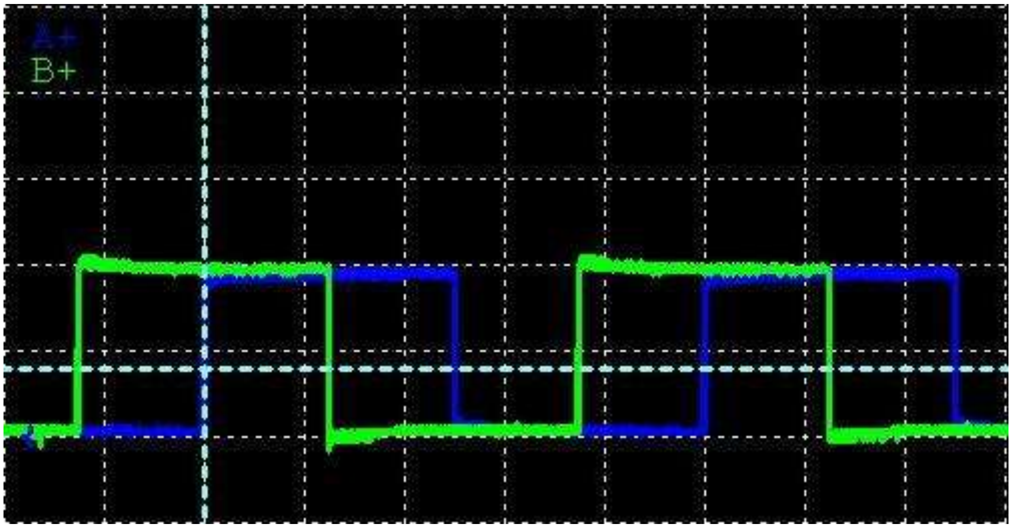


Figure 1-5

Circumference and Resolution

Resolution is calculated by dividing the circumference of the measuring wheel by the number of pulses per revolution generated from the encoder. Circumference is the total linear distance traveled for one revolution of the wheel, and is based on wheel diameter. It's calculated by multiplying the wheel diameter by pi, a mathematical constant approximately equal to 3.14. Once the circumference of the wheel is known, resolution can be calculated by dividing the circumference by the number of pulses per revolution from the encoder.

Example 1:

An encoder and measuring wheel are installed on a roll former. The wheel is 3.815" in diameter, and the encoder is rated for 8000 pulses per revolution. The circumference equation follows:

C = **π** · D

C = Circumference
π = 3.14
D = Diameter

π · 3.815" = 11.985"

Resolution is calculated by dividing the circumference of the measuring wheel by the number of pulses per revolution (PPR) from the encoder. The resolution equation follows:

R = **C** / **PPR**

R = Resolution
C = Circumference
PPR = Pulses Per Revolution from Encoder

11.985” / 8000 PPR = 0.001498” per pulse

Encoder Measuring Wheels

In example 1, the measuring wheel is assumed to be concentric (round). Even slightly out-of-round wheels can generate inconsistent results, usually in the form of long-short pieces in cases where part lengths are exact multiples of the measuring wheel circumference. For example, to guarantee the error due to non-concentricity to be less than 0.001” (0.0254 mm), the radius of the measuring wheel must be within 0.00016” (0.004064 mm).

For best results, encoder shafts should always be directly coupled to the measuring wheel, and the wheel should always ride directly on the material. Often, maintenance or engineering will construct a bracket that uses a flex (“zero backlash”), dual-spring, or spline couplers to isolate the encoder from the measuring wheel. This is usually done to protect the encoder from material crashes. Encoders are relatively cheap, and if the material has a tendency to crash in a certain area of the machine, this should be a flag that further engineering (or maintenance) of that machine element is required.

All too often, these couplers create long delays in troubleshooting problems with the encoder system. Flex couplers can break and allow backlash, but not so much that the damaged portion of the coupler is easy to see. The inner spring of a dual-spring coupler will break allowing significant backlash, but the problem can’t be seen until the coupler is physically removed. Spline couplers are notorious for inducing backlash over time, as the spider insert begins to wear.

Machine builders will sometimes couple the encoder shaft to a roll tool or pinch roll. This always results in poor encoder tracking. Unless the rolls are designed to ensure perfect tracking between the roll and material movement (i.e. embossing wheels), it is far better to use a separate, low-mass measuring wheel.

Measuring wheels should suit the application. Painted materials like those used for products that will be visible to the consumer in their finished form usually require a measuring wheel that will not mark the material. Metal wheels are generally not acceptable for such processes. There are several types of polymer wheels that are slick enough to avoid scratching the formed part, yet offer enough friction to track well. In these situations, an encoder should be chosen that offers a very low-friction bearing assembly, so there is less friction in the bearing than between the wheel and the material. Encoder shaft bearings that produce too much drag will cause the wheel to slip.

Hardened steel makes an excellent measuring wheel. It can be knurled so that it “bites” the material. This type of wheel will generally mark the material, but if this is aesthetically acceptable for the finished product, less tension is required to track the material. The marks left on material by a knurled wheel can be beneficial as a quick check for tracking quality. Often, a finished part can be held under the glare of shop lights to make the “tic” marks left on the steel visible to the naked eye. The quality of the encoder tracking can be easily checked based on the type of tracking patterns left on the steel.

Magnetic wheels are often used for steel forming, but the wheels tend to collect debris that can scratch paint, or minimally make the encoder wheel out-of-round. While rubber wheels might be commonly used by machinery builders, they should be avoided in applications requiring accuracy and repeatability. Rubber does not consistently compress, and is sensitive to temperature. On hotter days, rubber will expand and compress more. On colder days, rubber contracts and compresses less. These variances cause a change in the effective resolution that will result in part length variances.

Length Control System Calibration

While calibration features in a control system can help center tolerance error, proper alignment and good tracking are crucial to eliminating variance. Calibration is only useful in removing a consistent amount of error. If machine operators or maintenance personnel are attempting to chase variance by calibrating the machine, they are wasting time and material. Though variance could be caused by improper parameterization or poorly written software, it usually comes from a physical (real world) source. In any of these cases, calibration is not the solution to the problem.

In example 2, a machine has two problems; the part lengths are coming out long on average, and the lengths vary more than is acceptable for the defined part tolerance. Calibration removes the average error in length, but cannot make the machine more consistent.

Example 2:

In Figure 1-6, a 20 part sample is run from a roll forming machine and plotted on a graph. The lengths are examined to determine the longest and shortest parts. The target length is 60.000” (1524 mm), but the sample shows lengths ranging from 60.150” (1527.81 mm) to 60.400” (1534.16 mm).

Even though the parts are coming out an average of 0.229” (5.817 mm) long, the actual variance of the lengths produced is only ± 0.125” (3.175 mm).

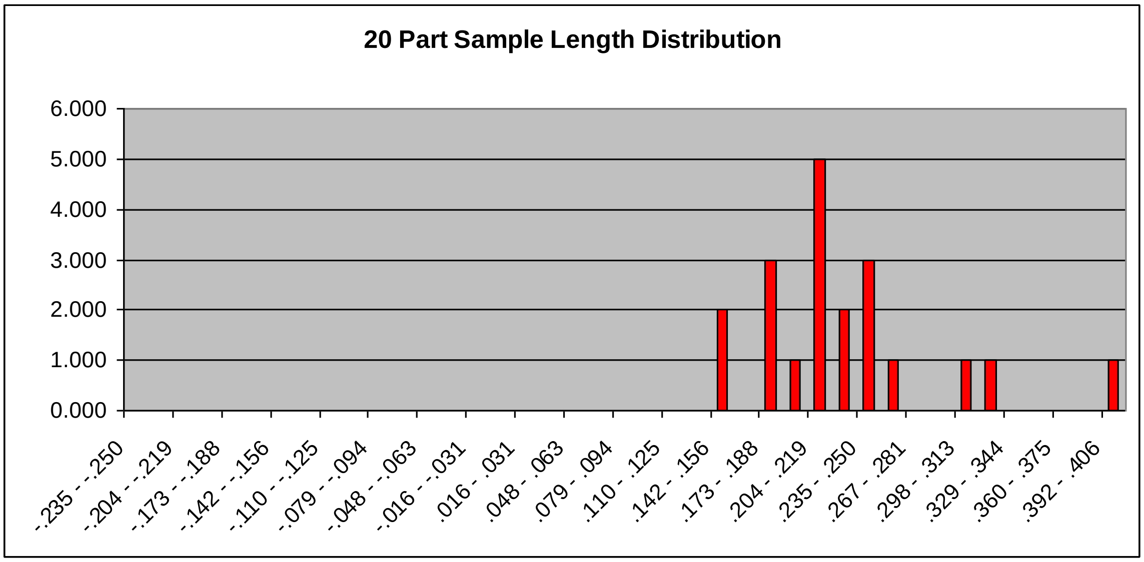


Figure 1-6

In order to calibrate the system, the average part length, 60.229" (1524 mm) must be used. If the length control system does not have an on-board trim correction feature, the measured length is divided by the programmed length to calculate a correction percentage. This percentage is multiplied by the control systems resolution parameter to calculate a new, corrected resolution.

Once the system has been corrected, a new 20 part sample is run and plotted on a graph (Figure 1-7). The calibration of the length control system allows the error to be centered around the target value, however, the variance is not affected by the calibration procedure.

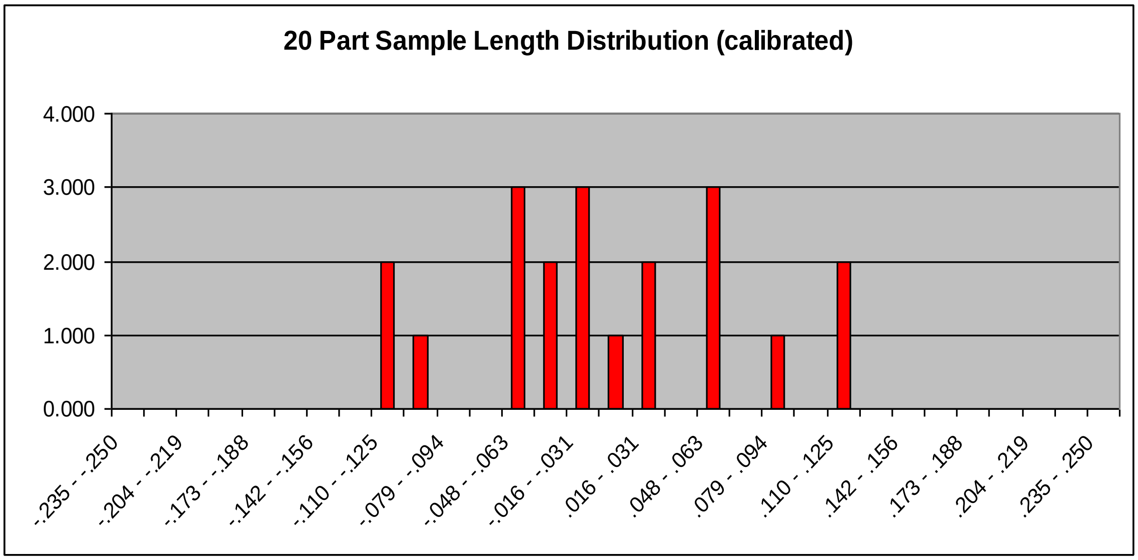


Figure 1-7

In this case, the defined tolerance for the product is ± 0.063" (1.6002 mm). The part lengths are still unacceptable. Something else must be done to eliminate the length variance.

Example 2 uses a part sample size of 20 pieces to establish the base machine consistency. This is important. Small samples of 1 – 2 parts, randomly selected from a production run, do not give the observer an accurate view into the capability of the machine. Too often, assumptions about length patterns are made and time is wasted chasing down problems that don't exist. Measuring parts in the order produced from the machine can also help in troubleshooting a variance, as patterns can appear that direct the troubleshooter to a specific area or machine element.

Encoder Bracket - Assembly Mounting and Orientation

There are two major concerns when it comes to mounting an encoder bracket on a roll former; bracket stability and material stability. The single most important feature of an encoder bracket is that it must be "solid". Often, a bracket will tension the measuring wheel and encoder to the material with air or a spring to allow some vertical movement of the material during the forming process. Vertical displacement is acceptable, so long as that is the only mechanical give in the assembly. Any side-to-side play, or "slop", in the bracket assembly is totally unacceptable.

The more rigid the bracket mounting, the more forgiving the perpendicular alignment of the wheel to the material can be. Best practices recommend riding the measuring wheel so that it is on a flat surface, perpendicular to that surface. Sometimes, this isn't physically possible. The part shape, or space constraints, might make perpendicular orientation of the wheel impossible. When this is the case, consistent riding of the wheel on a rounded surface, or at an angle to the perpendicular plane is possible, if the bracket allows for zero deflection of the wheel.

On most roll forming machines, the best place to mount the encoder (depicted in Figure 1-8 as the orange circle) is near the exit end of the machine by the shear, between the second-to-last and last pass of the roll former. Figure 1-8 shows a typical post-cut roll forming process.

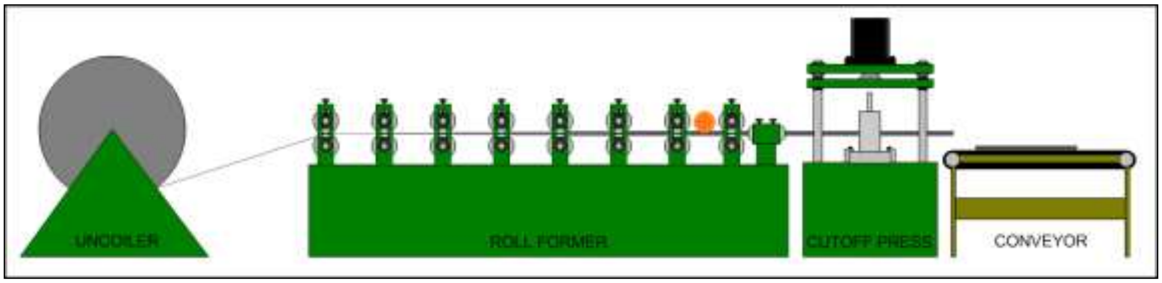


Figure 1-8

Mounting the encoder near the end of the forming process removes error due to material stretch. Usually, the last few passes of a roll former perform very little forming, and are typically used to finish the shape of certain part elements like flanges. This area should be very stable, as material is trapped on either side of the measuring wheel by the roll tooling. The tooling on the final pass, as well as the straightener help to dampen material vibration transmitted from the shearing operation. The material itself should provide a more rigid area for measurement since it has been formed by the machine.

The best possible method to allow for vertical material displacement is direct, vertical pressure on the encoder and wheel. Angular tension requires extra consideration. Many encoder brackets mount to a steel bar, and are designed to allow the bracket to rotate a few degrees around a pivot point (the same bar used for mounting). In this situation, vertical displacement of the material creates an angular displacement of the bracket, forcing the shaft of the encoder to turn, even though no linear material movement has occurred. The angular displacement creates a length error. This type of error is most often seen when material thickness changes, but it can also occur if the material fluctuates vertically during the forming process.

Figure 1-9 demonstrates the problem. If the material moves up, even if the wheel remains in a constant orientation, the shaft of the encoder must rotate to allow for the motion. The encoder will report reverse motion to the control system. Conversely, if the material moves down, the wheel must rotate the encoder shaft forward.

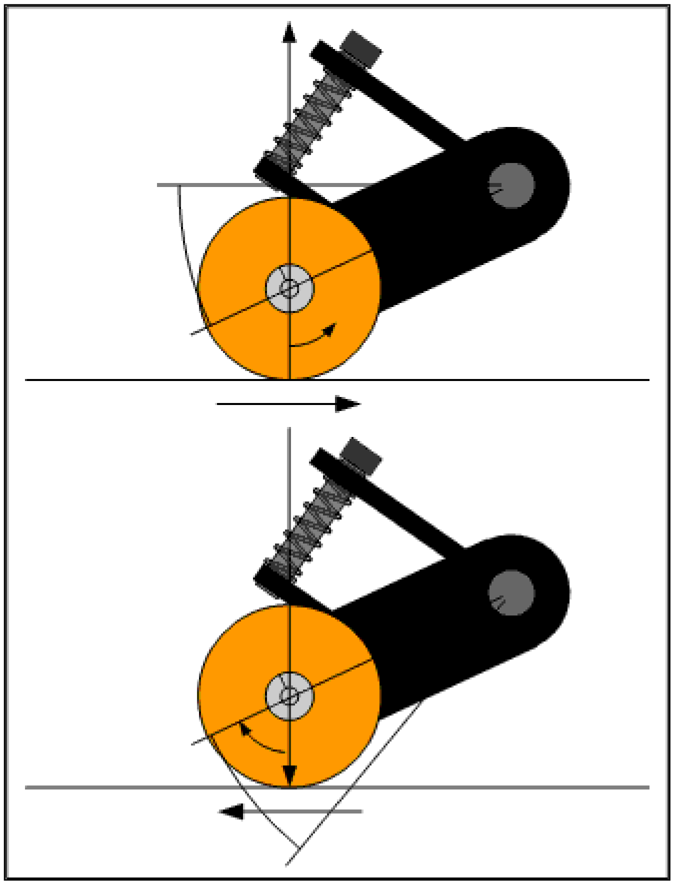


Figure 1-9

For this style of encoder bracket, the best mounting orientation is to lower the mounting bar so the centerline of the bar - and shaft of the encoder - are on the same horizontal plane, parallel to the material as in Figure 1-10.

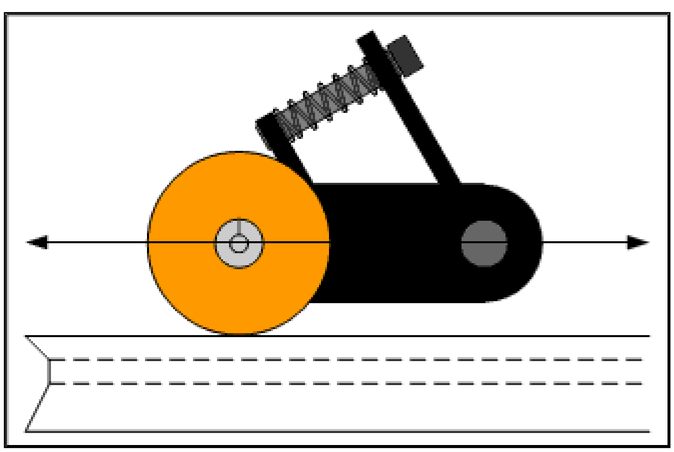


Figure 1-10

The issue of angular displacement creating a linear error still exists with this bracket, but the effects are mitigated by calibrating to a “center” position. Length shifts due to material thickness changes should be slight.

Material Stability

After bracket stability and rigidity, material stability must be considered. If the material is allowed to sag, buckle or hump as it travels past the encoder wheel, the end result is the same as if the encoder bracket is fluctuating. Length control systems view the material as a straight line through the measurement point and all the tooling the system controls. That is, if a length controller fires a punch press and a shear press, the distance between the punch and the shear must be a straight, unchanging line. If the encoder is mounted upstream or downstream from both presses, the extra distance from the encoder to the closest press must also be a straight line. A computer that relies upon a measuring wheel for length and position data cannot “see” material fluctuations, therefore it cannot account for those fluctuations and they will result in part length variances.

Long distances of unsupported material between the encoder and presses will tend to create a length problem. Gravity is an unyielding force that always creates a bow in any material. Even a welded steel pipe must bow to gravity, if the distance between supporting surfaces is great enough. Assuming the shop floor is flat and level, a dial indicator affixed to a cart can be set to measure the material near one end of an unsupported distance. As the cart is rolled down the length of the material, the pickup for the dial indicator will be dragged across the material surface. At the center of the unsupported distance, the maximum material sag can be measured. This error will be roughly equal to the length error.

Another problem with long sections of unsupported material is bounce from press firings. This can deform the material and change the distance measured. Products that have less rigid final forms will tend to “remember” the shockwave from the instantaneous contact of the press tooling. Even if the material is rigid enough to be immune to such forces, it could bounce and vibrate so hard that it has not settled before the next press firing.

Length control systems that use closed loop servos to position press tooling on-the-fly will suffer greatly from material bounce, especially if that bounce is transmitted to the encoder. If the encoder “sees” the material quickly fluctuate front-to-back, the tooling in the press could be forced to move front-to-back as the system attempts to match material position. This can result in damaged tooling and equipment, or material jam-ups inside the machine.

The most common problem with material/bracket stability (or a bent shaft) is a wobble that causes the measuring wheel to measure a wave, instead of a straight line. The axiom – the shortest distance between two points is a straight line – applies here. Figure 1-11 shows two lines connecting the same two points. One line is straight, and the other is a wave, crossing back and forth across the straight line.

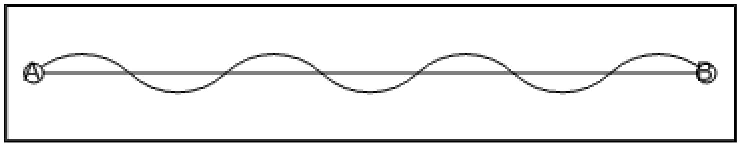


Figure 1-11

The straight line in Figure 1-11 measures 14” (355.6 mm). The wavy line measures 17.593” (446.862 mm). If the wavy line is straightened, as in Figure 1-12, the difference in length is obvious.

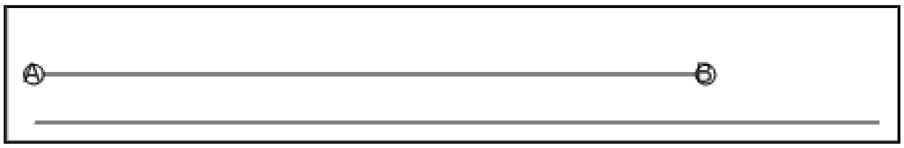


Figure 1-12

A major misconception regarding encoder measuring wheels is “as long as the wheel is in contact with the material, the tracking is okay”. Figures 1-11 and 1-12 illustrate that good encoder tracking is not a simple function of maintaining contact between the measuring wheel and the material. Only through measurement and diligence can an encoder bracket system be aligned such that the encoder and measuring wheel are reporting *true* material motion back to the length control system.

To understand the problem mathematically, example 3 shows what happens when the measuring wheel is allowed to oscillate, or wobble, down the length of a part.

Example 3:

Figure 1-13 demonstrates the problem of a “sloppy” bracket. The original resolution calculated for this measuring wheel was based on a diameter that is twice the radius (a). If the wheel ever rides up on one corner, the diameter changes based on the new radius (c). Both radii form a right triangle, where the new radius (c) is the hypotenuse of the triangle. Radius c is physically longer than the original radius on which the circumference (and thus the resolution) was calculated.

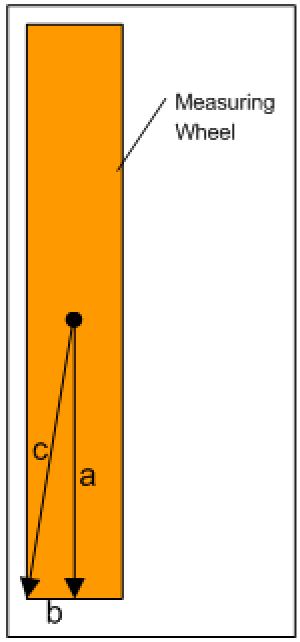


Figure 1-13

In the case of a wheel that wobbles side-to-side, the resolution is constantly changing, but the length measurement system cannot sense this error. In this case, the encoder bracket must be locked down. Shims may be necessary, or re-drilling and re-tapping mounting holes could be required to stabilize the setup.

Similarly, the material could be fluctuating under the wheel side-to-side. Such a fluctuation would have exactly the same effect as if the wheel, itself, were moving. Material should be guided and stabilized before and after the measuring wheel. The wheel should be "backed up" by a plate or idler wheel on the opposite side of the material perpendicular to the wheel.

Encoder Alignment

Once the tracking of the measuring wheel is stabilized via the mounting bracket, the wheel should be checked for square and parallel tracking. Square should only be measured using a machinist's square. Carpenter's squares are not square enough. The measuring wheel needs to be square (or perpendicular) to the material surface on which it rides (see Figure 1-14).

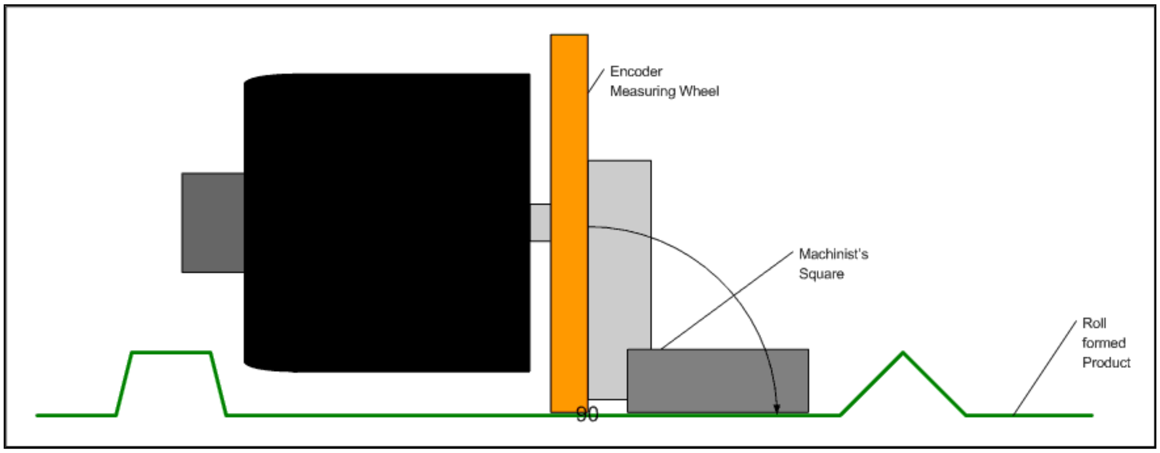


Figure 1-14

When checking for square, there should be no gap between the wheel and the square, or between the material and the square. Both surfaces should be flush with the square.

After checking perpendicular alignment, parallel alignment should be verified. A straight-edge or metal ruler should be used with a set of calipers. Lay the straight edge along the wheel in the direction of material flow and draw a line along the length of the straight-edge, as in Figure 1-15. If the measuring wheel is out of alignment, the error will be exaggerated by this line.

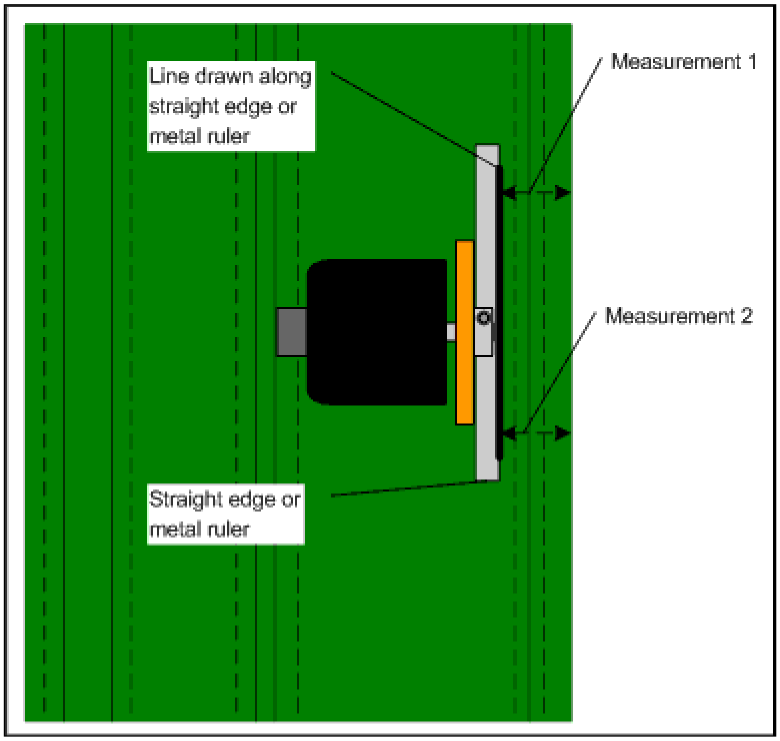


Figure 1-15

Using a set of calipers, the distance from each end of the line to the edge of the material should be measured. The difference between the two measurements should be less than 0.010" (0.254 mm) over 12" (304.8 mm). If the error is greater than that, the encoder bracket assembly should be re-aligned. Square and parallel alignment should be rechecked each time the encoder bracket is loosened and re-tightened.

Visual Inspection

Knurled, hardened, steel measuring wheels offer the best tracking characteristics for steel. When their use makes sense (aesthetically) for a roll forming application, they should be used.

One of the best features of the knurled measuring wheel is that it usually leaves behind a tracking pattern on the part. Tracking variance due to bracket mounting, material stability, and alignment are immediately visible to the user.

Presented here are some examples of common material tracking issues, from the perspective of observing the tell-tale "tic" marks left behind from a knurled measuring wheel. Figure 1-16 shows a hardened, knurled steel wheel riding on a part. The pattern left on the steel is the same width as the encoder wheel, for the entire length of the part.

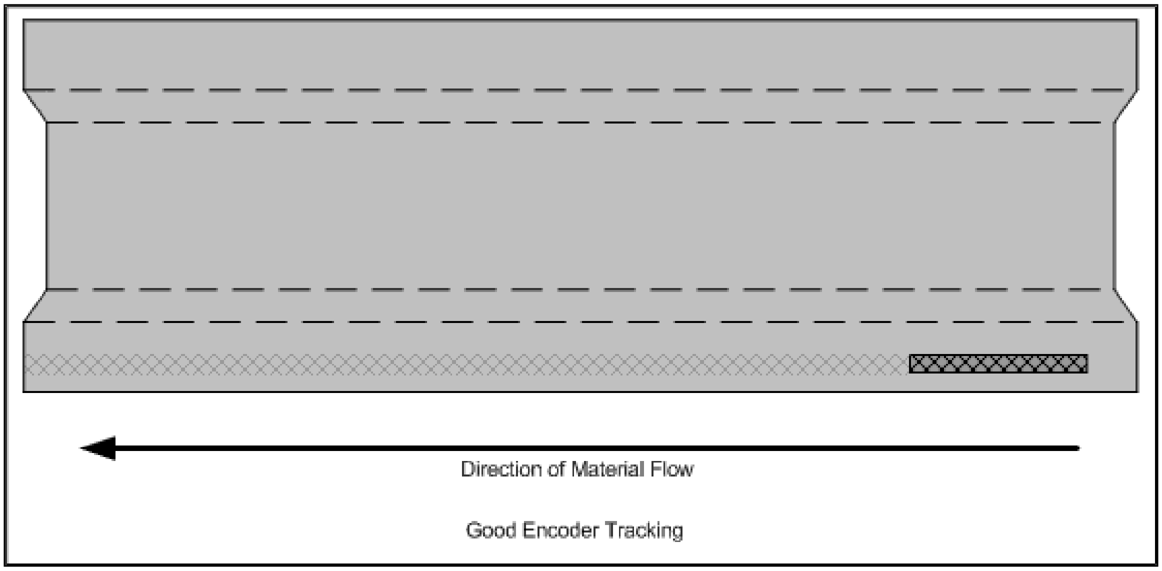


Figure 1-16

If the measuring wheel is not perpendicular to the surface of the material where it rides, the width of the marks left behind will not be consistent with the width of the wheel (Figure 1-17).

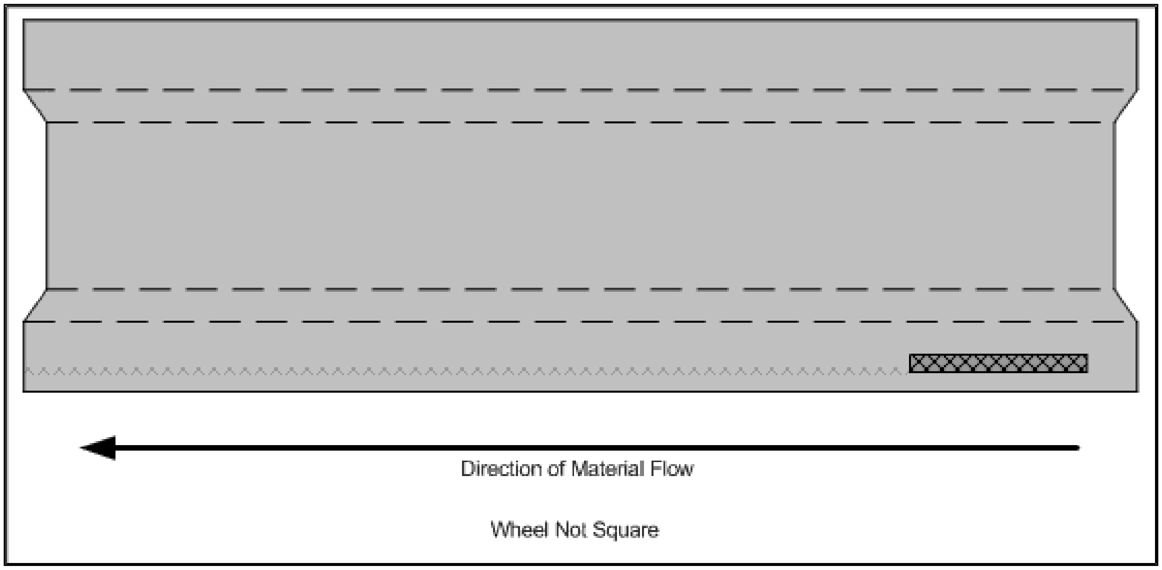


Figure 1-17

The illustration in Figure 1-17 shows a very consistent tracking pattern. If the bracket-assembly had mechanical slop, or if the encoder shaft was bent, this pattern would tend to drift back and forth down the length of the part like in Figure 1-18.

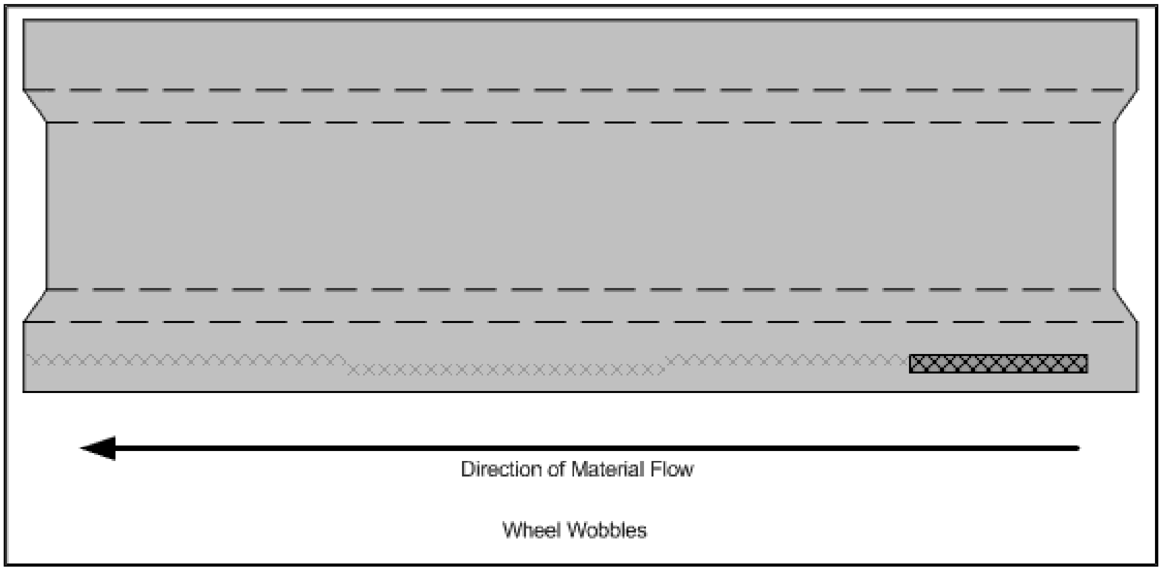


Figure 1-18

Clearly, the encoder mounting bracket assembly must be re-aligned, tightened, and possibly shimmed or re-mounted completely. With this type of tracking, it's also possible the material itself is not a flat surface. Bent roll former shafts will induce sinusoidal waves along the length of the material. The net effect is the same as if the wheel itself were wobbling.

For a system where the wheel is not riding parallel to the material, the "tic" marks left by the wheel would tend to look more like elongated slashes, as in Figure 1-19.

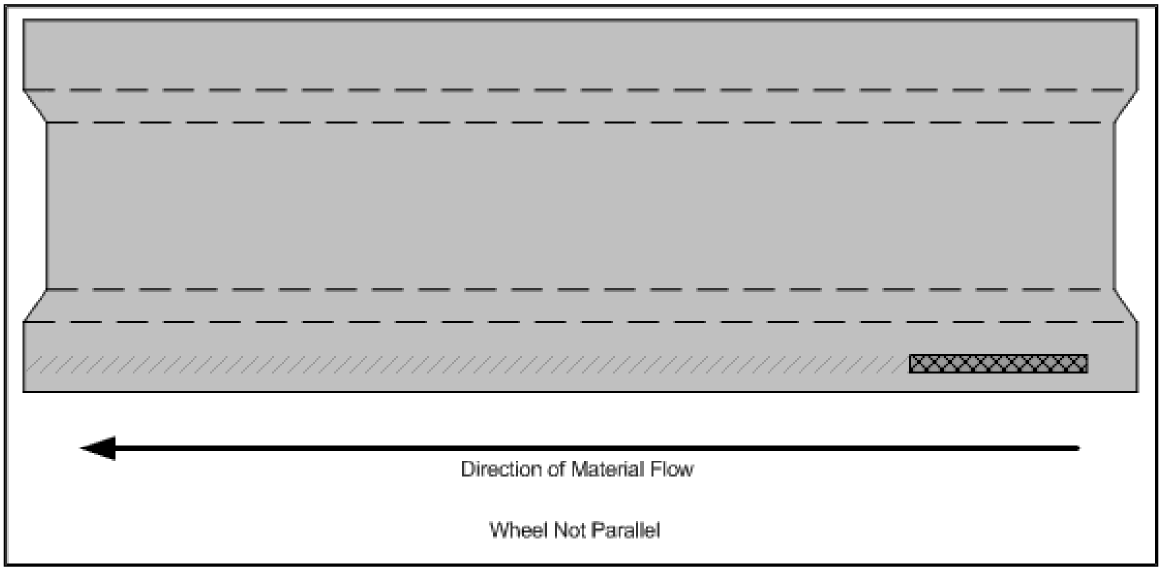


Figure 1-19

Summary

For computer controlled roll forming processes, length variance is most often attributed to material tracking issues. Since roll forming is a continuous process, the encoder and measuring wheel are critical components of the measurement system. The control system must be programmed with accurate information concerning the resolution of the encoder and measuring wheel used on each application.

The type of encoder can make a difference to measurement accuracy. Bi-directional encoders and quadrature length control systems allow higher resolution and tighter accuracy out of lower count encoders. Low-friction bearing assemblies for encoders help ensure consistent friction between the wheel and measuring surface to avoid “slip”.

The type of measuring wheel used is important based on the application, material type, and what is allowed based on the aesthetic requirements of the finished part. Rubber wheels should be avoided. Magnetic wheels are good for maintaining contact with low pressure, but can pick up metallic debris. Polymer wheels are good for painted material. Knurled, steel wheels offer the best tracking, and but tend to leave marks on the material.

Concentricity of the wheel is important for high accuracy applications.

When tracking a length problem, large sample sizes are best for determining what kind of problem exists. If a variance is detected, the variance should be eliminated before calibration begins. Calibration is useful for removing consistent error, but useless for eliminating variance.

Alignment of the encoder bracket-assembly, as well as its placement on the machine relative to the material can make an impact on consistency. Problems with the material, itself, can generate the same kinds of inconsistencies and inaccuracies as mounting problems with the bracket-assembly.

Finally, perpendicular and parallel alignment of the bracket-assembly and measuring wheel are crucial to consistency and performance. Sometimes gross errors can occur from a wheel that's miss-aligned and mounted to an encoder bracket-assembly that's not securely fashioned to the machine.

While length variance and error can come from sources other than the encoder assembly, the measuring system is the first step in the troubleshooting process. A microprocessor-based length control system capability to perform consistently and accurately is directly tied to the information that streams in from the outside world. If the measurement data is wrong, or if it varies, the output will vary.

Quadrature

What is Quadrature?

What does quadrature mean? Quadrature allows a length control system to count four counts for one pulse from a bi-directional (two-channel) encoder.

A two-channel encoder is capable of reporting direction as well as movement. Typically, there is an "A" channel and a "B" channel. As the shaft of the encoder turns, pulses from both channels are being sent to the length control system. The two channels are always offset by 90 degrees, so one channel will always lead the other channel depending on direction.

When the A channel leads the B channel, that is typically the forward direction:

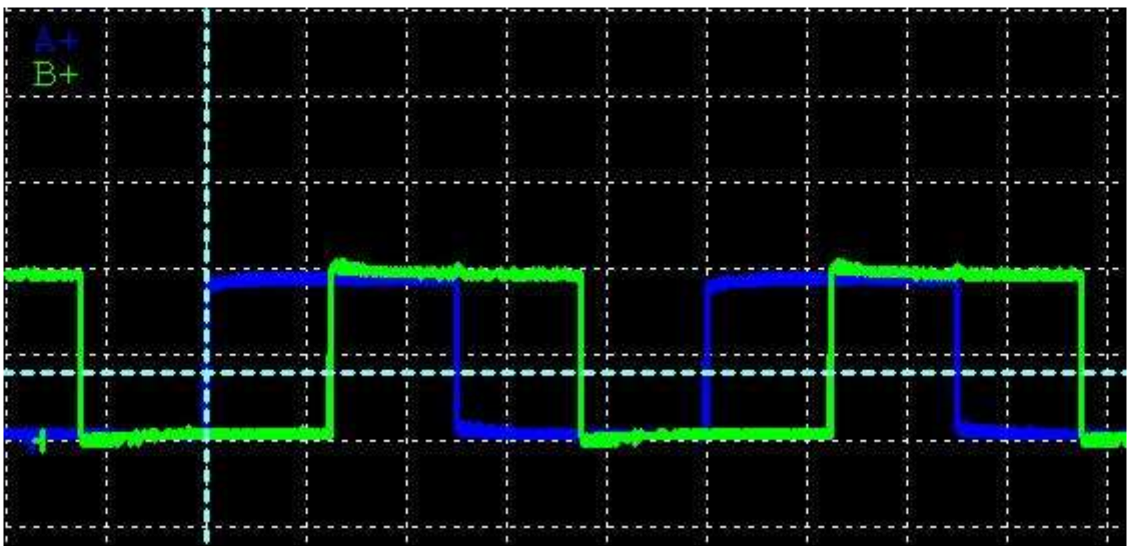


Figure 3-1

In the Figure 3-1, from left to right the first rising edge after the trigger (the vertical, light blue dashed line) is the A+ channel. Half way through the A+ pulse, a pulse from the B+ channel begins. A+ leads B+, therefore forward direction is indicated. When the B channel leads the A channel, reverse direction is indicated (see Figure 3-2).

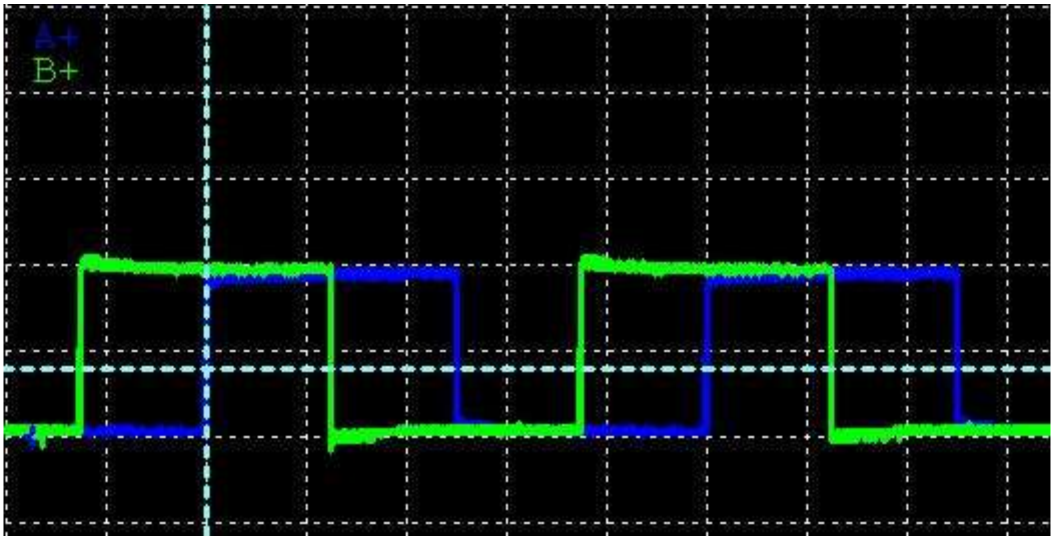


Figure 3-2

In both Figure 3-1 and Figure 3-2, the images show there are two pulses transmitted for each count from the encoder. Each pulse has a rising and falling edge.

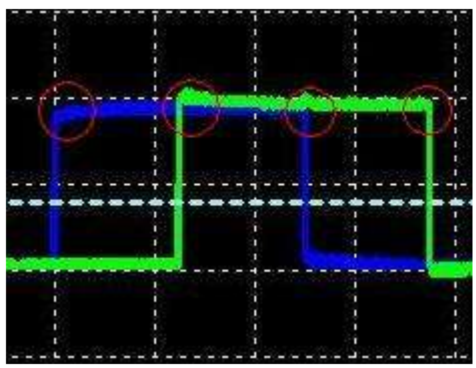


Figure 3-3

As illustrated in Figure 3-3, two rising edges and two falling edges - four transitions - are seen by the length control system. In this way, four counts are accumulated from one pulse of the encoder.

Differential Signals

Understanding Differential Signals

Differential describes a method of data transmission across a twisted-pair of wires. Differential signals rely on differential op-amps for noise immunity and signal boosting.

Two wires are twisted around each other from the transmission source to the receiving end. On one wire, the signal (A+) is transmitted. In the case of an encoder, this signal is in the form of a 0 - 5VDC square wave (or pulse). A mirror image of the signal (A-) is transmitted on the other wire in the pair. The two signals are 180 degrees out of phase with each other, in Figure 2-1.

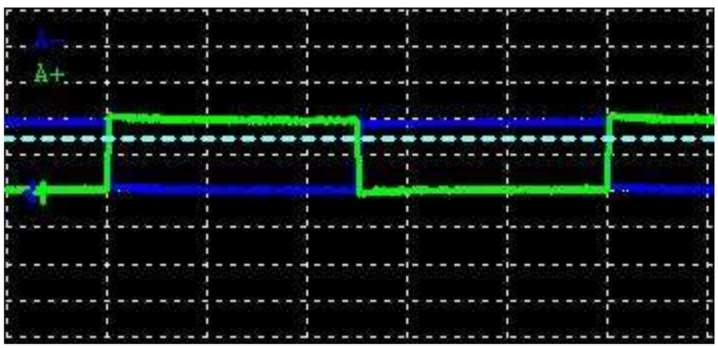


Figure 2-1

On the receiving side of the signal is an electronic device known as a differential op-amp. This device has an inverting and a non-inverting input. When the encoder signals reach the op-amp, one signal is inverted and added to the other. The result is amplified from the op-amp's output (see Figure 2-2).

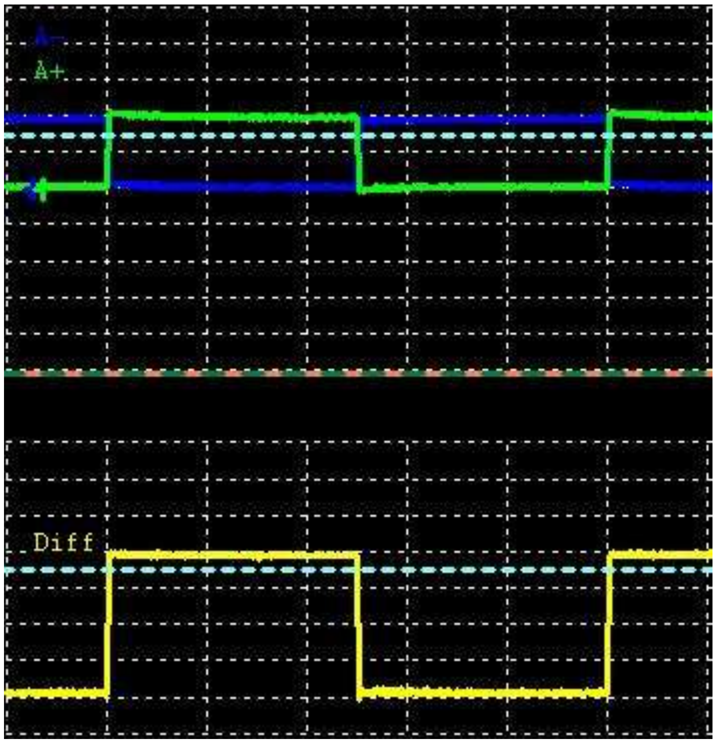


Figure 2-2

This functionality is key to the noise immunity of differential signals. The signals are sent via the twisted-pair to ensure any noise spikes picked up along the cable run are induced on both wires in the pair. This noise is called common mode. This means the noise spike is carried on both wires, like the signals, but the spike on one wire is not 180 degrees out of phase with the other. The two noise spikes are of the same amplitude and duration on both wires.

When the spikes and signals reach the op-amp, it inverts everything on one wire and adds that to the signals (and noise) coming in on the other wire. The spikes cancel each other out, but the encoder signals are added together.

Example 1:

In Figure 2-3, a noise spike was deliberately induced on only one signal wire of the twisted-pair. The result is a noise spike that is carried through the op-amp.

Figure 2-3

Because the noise spikes are not induced on both wires, the op-amp passes the difference of the two incoming signals, including the noise.

Example 2:

In Figure 2-4, a noise spike was induced on both wires of the twisted-pair. The differential op-amp “sees” the two spikes, inverts one and adds them together. As a result, the noise is eliminated.

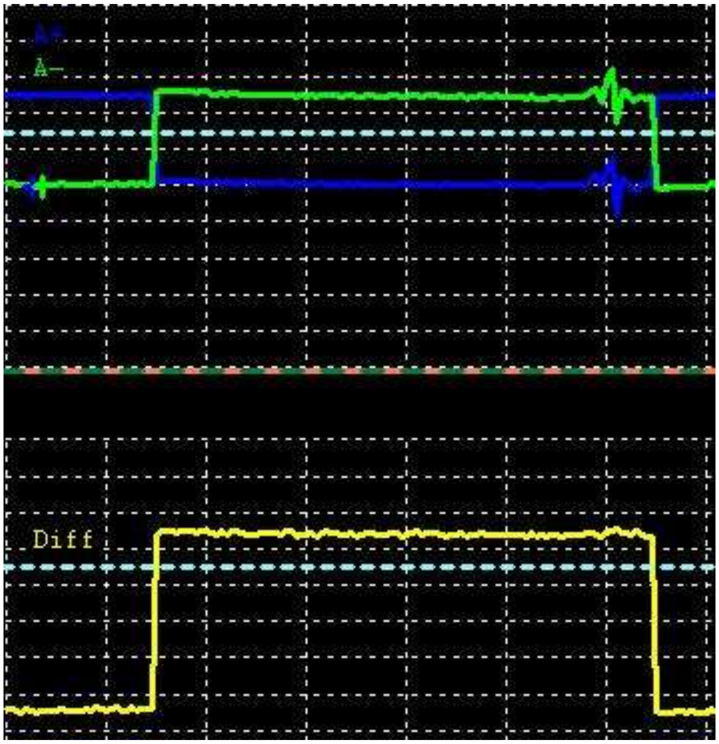


Figure 2-4

Testing for Noise on Differential Signals

The best way to check for suspected noise issues on a differential signal is to use a 2-channel oscilloscope (O’scope). The O’scope should be isolated from ground, to make sure other noise issues aren’t induced onto the signals being viewed by outside sources.

Each probe of the O’scope should be connected to one wire of the twisted-pair. The ground straps of both probes should be connected to signal ground of the differential signal to be measured. At this point, both sides of the differential signal (A+ and A-) can be viewed. To view the signal as it would be seen after the differential op-amp, the O’scope will need an “invert” function and an “add” function.

Set the O’scope to invert one of the probe inputs, and turn on the additive function. The resultant waveform should be close to what the receiving circuit should see after the op-amp does its job. It may be that the noise is powerful enough, or high enough frequency, to pass by the op-amp. Still, for most applications viewing the differential signal in this way will show a good approximation of what’s really happening.

AMS Controls recommends purchasing an oscilloscope from Link Instruments (http://linkinstruments.com/) if you don't have one already. The current model we recommend is the Mixed Signal Oscilloscope (MSO-9201), but this may change depending on future development. Ask our Training Group for the latest recommendation before purchasing a new oscilloscope.

The Four Application Types

Open Loop Feed-to-Stop
Open Loop Flying Die
Closed Loop Feed-to-Stop
Closed Loop Die Accelerator

Open Loop Feed-to-Stop

Open Loop Feed-to-Stop Specific Parameters

- **Minimum Slow Distance**
  This parameter is used to determine how soon before the target reaches a press operation to put the line into slow speed. Increase the MINIMUM SLOW DISTANCE parameter value to shift the material into slow speed earlier in time. Decrease the parameter value for a shorter slow distance. A longer slow distance can improve part accuracy but may slow down overall production. When the machine is producing good parts repeatedly, reduce the MINIMUM SLOW DISTANCE as much as possible to increase the production rate.
- **Stopping Reaction Time**
  Represents the time delay between when the controller turns off its movement outputs and when the material comes to a stop. This parameter causes the controller to command the line to stop at the given time prior to reaching the programmed target. It can be an automatically calculated value that is adjusted after every stop.
- **Stopping Reaction Mode**
  Auto: The controller recalculates the stopping reaction time after every stop.
  Manual: The controller uses the
  Off: No stopping reaction time is used or calculated. The controller does not test for tolerance when set to off.
- **Bump Tolerance**
  If the controller stops for a target and is out of tolerance, but within the BUMP TOLERANCE, it will automatically bump the material forward or backward to try to achieve tolerance.
- **Bump Time**
  The controller will turn on the forward or reverse motion outputs for the time specified by the BUMP TIME.

Open loop feed-to-stop machines are low cost roll forming solutions that have lower throughput rates, because as the name implies, the material must stop for press operations. The benefit of the feed-to-stop alternative is higher accuracy. Since the length control system doesn't have to hit a moving target, press consistency doesn't affect length. Instead, it is the ability of the material to *stop* consistently that dictates length repeatability.

Line speeds in feed-to-stop applications can vary greatly. Longer parts can be run at higher speeds to increase throughput, but shorter parts must run slower. Some systems have a 2-speed operation so the material is always driven at a constant "slow" speed some distance just prior to the press operation. This ensures the material is always coming to a stop (decelerating) from the same speed, regardless of how fast longer parts are run. Press speed also impacts throughput, because the material must stand still while the press completes its cycle.

Tolerance in open loop feed-to-stop applications is usually ± 0.032” (0.8 mm) or better. As long as the material is stopped consistently, or if the length control system has the ability to make small corrections prior to cycling the press, length accuracy can be very tightly controlled.

Open Loop Feed-to-Stop Key Features

- Low Cost
- Low Cycle Rates / Lower Average Line Speeds
- High Accuracy
- Sensitive to Timing / Tracking Variations
- Press Variations Do Not Affect Length

The open loop feed-to-stop machine type is commonly used for light gauge steel framing (stud and track) and metal building components (wall and roof panels). The application doesn’t lend itself to mass producing large quantities quickly, but this machine type does offer high quality parts on a low cost machine for smaller operations, do-it-yourself builders, and users who service local areas.

Stopping Reaction

When a length control system attempts to stop material for a punch or shear target, the material must decelerate to a stop before the press can be fired. The time required to bring the material to a stop from run speed is the machine’s Stopping Reaction time. Figure 4-1 describes Stopping Reaction time with a state diagram.

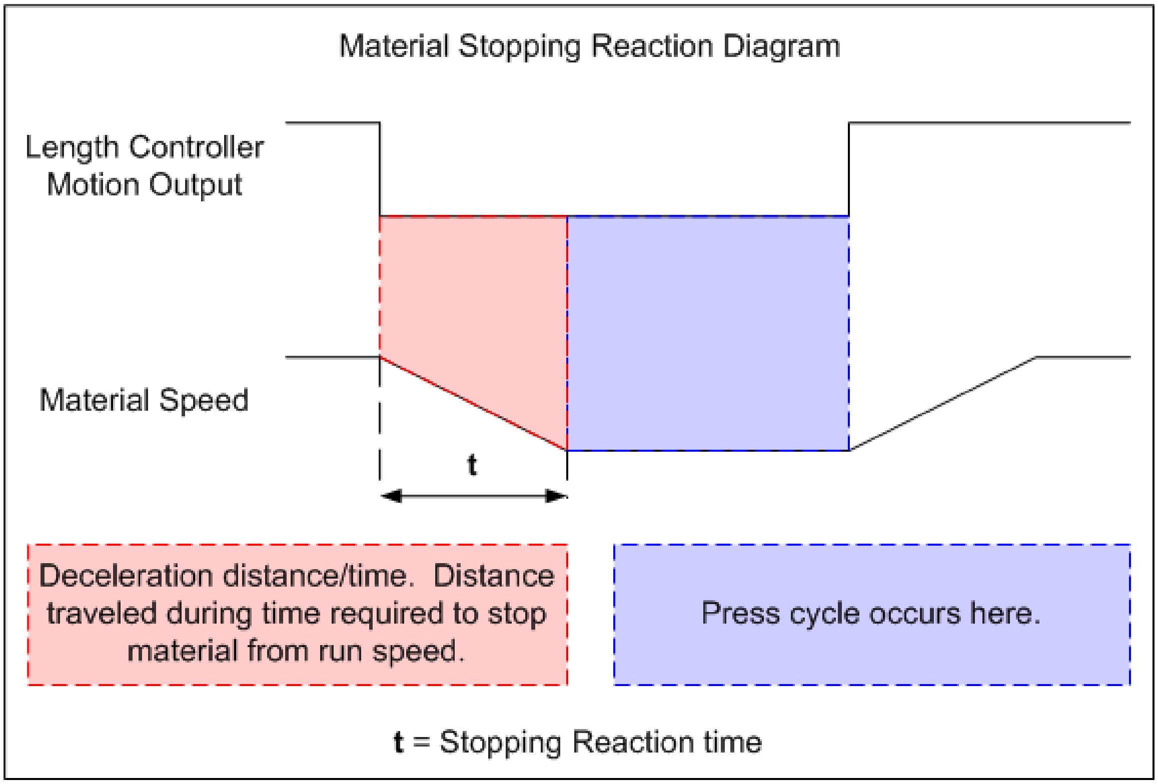


Figure 4-1

When the length controller turns off its motion output, the material decelerates to a stop. If the system waits until the target length is directly beneath the press tool, the press will miss the target. The material will have traveled (coasted) beyond the press tool by the time it stops, as in Figure 4-2.

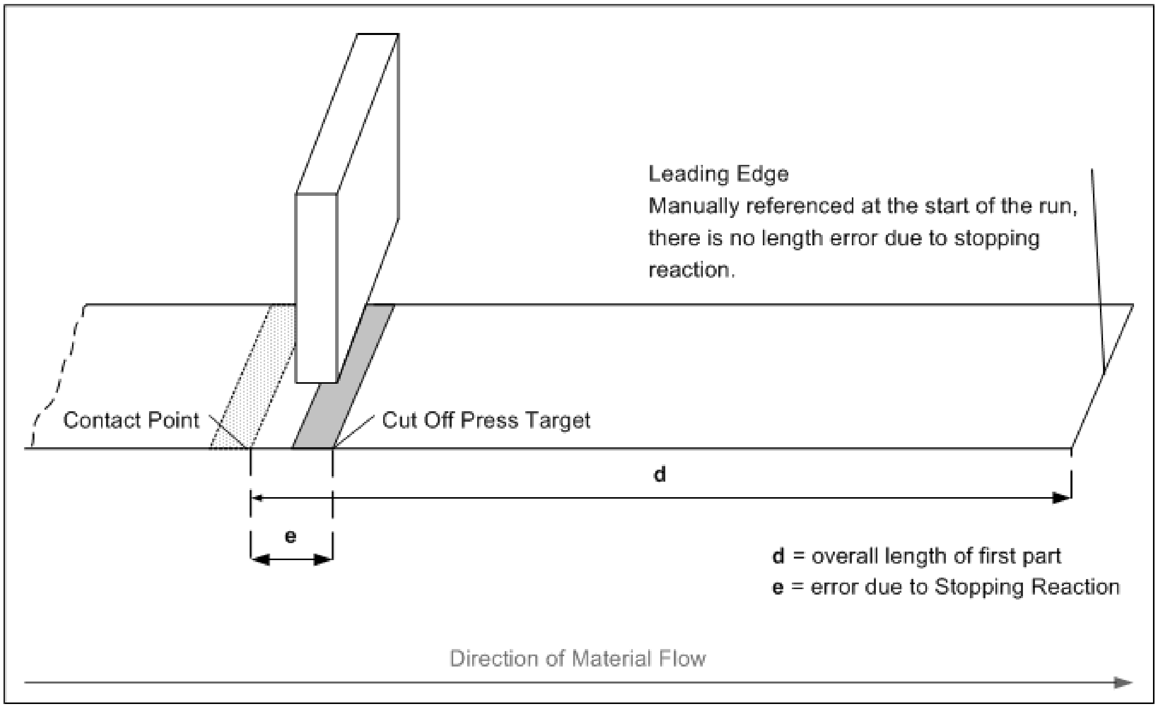


Figure 4-2

Stopping Reaction time can cause the first part after a manual reference to be long or short, and will tend to produce varying lengths due to timing variances in the motor or linkage that drives the material. Timing variances could be the result of varying amounts of material loading the machinery, inconsistent action of valves and solenoids, mechanical backlash in drive systems, or speed changes. Hydraulically driven machines can experience timing variances in cold weather as they tend to be sensitive to temperature.

If the control system can compensate for machinery timing variances, most of the length error can be eliminated. On an open loop feed-to-stop machine, the worse the variance, the harder the control system must work to correct lengths. There is a trade-off between throughput and accuracy in the form of longer stops as the system tries to force press targets into tolerance.

Stopping Reaction Key Points

- **Uncompensated Systems**
  - Produces a Long Part on Startup
  - Sensitive to Speed Changes
  - Sensitive to Environmental Changes
  - Sensitive to Material Changes
- **Compensated Systems**
  - Part Lengths More Accurate from First to Last
  - Compensates for Shifts in Machine Timing
  - Lower Throughput When Compensating for Machine Timing Changes

- Parameters Must be Set Properly

The XL200 Series and Stopping Reaction

The XL200 controller supports the open loop feed-to-stop application with an array of features. On board functionality, such as 2-speed stopping capability, automatic Stopping Reaction compensation, a *Bump Into Tolerance* feature, and hydraulic purge allow users to achieve very accurate and consistent lengths. This section also covers Deceleration Factor due to its association with the Minimum Slow Distance parameter and 2-speed stopping.

2-Speed Stopping

One of the key factors in achieving a consistent Stopping Reaction is to ensure the material is moving at the same speed during each material move before coming to a stop. In a single speed system, the speed at which the material runs is based on part length. As lengths change, the machine can't always get to the same speed with each move. Figure 4-3 shows an example of the motion profile of a machine that runs in single-speed mode.

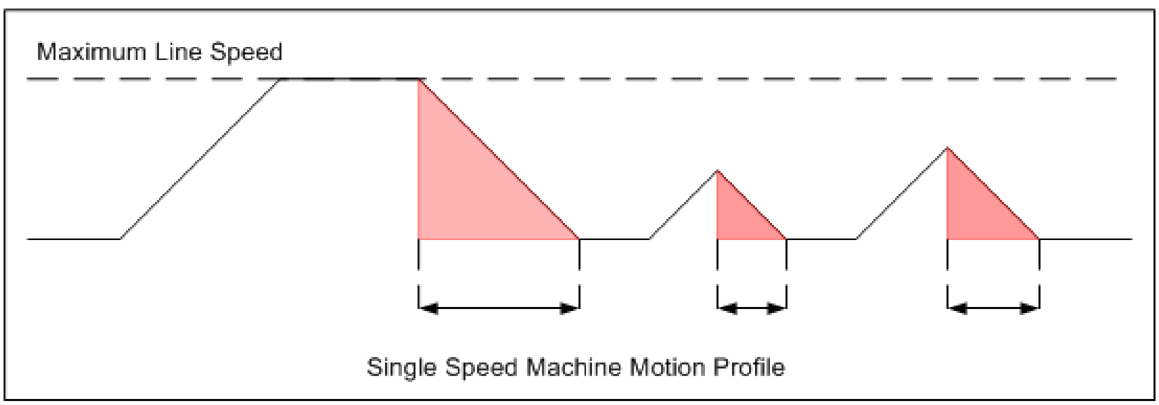


Figure 4-3

The red areas in Figure 4-3 represent the decelerations for each material move. From left to right, a long part is run followed by a very short part, which is followed by an intermediate length. Since the machine doesn't always have time to reach full speed before it must stop for the next press operation, the material isn't always traveling at the same rate when the line halts. The amount of time required to stop the machine changes with each move. Since time and distance are proportional to each other, the distance required to stop the material must also change.

By shifting the material into a pre-set “slow” speed before each stop, the XL200 series controller ensures the material is always traveling at the same speed from stop to stop. This is done by setting a Minimum Slow Distance. When press targets that are closer to each other than the programmed Minimum Slow Distance occur, the controller starts the machine in slow speed, to ensure an accurate stop. An example of a machine using 2-speed operation can be seen in Figure 4-4.

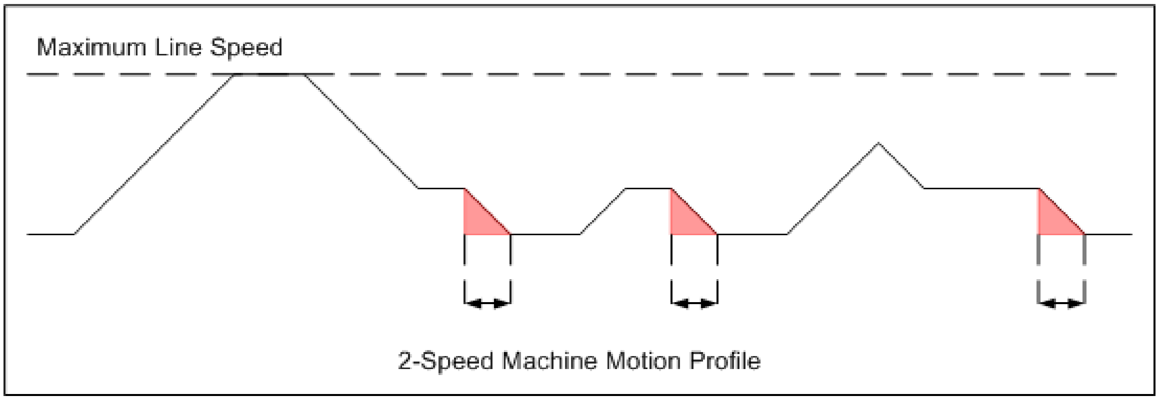


Figure 4-4

It is apparent from Figure 4-4, that when a machine stops from a pre-set slow speed, the stopping action tends to be very consistent. This figure demonstrates the XL200's ability to always shift the material to the same speed before stopping for a press operation. In the case of a short move, such as the second move in the figure, the controller starts the material at slow speed because it calculates the next press target is within the Minimum Slow Distance parameter.

2-Speed Stopping Key Points

- Consistent Lengths Come from Consistent Stopping Action
- Consistent Stopping Action is Achieved by Reaching Consistent Speeds

Deceleration Factor

One of the most misunderstood features of the XL200 series controller is Deceleration Factor. The XL200 does not have direct control of how quickly the machine decelerates. Deceleration is a function of how the machine is driven, the sizing of the motor and what drives it - inverter, hydraulics, or reversing contactors. The amount of material and its hardness also play a role in deceleration.

The XL200 can only monitor deceleration and minimize its impact on throughput. Since throughput is affected by how long the material must remain at slow speed, this feature is available to shorten the time the machine runs at the slower rate by accounting for how long it takes the material to decelerate. The controller will shift the machine into slow earlier, so it decelerates and reaches slow speed at the Minimum Slow Distance.

It's important for the material to run at slow speed for some period of time. For consistent stopping times to occur, a consistent speed must be reached. That's because time during deceleration is a function of speed and distance. If speed varies distance must vary, and in roll forming distance equals "length".

In Figure 4-4, the motion profile of the machine was represented as a perfect trapezoidal wave form. In reality, each time the machine slows from fast to slow, the material will require a small time period to settle to the exact slow speed desired before stopping. This time is usually small, but for accurate stops, it is important that the machine and material be given enough time to settle into slow speed. Figure 4-5 provides a more realistic example of what happens when a machine changes speed.

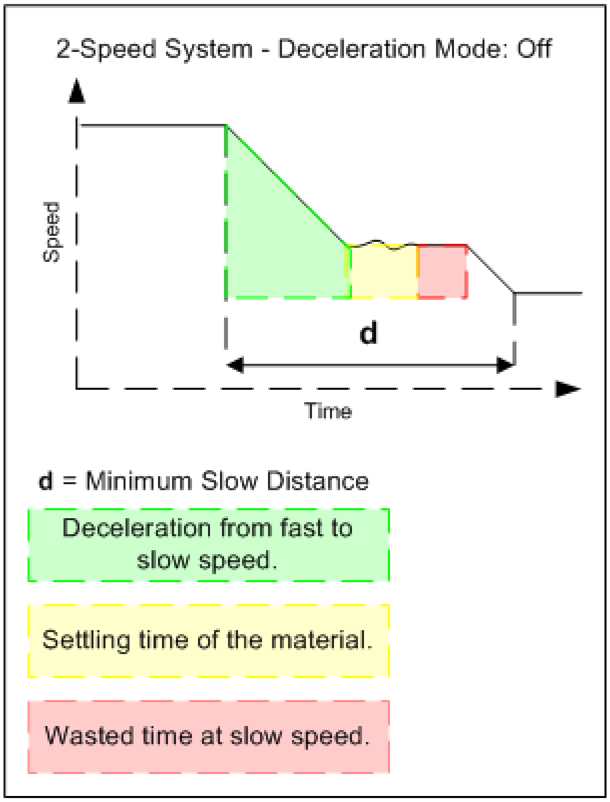


Figure 4-5

As the descending line in Figure 4-5 demonstrates, the material speed is not constant for a short time after the machine shifts speeds. Too much time at slow speed is wasted throughput. If 0.1 s of time is removed from a process that yields 1 part per minute, then in an hour the same machine could produce 6 more parts.

With Deceleration Mode set to Automatic, the XL200 series controller calculates the deceleration ramp when the machine shifts from fast to slow. On successive speed changes, the controller shifts the machine into slow speed earlier, so the material is at slow speed by the time the material reaches the Minimum Slow Distance. Figure 4-6 continues the example after setting Deceleration Mode to Automatic, but without adjusting any other parameters.

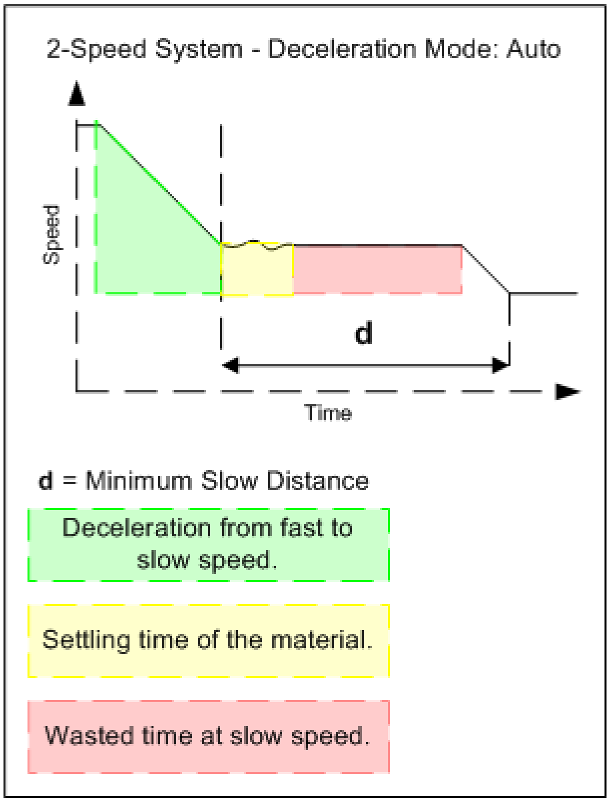


Figure 4-6

In Figure 4-6, the XL200 controller can shift the machine into slow speed so that the material is at slow speed at the programmed distance. Now, maintenance or engineering can adjust the Minimum Slow Distance parameter until the machine stops consistently, but doesn't run for too long at slow speed (See Figure 4-7).

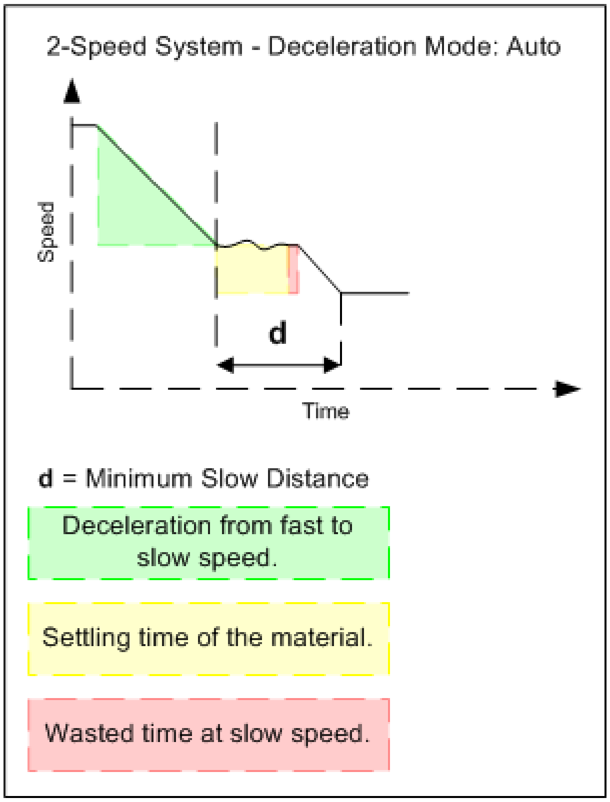


Figure 4-7

Deceleration Compensation Key Points

- Deceleration Compensation Reduces Minimum Slow Distance
- Shorter Minimum Slow Distance Translates to Greater Throughput

Automatic Stopping Reaction Compensation

By default, each time the machine stops for a press operation in the Run mode, the XL200 series controller calculates how much time elapsed from the point when its motion outputs turned off till the material speed reached 0 fpm (0 mpm). It updates this value in a parameter called Stopping Reaction Time.

On the next stop, the controller uses the time from the last stop to help minimize variance. In this way, the XL200 series controller compensates for some machine time variances.

If the machine has large swings in Stopping Reaction time, then the material will probably fall out of tolerance. When this happens, the controller will warn the user and exit the Run mode. The Stopping Reaction Time parameter is not updated when an out of tolerance stop is made, because the assumption is that the time is not a good value.

In many cases, a large shift in Stopping Reaction time indicates there is something wrong with the material or equipment. It could be the material is dragging on a guide or becoming jammed in the machine. The machine could have a problem with a solenoid that is failing, or a valve that has become “sticky”. Wear and tear on the chains, gearing or couplers of the machine will create backlash causing the material to actually back up a bit after it stops. This is common with chain driven machinery, because chains will slacken over time.

Sometimes a machine is built with these issues inherent in the machine design. Because the application is very low cost, the user of the equipment is expected to accept the nature of the machine and the process. Constant maintenance is required to keep the machine operating at peak efficiency. Otherwise, the user must rely on control features such as the XL200’s B*ump Into Tolerance* functionality to produce accurate and consistent parts on a machine that would otherwise be incapable of doing so.

Bump Into Tolerance

The XL200 Series controller can make small adjustments to the material position before firing a press in the automatic mode. AMS Controls calls this “bumping into tolerance”.

The *Bump Into Tolerance* feature uses three parameters to force the machine to produce good parts:

- **Tolerance** – The Tolerance parameter is a standard parameter that is always used in the open loop feed-to-stop application. When the user sets this value, he tells the XL200 Series controller that lengths outside of this range (+/- the value entered) are unacceptable.

  If the machine stops for a press operation in the Run mode, and the material stops outside the programmed range, the XL200 will exit the Run mode and display the “Out of tolerance” error to the operator.

- **Bump Tolerance** – Bump Tolerance should be programmed at a value larger than the Tolerance parameter.

  If the machine stops for a press operation in the Run mode, and the material is outside of the programmed Tolerance, but still within the programmed Bump Tolerance range, the controller will not display “Out of tolerance”. Instead, the XL200 will attempt to force the material into Tolerance by turning on its motion outputs for a time equal to the programmed Bump Time.

  If the material stops outside of the programmed Bump Tolerance, the XL200 will exit the Run mode and display the “Out of tolerance” error to the operator.

- **Bump Time** – The Bump Time is the amount of time required to get the material into motion. Generally, this should be a very small amount of time, as the longer the time, the larger the material move. This time will be different for every machine and is based on the mechanics of the machinery.

Figure 4-8 graphically represents the concept of Bump Tolerance. The green band of acceptable tolerance represents the value programmed into the Tolerance parameter. The red bands on either side represent the area described by the Bump Tolerance.

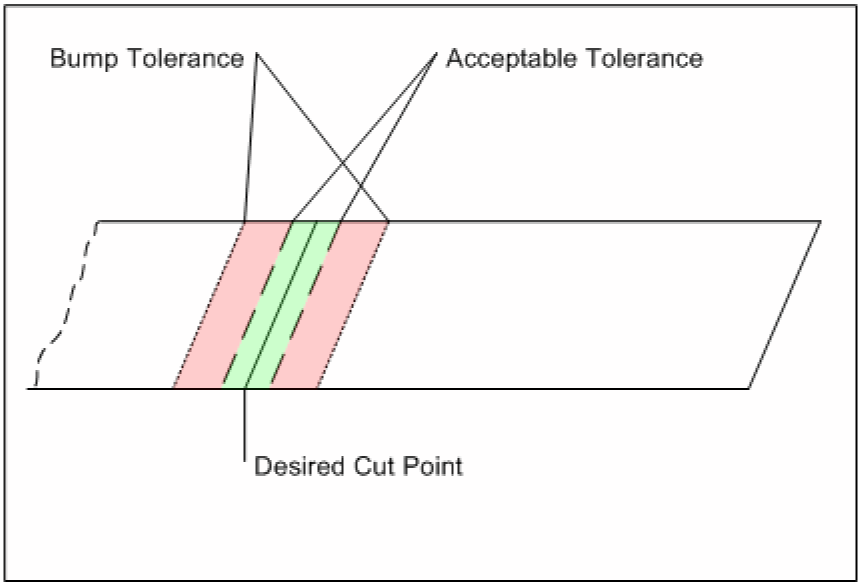


Figure 4-8

The XL200 Series controller will use its outputs to cause the machine to bump the material forward if the material stops short (Figure 4-9) or reverse if the material stops long (Figure 4-10), respectively.

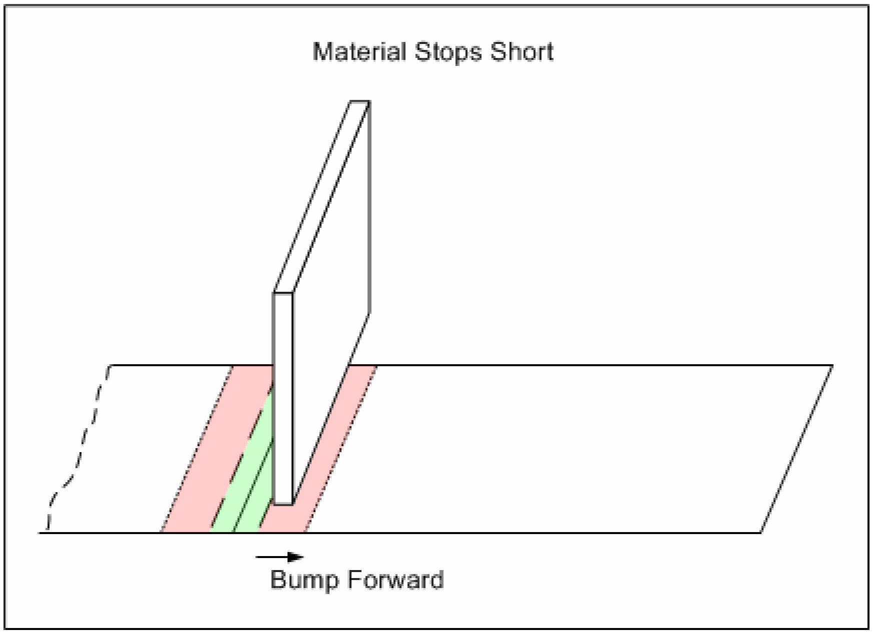


Figure 4-9

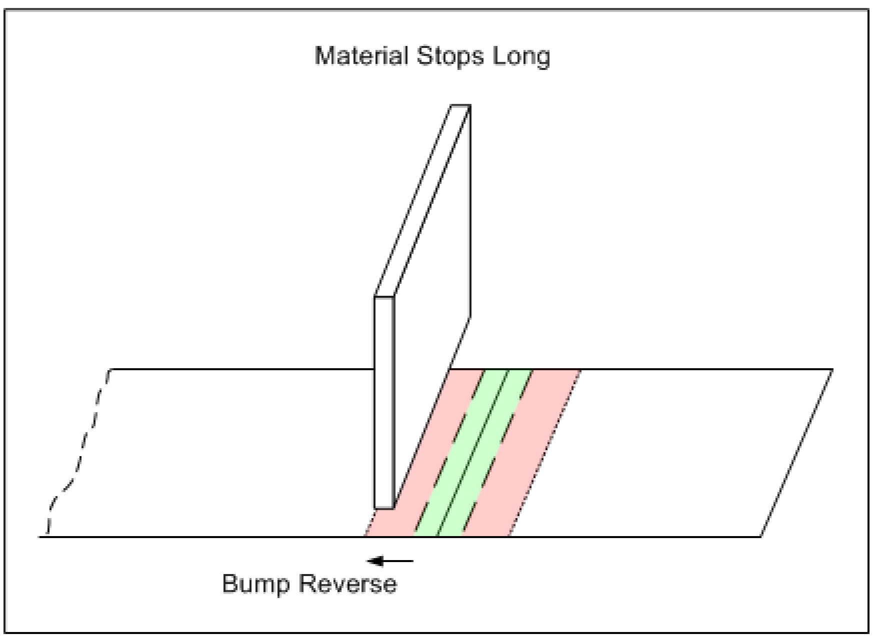


Figure 4-10

Bump Into Tolerance solves a lot of problems related to the machine, but the trade-off is a reduction in throughput. If the machine cannot consistently stop the material, the XL200 Series controller must work harder to nudge the material into Tolerance. The tighter the Tolerance and the less consistent the machine, the longer it will take to produce a good part.

Situations where the machine spends a lot of time “bumping” could indicate the Bump Time is set too long, or the machine has become mechanically less consistent over time.

Hydraulic Purge

Hydraulic systems are often used in the open loop feed-to-stop application for machine movement, because hydraulic fluid is generally considered to be incompressible, for practical roll forming purposes. This provides a very stable means of control.

When valves open to allow fluid to flow, the machine reaches Run speed very quickly. Consequentially, the stopping action on a hydraulically driven machine tends to be very consistent. As long as high-quality valves are used, and those valves are driven directly by the controller’s outputs, timing variances should be kept to a minimum.

A potential pitfall of using hydraulics is the viscosity of hydraulic fluid, the resistance of the fluid to flow, changes based on temperature. Most of the time this is not a problem, but when a machine sits idle for a long period of time (overnight) and the temperature in the building is cold, the machine’s timing is going to be affected by the cold hydraulic fluid.

One solution to this problem is to add a heater element to the reservoir. For systems that don’t incorporate a heater element, the XL200 Series controller provides a Hydraulic Purge function. Hydraulic Purge is a function found under the Diagnostic menu of the XL200.

The operator can choose to cycle the shear press, punch presses, or all presses using Hydraulic Purge. This feature causes the controller to cycle the selected presses over and over. This forces hydraulic fluid to flow through the system, warming the fluid and ensuring it’s cycled through the cylinders and hoses. If this is done at the beginning of the shift for a period of time, then the machine should be “warmed up” by the time production begins.

Summary

Open loop feed-to-stop systems provide a low cost, high accuracy solution for roll forming applications. Throughput is relatively low, especially when tolerance requirements are tight.

Part length repeatability is not affected by press consistency, but relies instead upon the machine’s ability to stop consistently. Reliable stopping action comes from hitting uniform speeds, and avoiding mechanical backlash.

The XL200 Series controller has several on-board features that compensate for timing variances that come from mechanical inconsistency. The greater the variance, and the tighter the tolerance requirement, the more throughput can be affected.

Open Loop Flying Die

Open Loop Flying Die Specific Parameters

- **Shear Reaction**
  SHEAR REACTION is the programmed amount of time that that reflects how long it takes the shear press to engage the material from the time the shear signal first turns on. This time value is used to determine the most accurate point at which to fire the press for a given material velocity. This is especially useful when material is being fed at a varying line velocity. This parameter and calculation corrects for the "first piece long" problem that many other control systems encounter when running material after a shear crop.
- **Shear Boost Dwell**
  The SHEAR BOOST DWELL time is the total amount of time that the shear boost output stays on. This output is used to put the die into forward motion while the shear is performing its cut. The programmed time needs to be long enough to allow the shear to fully cycle down and back out of the material.
- **Shear Boost Reaction**
  The SHEAR BOOST REACTION time is used to advance the firing of the shear boost by a given amount of time. The larger this time is, the earlier the boost output will fire. When timed correctly with a properly calibrated boost, the die will appear nearly "weightless" when the cutoff die hits the material. This parameter is not used to obtain accuracy, but instead is used to improve the quality of the cut. A larger boost reaction will correct for the die causing a buckle on the leading edge of the part. A smaller boost reaction will correct for the die tearing the material and the leading side of the part.
- **Shear Boost Enable Velocity**
  The SHEAR BOOST ENABLE VELOCITY parameter sets the velocity at which the shear boost begins turning on. If the material velocity (line speed) is less than this programmed value, the boost output will not turn on when the press is fired. A value of "0.000" enables the boost output at any speed.
- **Shear Boost Compensation**
  The SHEAR BOOST COMPENSATION DISTANCE is the distance that the boosted shear die travels forward from its home location to the location it engages the material while in the run mode. This becomes a reference to keeps parts accurate between standing cuts and flying cuts.
- **Velocity at Max Analog Voltage**
  This parameter is defined for Analog Output #1 on the XL200 Series Controller. This setting will allow the controller to "reflect" what the line velocity is by a proportional, 10-volt output from the XL controller. The range for this parameter is 0 to 1000 FPM. The default setting of "0" disables this feature. With this option, the controller provides an analog output proportional to line speed measured by the line encoder. The user programs the maximum velocity in Feet Per Minute (FPM). The controller will output 10 VDC at line speeds equal to or greater than this

parameter. As speed decreases, the output is scaled down linearly until zero FPM is equal to zero volts DC.

The open loop flying die machine is a low cost solution that offers high throughput. Line speeds can exceed 500 fpm (150 mpm). Accuracy on this type of machine is usually around ± 0.06” (1.5 mm). Tighter accuracies are possible with this application, but they require precision in the setup of the material encoder, and robust maintenance of the equipment to keep it functioning optimally.

Open Loop Flying Die Key Features

- High Cycle Rates / High Line Speeds (up to 4 hits per second)
- Low Cost
- Moderate Accuracy
- Higher Accuracies Require Regular Maintenance
- Sensitive to Timing / Tracking Variations

One of the most common uses of this application is in steel stud production. Stud lines typically use closed loop flying dies for their cut off operations, but the punching of the knockouts (holes in the stud used to run conduit and plumbing) are generally open loop flying die with boosts. Knockouts on a steel stud don’t require tight tolerances, but punch presses must fire at short intervals – as close as 18” (460 mm). On machines that produce studs at speeds in excess of 400 fpm (120 mpm), open loop flying die is the perfect application for knockout punches.

There are generally two major variations of the open loop flying die application; boosted and unboosted dies. A boost is a hydraulic or pneumatic cylinder used to push or pull the die up to material speed. Some systems even use a proportional valve to more accurately match material speed with the die. Generally, boost cylinders are required for higher line speeds.

Press Reaction

Whenever a length control system signals a press to begin its operation, the time between when the control system turns on its output, and when the press tooling contacts the material is called Press Reaction time (see Figure 3-1).

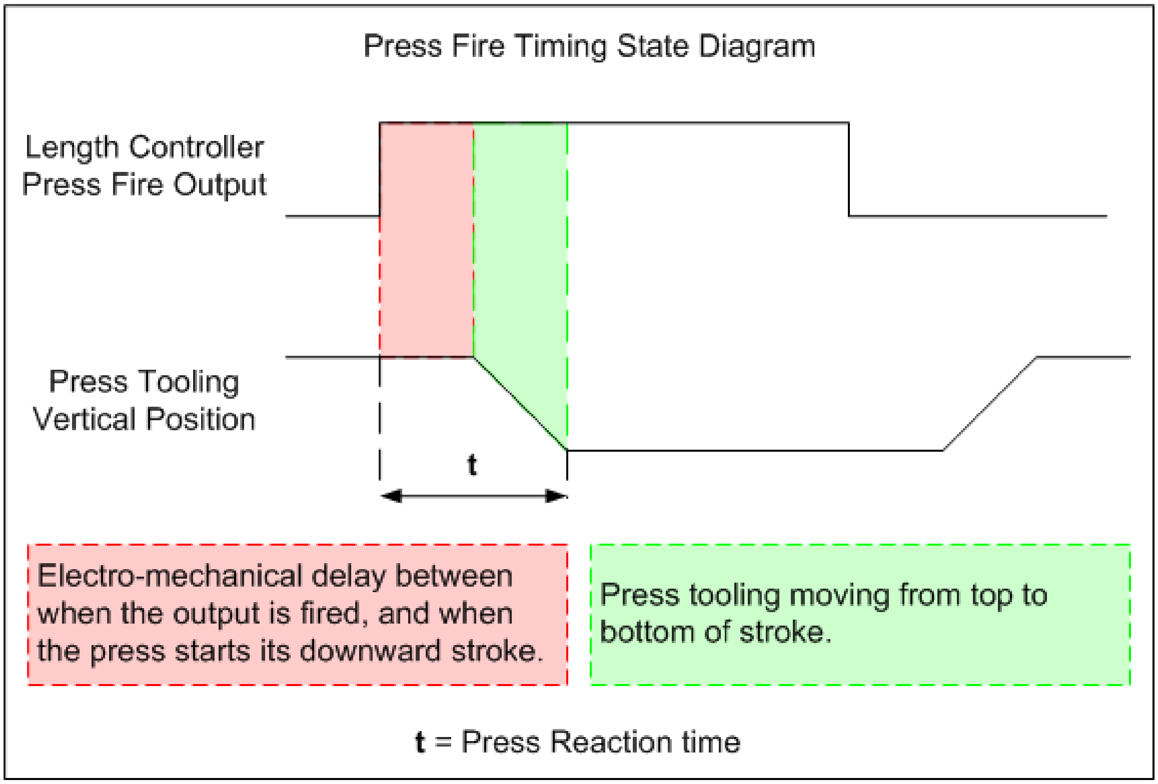


Figure 3-1

If the first part produced by a machine is long, it's usually because of Press Reaction time (Figure 3-2). The industry commonly accepts this wasted material, because many control systems lack timing parameters to compensate for the error. Roll forming operations that use in-line punching struggle with the problem of uncompensated press reaction by virtue of having multiple reference points to keep aligned on a finished part.

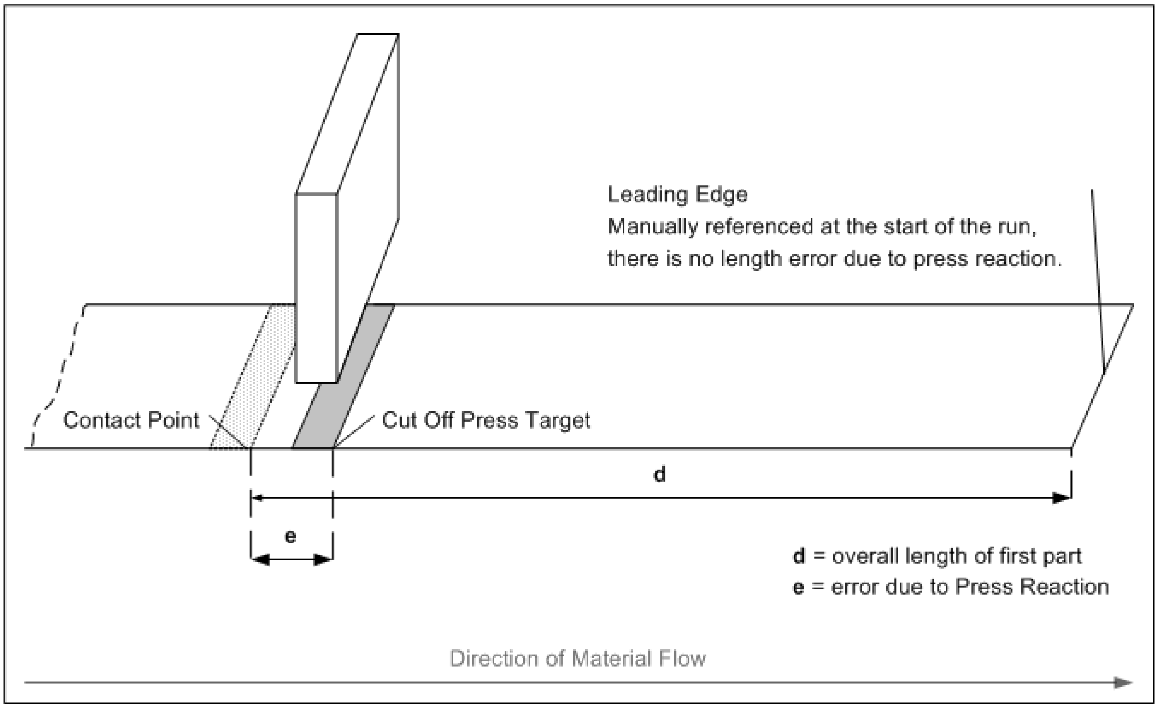


Figure 3-2

Because time, distance and speed are directly proportional on a roll former, lengths on an open loop flying die must grow when the line speeds up, and shorten as the roll former slows. After a couple of parts, the lengths will appear to stabilize. Unfortunately, on an open loop flying punch, the entire pattern can shift in relationship to the leading or trailing edge.

If the system cannot compensate for Press Reaction, the error must be reconciled by changing the distance values for the presses. Length control systems that are capable of automatically compensating for Press Reaction can reduce or eliminate length shifts due to speed change for all presses they control. But even compensated length control systems can miss targets when improperly parameterized.

Press Reaction Key Points

- **Uncompensated Systems**
  - Produce a Long Part on Start Up (after a manual reference)
  - Lengths and Punch Patterns Shift During Speed Changes
  - Encourages Incorrect Parameterization by Operations
- **Compensated Systems**
  - Part Lengths Accurate from First to Last
  - Part Lengths Do Not "Shift" During Speed Change
  - Punch Patterns Do Not "Drift" During Speed Change
  - Parameters Must be Properly Set

The XL200 Series and Press Reaction

The XL200 controller has several features to support the operation of open loop lines that cut and punch on-the-fly. Primarily, the XL200 accepts a Press Reaction value for each press it controls.

Assuming a press is operating consistently, its reaction time must still be factored into the firing of the press for length accuracy for all parts. When any length control system tries to hit a moving target with an open loop press, it's going to miss the target if it waits to fire the press until the target is directly under the tooling.

The XL200 pre-fires presses based on their reaction time and the current speed of the material. If the speed changes, the controller adjusts the distance from target that presses are fired. This eliminates long parts on startup and creates smooth transitions for punch patterns during speed changes.

To gain these benefits, the XL200 must be properly parameterized. The Press Reaction Calculation Procedure offers a step-by-step method for calculating Press Reaction time.

Length Variance

In the open loop flying die system, the only feedback for length control comes from the material encoder. The length control system references the encoder to the shear (and all other flying presses on the line) by virtue of the fact that the material should be a straight line between those points. When the roll former pushes material forward in the automatic mode, the length control system counts encoder pulses for distance measurement and fires presses based on that measurement.

For part length consistency and accuracy, encoder tracking is critical, but so is press consistency. Fast acting and repeatable valves are important for producing consistent punch locations and part lengths. The faster the line runs, the more important the timing of the press firing becomes.

The only way to verify Press Reaction time is to measure it. If the timing is consistent, this is a simple matter, but if a variance is suspected, the measurement process is more involved. Example 1 describes a situation where variance in Press Reaction time is a problem:

Example 1

A roll former produces parts at a rate of 100 fpm (30 mpm) and the acceptable tolerance range on finished parts is ± 0.060" (1.5 mm). Part tolerance has been varying by 0.6" (15 mm) for the last few days.

After examining the encoder assembly and performing some basic tests on the control system, the determination is made that these areas are functioning as expected. Suspecting a variance in press timing, maintenance checks press consistency using an oscilloscope.

Maintenance finds that the press has a reaction time variance of 0.03 s. "30 milliseconds" doesn't sound like much time, but speed multiplied by time equals distance:

$$\mathbf{s \cdot t = d}$$

s = speed

t = time

d = distance

s = 100 fpm (30 mpm) or 20 ips (500 mmps)
t = 0.03 s

20 ips (500 mmps) · 0.03 s = **0.6" (15 mm)**
Simply due to the inconsistency of the press, the part lengths on this machine vary by more than 0.5" (12.7 mm).

Speed fluctuations can cause length problems that look like timing variances. Solenoid driver (slammer) boards, such as the AMS Controls 6390 board, can help mitigate the effects of such speed changes. The 6390 board accepts the 24 VDC signal from the length controller and changes it into a 45, 60, 75, or 90 VDC signal.

DC solenoids are more responsive than AC solenoids, due to the nature of how the coil builds its electrical field. AC solenoids can often be fired using DC current, making them more consistent. Even DC solenoids can be made faster acting and more consistent by using a slammer board. The 6390 fires its output at the higher voltage only for the first 0.03 seconds, to get the solenoid to shift quickly, then the 6390 drops its voltage to a 24 VDC holding signal for the remainder of the press cycle time to protect the life of the solenoid coil.

Calculating Press Reaction

Collect a notebook, pen, and calculator. During this procedure, the line speed displayed on the controller must be noted. Measurements must be taken in the order parts are produced from the machine. It might be helpful to have support personnel available to observe and record.

1. Program two press operations (in the case of a shear, two part lengths). Be sure to program them at a distance that is long enough so that when the XL200 fires the press in automatic, the line is ***at speed***. If the line is still accelerating up to speed, the test will be invalid.

   If the machine supports in-line punching, program the shear and punch tool at the same offset distance for the purpose of the test. After the test, reprogram the punch tool to the correct physical distance.

2. Perform a standing press operation (fire the press manually while the material is halted).
3. Run the line.
4. After the controller has fired the press twice, measure the distance from the standing press hit to the first automatic press hit. Then measure from the first automatic press hit to the second.
5. Subtract the second length from the first.
6. Divide the result by the line speed in feet per minute (meters per minute).
7. Multiply the result by 5 (0.06 if using the metric system).
8. The result is the Press Reaction time.

If part lengths are inconsistent due to encoder tracking problems or press reaction variances, this test is a waste of time. Inconsistencies *must be eliminated first* before measurements to eliminate constant errors can be performed. To entertain any other methodology is an exercise in futility and frustration.

When performing the Press Reaction Calculation Procedure for the first time, it is often helpful to run at least 5 parts in a row. The first two can be used to calculate reaction time, if the last 4 parts are consistent.

Example

Maintenance (Joe) is called to examine an open loop flying die machine. Larry, the machine operator, complains that the machine produces varying lengths on startup and sometimes during the production run. Upon examination, Joe can see that the XL200 was never programmed with a Shear Reaction value (or he suspects the value has been changed).

Joe begins by programming 5 parts at 60” (1524 mm). It is well known that this machine reaches speed after a short distance, so there is no need to program a longer part that might potentially become scrap. He sets the line to run at 150 fpm (46 mpm) for the purpose of the test.

Joe performs a Manual Shear operation to reference the cutoff, and then he runs the line. After 5 parts are produced, he halts the line and measures the parts in the order they were produced, first to last. His results are:

62.375”	1584.3 mm
59.875”	1520.8 mm
60.25”	1530.4 mm
60.5”	1536.7 mm
60.06”	1525.5 mm

Based on the numbers, Joe can see that there is an overall length variance that he must address before he continues with any other efforts. He knows how critical the material encoder tracking is to the accuracy of the process, so he begins by checking the alignment of the encoder wheel and bracket to the material.

Joe finds the wheel to be significantly out of alignment and corrects the problem. He programs another 5 parts, performs a Manual Shear, and runs a second set of 60” (1524 mm) parts. This time, his results are:

64.5”	1638.3 mm
60.31”	1531.9 mm
60.25”	1530.4 mm
60.218”	1529.5 mm
60.282”	1531.2 mm

From the results, Joe is satisfied that the machine is performing consistently enough that he can now use the features built into the XL200 to eliminate the rest of the length issues. He runs through the procedure for calculating Press Reaction, using the average of the last 4 parts as his “second length”:

1st length – 2nd length = 4.235” (107.6 mm)

4.235” (107.6 mm) / 150 fpm (46 mpm) = 0.02823 (2.3528)

0.028233 (2.3528) · 5 (0.06) = 0.1412 s

Joe enters the value 0.1412 s into the Shear Reaction parameter in the XL200 controller. He also knows he can use the Calibrate Trim feature to remove the consistent 0.265” (6.73 mm) error from his overall length.

Now, when Joe turns the line over to Larry, production can expect part lengths to be consistent and accurate from first-to-last, even when Larry changes speeds during production.

Press Consistency

Checking Press Consistency with an Oscilloscope

For open loop flying die processes, press consistency is critical. The ability of the press to perform its operation in a repeatable fashion is directly linked to length tolerance.

Press reaction time is the amount of time it takes for the press to react to a signal to begin its operation. If reaction time is stable and consistent, the resulting part lengths should be stable and consistent. That’s because speed, time, and distance are in direct proportion with each other:

s · t = d
s = speed
t = time
d = distance

If speed is consistent, but time varies, distance must also vary. Because of this, open loop flying die applications rely heavily on the ability of the equipment to behave in a repeatable fashion. When a press's reaction time is suspect, maintenance or engineering can test the press timing to verify its operation.

To check the timing of a press, the following equipment is required:

- 2-channel oscilloscope
- Magnetic base
- High-speed proximity sensor
- Bracket to mount prox. sensor to magnetic base

Begin by removing material from the press die. This test should be performed while the machine is standing still. There is absolutely no need to perform this test while the machine is in motion. Whatever time is required to fire the press is the same amount of time, regardless of the speed of the material.

Mount the prox. sensor to its bracket, and fix the bracket to the magnetic base. Wire voltage to the prox. sensor. Mount the magnetic base as close to the press as possible, and set the prox. sensor so it will detect the press tooling at the bottom of the stroke.

Connect one probe of the O'scope to the press fire signal from the length control system. Connect the other probe to the output signal of the prox. sensor. Test fire the press a few times to be sure the prox. sensor is picking up the tooling as close to the bottom of the press stroke as possible. Also, verify the magnetic base is not moving due to vibration from the press.

Once all the components are physically in place and verified, set the O'scope to trigger off the press fire signal of the length controller. This test will display two pieces of information – the true reaction time of the press (though this can be found in a much simpler way), and any variance in the reaction time.

Each time the length controller fires its output, the O'scope should display the transition of the press fire output, as well as the transition from the prox. sensor. The time difference between the two signals is the press reaction time. Manually fire the press through the length controller at least 50 times to be sure the full range of reaction variance is displayed. Each time the O'scope updates the signals, record the time. The maximum and minimum times are the reaction time variance from the press, solenoid, and any relays or boards between the output of the length controller and the press tooling contacting the material.

Many O'scopes have slider bars on their display that can be used to mark the trigger points of signals. These make measuring the time variance convenient. Once the total time variance is known, multiply the time in seconds by the maximum line speed in inches per second. The result should be the length variance from the machine. Any additional variance is probably attributable to encoder tracking issues.

Boosted Dies

Boost cylinders are most often used in open loop flying die applications to keep the material and tooling from being damaged by the press operation. If the die is heavy, or the press operation generates too much force, the material might not be strong enough to support the die and retain its form. Using the material to drag the die up to speed can result in excessive wear on the press tooling. In these cases, the die will need a boost cylinder.

High speed lines usually require boost cylinders for the dies. If these lines run at lower speeds, though, the boost might not be necessary. Boosts sometimes add variance to the overall length of the system. Some boosts are driven directly by shop air, and don't have their own accumulators. As leaks occur in the system, or as other equipment draws down the pressure, the boost doesn't consistently push the die at the same speed and with the same timing characteristics from stroke to stroke.

The boost cylinder can also benefit from a slammer module, just like the press cylinder. The action of the solenoid can be made faster and more consistent, thus eliminating timing and speed variances inherent in the system.

The XL200 Series and Boosted Dies

Boosted dies are well supported in the XL200 Series controller.

Boost Enable Velocity

In order to help compensate for a "sloppy" boost at lower speeds, the XL200 allows the user to define a speed under which the boost is not used when firing the press. When running production under this velocity, the boost is not required to support the weight of the die. Above this speed, the material is moving too fast to avoid being damaged if the tooling enters the material unboosted.

Velocity at Max Analog Voltage

Sometimes, the boost is hydraulically driven. Often, hydraulic boosts are controlled with a proportional valve. This gives the user the ability to more accurately control the speed of the die with relation to the speed of the material, providing a more accurate and cleaner press operation.

The XL200 has an analog output (± 10 VDC) that can be directly scaled to line speed. The parameter **Velocity at Max Analog Voltage** assigns the upper limit of scaling for the analog output. For instance, setting **Velocity at Max Analog Voltage** to 200 fpm (60 mpm) means the controller's analog output will be linearly scaled from 0 – 10 Volts from 0 – 200 fpm (60 mpm).

Die Boost Compensation

Since the boost should not fire unless the material is in motion, the XL200 only fires the boost output when in the Run mode. In order to compensate for the distance not traveled by the die when the press is fired during standstill, there is a **Die Boost Compensation** distance parameter. When the operator references the cutoff press during standstill, the XL200 will adjust the first part by the distance the cutoff die will travel when the boost operates in the Run mode.

Boost Dwell and Boost Reaction

Just as each press fired by the XL200 has a dwell and a reaction time, each boosted press will have dwell and reaction parameters. Boost Dwell is the amount of time the controller fires the boost output. Boost Reaction is how early it fires the output.

Some machines are designed so the die must be boosted up to material speed before the press is fired. This gives the die time to reach material speed so the die’s weight is not resting on the leading edge of the material. On other machines, the boost is so powerful the press should be fired before the boost. Still on others machines, the press and boost should be fired simultaneously.

For greatest flexibility, starting with XL200 v2.10 software, AMS Controls allows the user to program the boost dwell and boost reaction parameters with as much independence as possible. The initial boost output is based on the original press fire target, regardless of any other settings.

The Shear Dwell parameter functions identically in both the old and new software versions. The time entered must still be found by trial-and-error by performing standing cuts on the thickest material that will be run through the machine.

With only the Shear Dwell set, the corresponding boost output will *not* turn on. In Figure 3-3, a shear/boost combination is programmed with Shear Dwell time. Only the shear will turn on for 0.1 s of time.

Shear Dwell Down: 0.100 s
Shear Boost Dwell: 0.000 s
Shear Reaction: 0.000 s
Shear Boost Reaction: 0.000 s

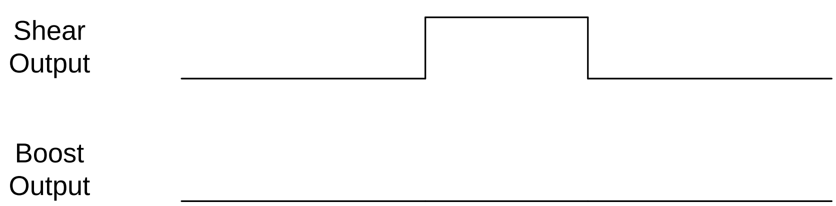


Figure 3-3

In any mode of operation, the system must account for the reaction time of the press in order to make accurate parts from start to finish and through all speed ranges. While establishing the Shear Reaction time, the boost cylinder should be disabled so that it does not impact the operation of the shear die. This can typically be accomplished by removing the solenoid of the valve that controls the boost. The test for Shear Reaction can then be performed at a speed slow enough that the material will support the weight of the die without the boost.

In some cases, it is not possible to fire the shear without using the boost. In this case, the parameters will have to be "dialed in" through trial-and-error.

Once the shear press reaction time is determined, it is entered into its corresponding parameter. This only affects the shear output in Figure 3-4. The boost output "on" state will be based on the original target coincidence point (where the shear would have originally turned on).

Shear Dwell Down: 0.100 s
Shear Boost Dwell: 0.000 s
Shear Reaction: 0.050 s
Shear Boost Reaction: 0.000 s

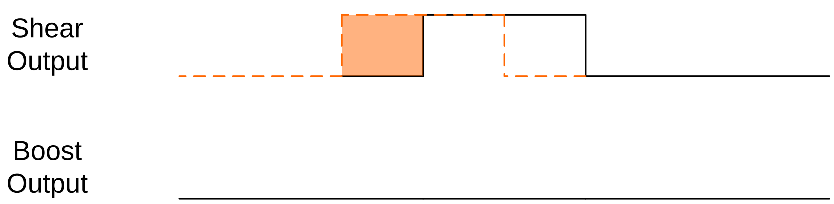


Figure 3-4

After entering the parameters above, the boost is reconnected to the die and some sample parts are run. Often at this point, it might be observed that the shear blade is dragging, or "hanging up" on the leading edge of the material. To solve this problem, some amount of Shear Boost Dwell is added in Figure 3-5 to continue pushing the die forward as the shear blade retracts out of the material.

Shear Dwell Down: 0.100 s
Shear Boost Dwell: 0.200 s
Shear Reaction: 0.050 s
Shear Boost Reaction: 0.000 s

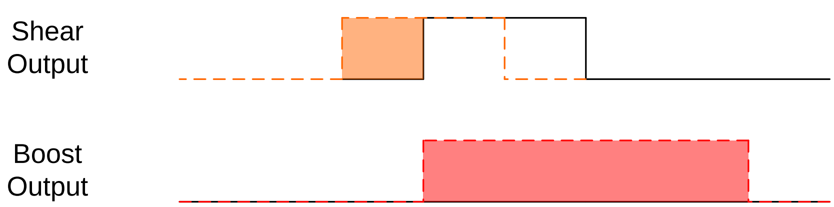


Figure 3-5

At this point, the shear is fired 0.05 s before the boost turns on. When the boost is fired, it stays on longer than the shear output, allowing the shear to retract with no back pressure on the material.

However, at higher speeds, the user might notice some buckling on the leading edge of the next piece. This is an indication that the shear die is not fully up to speed by the time the shear blade contacts the material. To solve this problem, Shear Boost Reaction is added in Figure 3-6 as a way to get the shear die moving earlier, so the die has time to more closely meet line speed by the time the blade contacts material.

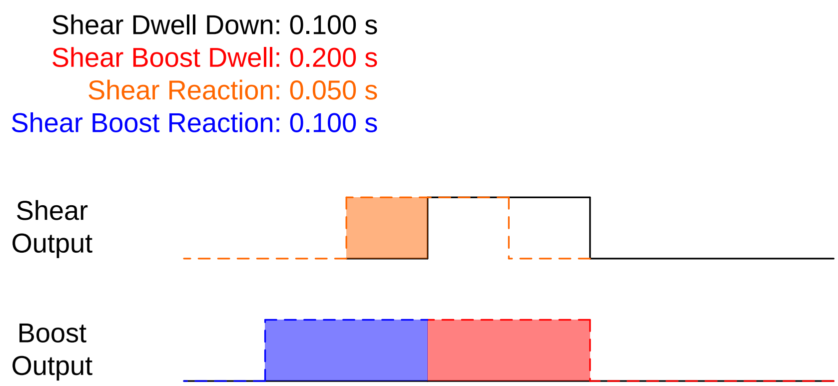


Figure 3-6

After the last parameter change, the boost output fires 0.05 s before the shear output, helping to bring the die up to material speed before the blade contacts the material. Because of the shift in reaction time, it might be necessary to go back and increase the Shear Boost Dwell parameter to force the boost to keep pushing the die as the blade retracts out of the material, if the material starts to hang up on the blade again.

Summary

Open loop flying die applications provide low cost, high speed solutions for roll forming customers. Good accuracy is possible, but requires diligence and maintenance of the system, especially over time.

Repeatability of part lengths relies on good encoder tracking and consistent press timing. Slammer boards are helpful in reducing press reaction times and increasing press solenoid consistency.

Through the use of the Press Reaction parameters in the XL200 series controller, open loop flying die machines can provide good part lengths from first-to-last, and through speed changes. For machines that use boosted dies, the XL200 controller provides a range of support options that allow the user to customize the system to their specific equipment needs.

Boosted Dies

Understanding Boosted Dies

A boost is a hydraulic or pneumatic cylinder used to “shove” a punch or cut tool up to material speed on a roll forming machine. This method of die acceleration is crude and less precise than servo actuation, but it’s cheap and effective. Typically, a boost is only used when the material is not strong enough to support the weight of the die. In this case, the boost helps by pushing the die out as the press is firing so the tooling is already in motion by the time it hits the material.

Boosts are not really used for accuracy, and the boost should not play a role in determining calibration or accuracy on the machine. When establishing press reaction times, the boost should be completely disabled if at all possible. Once the press reaction times and calibration are established, then the boost should be reconnected and it’s timing established. The function of the boost is to prevent material deformation due to the forces involved when trying to use the material to accelerate the weight of the die.

In AMS controllers, the boost output and the press output have a special relationship based on the series of controller (MP300, XL100, XL200). It’s important to understand this relationship to get the best results from the equipment. There are four parameters that work together to determine the timing states of the two outputs; Press (or Shear) Dwell, Press (or Shear) Reaction, Boost Dwell, and Boost Reaction.

MP300, XL100 Series and XL 200 series (up to v2.06)

The Shear Dwell parameter should be set to a time corresponding to the time required to break through the thickest/strongest material run on the machine. This time is found by trial-and-error, requiring the user to load his thickest material into the shear and perform a standing cut, increasing or decreasing the Shear Dwell parameter until just enough time is programmed to break through the material with a single press fire. For the purpose of this document, it is assumed that a Shear Dwell time of 0.1 s is sufficient to break through the thickest material run, and that the shear/boost combination is installed on a functioning roll forming machine.

With only the Shear Dwell set, the corresponding boost output will turn on at the same time and for the same amount of time as the its press output. In Figure 6-1, a shear/boost combination is programmed only with Shear Dwell time. Both the shear and the boost will turn on for 0.1 s of time.

Shear Dwell Down: 0.100 s
Shear Boost Dwell: 0.000 s
Shear Reaction: 0.000 s
Shear Boost Reaction: 0.000 s

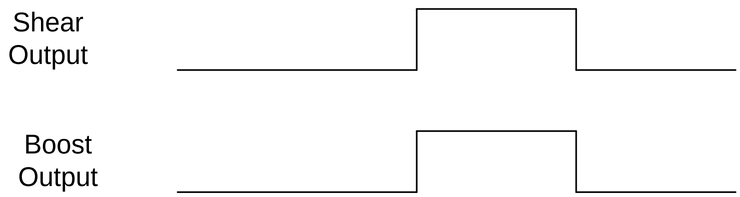


Figure 6-1

Because of the nature of attempting to hit a moving target, it is necessary to compensate for speed changes on the machine. The Shear Reaction parameter handles the time error induced when speed changes occur. While establishing the Shear Reaction time, the boost cylinder should be disabled so that it does not impact the operation of the shear die. This can typically be accomplished by removing the solenoid to the valve that controls the boost. The test for Shear Reaction can then be performed at a speed slow enough that the material will support the weight of the die without the boost. Press reaction formulas are listed in the AMS controller manual, as well as in other documentation, and will not be covered here.

Once the shear's reaction time is determined, it is entered into its corresponding parameter. This affects both the shear and the boost in *figure 6-2*. Because the boost output is tied to the shear output, both signals are shifted forward in time by the programmed reaction time. Both outputs will turn on 0.05 s earlier, and off 0.05 s earlier. The original timing states are shown to represent the original starting point.

Shear Dwell Down: 0.100 s
Shear Boost Dwell: 0.000 s
Shear Reaction: 0.050 s
Shear Boost Reaction: 0.000 s

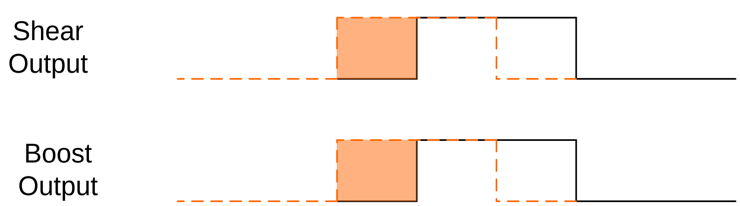


Figure 6-2

After entering the parameters above, the boost is reconnected to the die and some sample parts are run. Often at this point, it might be observed that the die is dragging, or "hanging up" on the leading edge of the material. To solve this problem, some amount of Shear Boost Dwell is added in *figure 6-3* to continue pushing the die forward as the die retracts out of the material.

Shear Dwell Down: 0.100 s
Shear Boost Dwell: 0.100 s
Shear Reaction: 0.050 s
Shear Boost Reaction: 0.000 s

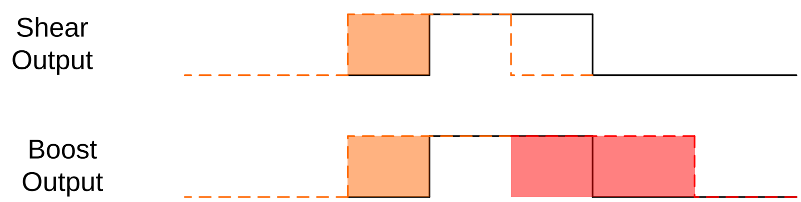


Figure 6-3

This is the first time that the boost begins to behave differently from the shear. Up to this point, the boost turned on at the same time, and for the same amount of time as the shear. Now, the boost stays one for an extra 0.1 s for a total time of 0.2 s. Even though the shear and boost are fired simultaneously, the boost stays on longer, allowing the shear to retract with no back pressure on the material. However, at higher speeds, the user might notice some buckling on the leading edge of the next piece. This is an indication that the shear die is not fully up to speed by the time the shear blade contacts the material. To solve this problem, Shear Boost Reaction is added in *Figure 6-4* as a way to get the shear die moving earlier, so the die has time to more closely meet line speed by the time the blade contacts material.

Shear Dwell Down: 0.100 s
Shear Boost Dwell: 0.100 s
Shear Reaction: 0.050 s
Shear Boost Reaction: 0.050 s

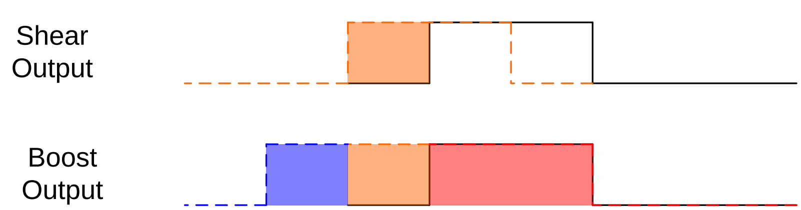


Figure 6-4

It should be noted that the boost output is still only on for a total of 0.2 s, but it turns on 0.05 s before the shear and stays on for 0.05 s after the shear has turned off.

XL200 Series (v2.10 and higher)

Starting with v2.10, it was decided that the XL200 series controller should allow the user completely independent control of the press and boost outputs. This significantly impacts the functionality of the boost output, especially if the user is familiar with the old operation method.

The Shear Dwell parameter functions identically in both the old and new software versions. The time entered must still be found by trial-and-error by performing standing cuts on the thickest material that will be run through the machine.

With only the Shear Dwell set, the corresponding boost output will *not* turn on. In *Figure 6-5*, a shear/boost combination is programmed with Shear Dwell time. Only the shear will turn on for 0.1 s of time.

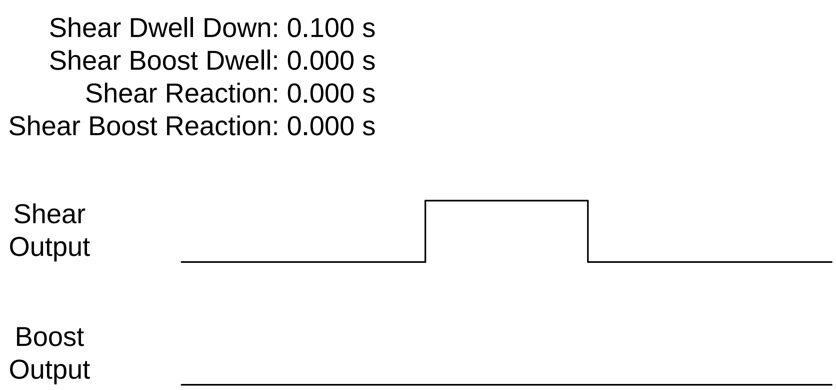


Figure 6-5

In any mode of operation, the system must account for the reaction time of the press in order to make accurate parts from start to finish and through all speed ranges. While establishing the Shear Reaction time, the boost cylinder should be disabled so that it does not impact the operation of the shear die. This can typically be accomplished by removing the solenoid of the valve that controls the boost. The test for Shear Reaction can then be performed at a speed slow enough that the material will support the weight of the die without the boost. Press reaction formulas are listed in the AMS controller manual, as well as other documentation, and will not be covered here.

Once the shear press reaction time is determined, it is entered into its corresponding parameter. This only affects the shear output in *Figure 6-6*. The boost output "on" state will be based on the original target coincidence point (where the shear would have originally turned on).

Shear Dwell Down: 0.100 s
Shear Boost Dwell: 0.000 s
Shear Reaction: 0.050 s
Shear Boost Reaction: 0.000 s

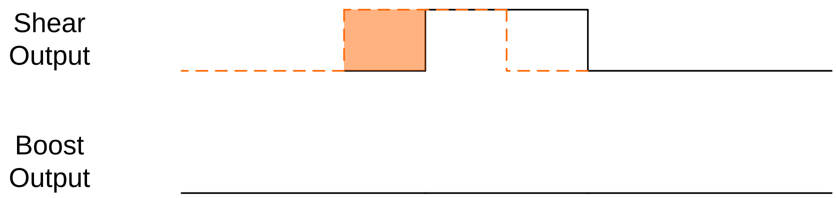


Figure 6-6

After entering the parameters above, the boost is reconnected to the die and some sample parts are run. Often at this point, it might be observed that the die is dragging, or "hanging up" on the leading edge of the material. To solve this problem, some amount of Shear Boost Dwell is added in *Figure 6-7* to continue pushing the die forward as the blade retracts out of the material.

Shear Dwell Down: 0.100 s
Shear Boost Dwell: 0.200 s
Shear Reaction: 0.050 s
Shear Boost Reaction: 0.000 s

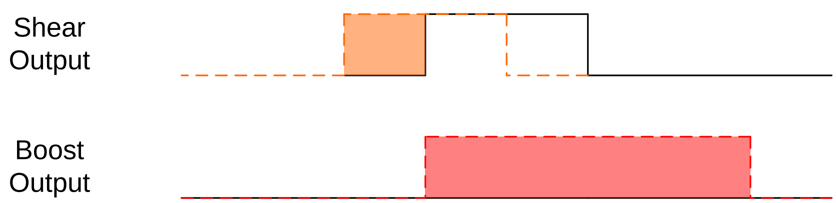


Figure 6-7

At this point, the shear is fired 0.05 s before the boost turns on. When the boost is fired, it stays on longer than the shear output, allowing the shear to retract with no back pressure on the material. However, at higher speeds, the user might notice some buckling on the leading edge of the next piece. This is an indication that the shear die is not fully up to speed by the time the shear blade contacts the material. To solve this problem, Shear Boost Reaction is added in *Figure 6-8* as a way to get the shear die moving earlier, so the die has time to more closely meet line speed by the time the blade contacts material.

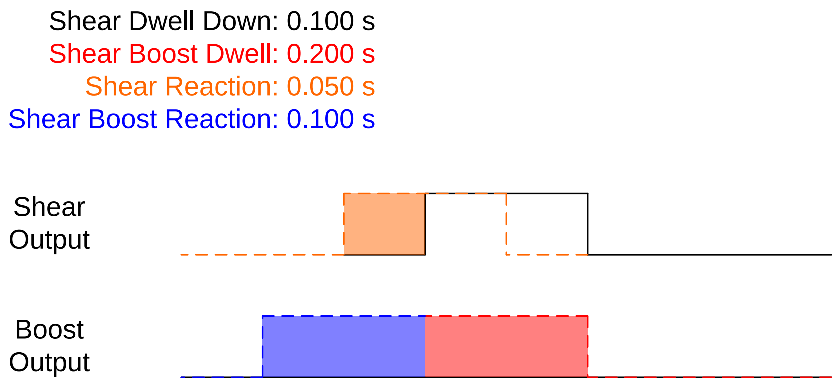


Figure 6-8

After the last parameter change, the boost output fires 0.05 s before the shear output, helping to bring the die up to material speed before the blade contacts the material. Because of the shift in reaction time, it might be necessary to go back and increase the Shear Boost Dwell parameter to force the boost to keep pushing the die as the blade retracts out of the material, if the material starts to hang up on the blade again.

Closed Loop

Closed Loop Feed-to-Stop Specific Parameters

- **Line Resolution**
  The LINE RESOLUTION parameter defines the length of material movement for each increment of the encoder. It is a function of the circumference of the measuring wheel and the number of counts per revolution of the encoder.
  Resolution = Wheel Circumference/(4 x Encoder Count)
- **Motor Resolution**
  MOTOR RESOLUTION defines the value of one count from the motor encoder. This parameter is available only on machines using two-encoder operation.
- **Loop Gain**
  LOOP GAIN is a parameter that sets the sensitivity of the servo loop. Lowering this number will make the drive less responsive. If it is too low, the system will become sluggish. Raising this number will make the system more sensitive and responsive. If the LOOP GAIN is too high, the system can become unstable and cause the motor to oscillate. Great care should be used in changing this number. Make gradual changes.
- **Offset Integral**
  The OFFSET INTEGRAL defines the integral time constant for the removal of position error (DRIFT), when the closed loop servo system attempts to hold the die/feed rolls in a locked position. An OFFSET INTEGRAL time constant of 100 seconds is recommended and is the default value
- **Offset Integral Delay**
  Specifies the time, after the material is supposed to be stationary, that the offset integral begins integrating.
- **Offset Voltage (Auto)**
  The OFFSET VOLTS is the voltage required to hold the drive motor at a stopped position, with no drift in either direction. The AMS controller automatically updates this informational parameter but allows the user to edit it. This would only be done if the initial value is grossly off, and it would take too long for the controller to integrate out the error. The more common usage of this parameter is for monitoring the amount of offset, and making external balance adjustments to the drive. This parameter should be as close to zero as possible to give the controller the maximum control range.
- **Derivative**
  This parameter is used in special application loop control systems. On systems that use hydraulics or have a lot of inertia, it is possible that the system may have a slow response time. If this is the case, it may be possible to have a faster response by entering a DERIVATIVE value.

The sluggish response of the machine will result in an error, and the purpose of the DERIVATIVE is to anticipate the rate of change in the error, and amplify the rate of change to improve performance. If it is determined that this parameter is to be used, start with a value of 3 seconds and then decrease the value until a change in pitch or "hum" is heard in the motor. The "hum" indicates that the controller is overcorrecting the error. When this occurs, increase the value until the system stops oscillating. CAUTION: Changing this value will amplify any noise in the system, as well as the error, which can cause problems in the system. Entering a zero for DERIVATIVE will disable the parameter.

- **Traction % Threshold**
  Traction control starts when the motor velocity exceeds the material velocity by this percentage. Zero disables traction control.
- **Traction % Hysteresis**
  Traction control stops when the motor velocity falls below this percentage of the material velocity saved when traction control started.
- **Jog Velocity**
  The JOG VELOCITY sets the speed that the rolls turn on a feed-to-stop machine during jog operations.
- **Slow Run Velocity**
  Sets the velocity for material feeding when the "Slow Run" input (input #16) is activated.
- **Maximum Velocity**
  The MAXIMUM VELOCITY parameter sets the maximum running speed for a feed to stop machine. This is the speed the controller will attempt to run at between operations.
- **Acceleration**
  ACCELERATION sets the rate of change of velocity for the feed rolls.
- **Retract After Cut**
  Defines the distance on a feed-to-stop line that the material will retract after the shear down during the shear up. The purpose of this parameter is to prevent the shear blade from scraping against the leading edge of the metal as it moves up.

Closed Loop Flying Cut Specific Parameters

- **Tolerance Mode**
  If STOP NO CUT is selected, the controller will check for tolerance before firing the shear. Tolerance will be checked starting at the Minimum Die Distance until tolerance is achieved. If tolerance is not achieved by the time the die reaches the Maximum Die Distance, the controller will display an error message and stop the line without making the cut. If CUT & STOP is selected, the controller will make the cut at the Minimum Die Distance and then check for tolerance at the end of the "Shear Dwell Down" time (bottom of stroke). If tolerance is not met, the controller will then stop the line and display an error message. The die control parameters must be properly set in order to avoid unnecessary tolerance errors.

- **Minimum Die Distance**
  Defines the shortest distance from the die home position where a cut can occur. As the die accelerates for a cut during the run mode, it must pass this MINIMUM DIE DISTANCE before the Shear Down output will turn on.
  Minimum Die Distance = (Line Velocity^2)/(2 x Acceleration)
- **Maximum Die Distance**
  The MAXIMUM DIE DISTANCE defines the furthest distance from the home position that a shear can occur. When the machine is being operated in a "no cut" mode and the tolerance is not obtained by the time the die reaches the Max Die Distance, no cut is made. If the tolerance is obtained at the MAXIMUM DIE DISTANCE, the cut will be made. Because of this, there must be enough travel left to complete a cycle. The MAXIMUM DIE DISTANCE should be adjusted so that there is enough travel left for the die to cycle the press within the remaining travel distance.
- **Shear Die Distance**
  Defines the point at which all manual cuts will be made when the controller is not running. Note: This value is measured relative to the Die Home Switch
- **Reference Die on Manual Shear**
  Determines whether or not the die will reference itself on the home switch whenever a manual operation is performed. Setting this parameter to NO causes the manual operation to activate the press at the die's current position.
- **Line Resolution**
  The LINE RESOLUTION parameter defines the length of material movement for each increment of the encoder. It is a function of the circumference of the measuring wheel and the number of counts per revolution of the encoder.
  Resolution = Wheel Circumference/(4 x Encoder Count)
- **Die Resolution**
  DIE RESOLUTION defines the value of one count from the die encoder as reflected in the movement of the die. See Line Resolution above.
- **Loop Gain**
  LOOP GAIN is a parameter that sets the sensitivity of the servo loop. Lowering this number will make the drive less responsive. If it is too low, the system will become sluggish. Raising this number will make the system more sensitive and responsive. If the LOOP GAIN is too high, the system can become unstable and cause the motor to oscillate. Great care should be used in changing this number. Make gradual changes.
- **Offset Integral**
  The OFFSET INTEGRAL defines the integral time constant for the removal of position error (DRIFT), when the closed loop servo system attempts to hold the die/feed rolls in a locked position. An OFFSET INTEGRAL time constant of 100 seconds is recommended and is the default value
- **Offset Integral Delay**
  Specifies the time, after the material is supposed to be stationary, that the offset integral begins integrating.

- **Offset Voltage (Auto)**
  The OFFSET VOLTS is the voltage required to hold the drive motor at a stopped position, with no drift in either direction. The AMS controller automatically updates this informational parameter but allows the user to edit it. This would only be done if the initial value is grossly off, and it would take too long for the controller to integrate out the error. The more common usage of this parameter is for monitoring the amount of offset, and making external balance adjustments to the drive. This parameter should be as close to zero as possible to give the controller the maximum control range.
- **Derivative**
  This parameter is used in special application loop control systems. On systems that use hydraulics or have a lot of inertia, it is possible that the system may have a slow response time. If this is the case, it may be possible to have a faster response by entering a DERIVATIVE value. The sluggish response of the machine will result in an error, and the purpose of the DERIVATIVE is to anticipate the rate of change in the error, and amplify the rate of change to improve performance. If it is determined that this parameter is to be used, start with a value of 3 seconds and then decrease the value until a change in pitch or “hum” is heard in the motor. The “hum” indicates that the controller is overcorrecting the error. When this occurs, increase the value until the system stops oscillating. CAUTION: Changing this value will amplify any noise in the system, as well as the error, which can cause problems in the system. Entering a zero for DERIVATIVE will disable the parameter.
- **Lag Integral**
  The LAG INTEGRAL defines the integral time constant for the removal of velocity error (LAG), when tracking a moving target. The “Lag Compensation” parameter has 66% of its error removed after the accumulated time given in the Lag Integral parameter. This lag time is only accumulated while the die is between the minimum and maximum die locations.
- **Lag Compensation (Auto)**
  LAG COMPENSATION is the integral that is used to correct for a condition where the speed is matched, but the position lags behind the target. This parameter is automatically adjusted and is not normally changed by the user. If this value becomes unstable, there may be a mechanical problem in the system.
- **Lag Integration Limit**
  This parameter, if non-zero, limits the amount of change that can occur to the Lag Compensation (Auto) setup parameter during one press cycle. This can be used to minimize the integral windup that may occur with long press dwells. It is disabled during Die-Test.
- **Jog Select Mode**
  Defines how the controller’s jog inputs are used. JOG LINE causes the jog forward and jog reverse inputs to jog the material unless the controller is in Die Jog Mode. JOG DIE causes the inputs to jog the die regardless of what mode the controller is in.
- **Jog Velocity**
  On a flying die machine, the JOG VELOCITY sets the speed during die jog operations and also for referencing.

- **Minimum Die Return Velocity**
  When the Die on a Die-accelerator is returning after a cut, it will return only as fast as is necessary to make the next target. If a faster return is desired, the “Min Velocity” parameter can be used to set the lowest allowable return velocity. The range of this parameter is 10 to 500 FPM.
- **Maximum Die Return Velocity**
  MAX VELOCITY sets the maximum return speed of the die.
- **Acceleration**
  ACCELERATION sets the rate of change of velocity the die travel. This parameter controls both the acceleration and deceleration of the forward travel for Die Accelerators.
- **Return Acceleration**
  The RETURN ACCELERATION sets the acceleration for the flying die to return to home after the cut has been made. This parameter typically can be set higher than the forward ACCELERATION since the die return is not a critical movement. This will decrease the overall cycle time of each cut. The RETURN ACCELERATION can also be adjusted for a lower value, which will result in less wear and tear on the actuating system. Units are expressed in inches per second, per second (Inches/second^2).
- **Advance After Cut**
  ADVANCE AFTER CUT is the distance on a non-stop line that the die will advance after the shear down and before the shear up. The purpose of this parameter is to prevent the shear blade from scraping against the leading edge of the metal as it moves up.
- **Die Reference**
  Adjusts the position where the die waits to make a cut during the run mode. When this is set to MIN or MAX DISTANCE, the AMS controller calculates the distance needed to accelerate the die up to match the current line speed, and positions the die so that it reaches speed when it hits the reference point. When this is set to HOME SWITCH, the die sites at the home switch while waiting to make a cut.

Closed Loop Fundamentals

This document is written to instruct users of AMS Controls’ microprocessor-based machine controllers in the theory, use, and application of closed loop systems. The information presented here offers an explanation of “closed loop” that ranges from basic to advanced concepts.

Setup, tuning, application, and troubleshooting are covered throughout this document. Specific machine control types are discussed in great detail as well as two special machine applications.

Safety & Voltages

Servo amplifiers (drives) are designed to control powerful currents at high voltage. These drives are typically built using large capacitors which can store a charge for several minutes, even after power has been removed from the system. Many drives are capable of applying up to 300% of their rated output.

It is critical that any service to a servo drive be performed only by a qualified electrical technician, and all service must be performed to the manufacturer’s specifications. Even the installation or removal of cables should be done carefully, and all pertinent manuals and procedures should be carefully read and followed.

The voltages carried by a servo drive can maim or kill.

Safety & Mechanics

During a startup or when testing for problems with servo actuated tooling, it is recommended that the tooling be disconnected from the servo motor. The motor body should be strapped to a solid surface or mechanically fixed in position.

When control problems arise, the servo motor can spin out of control so quickly that it is impossible to react in time to stop it. These motors are capable of producing a great deal of torque which can rip heads off of bolts, fold solid steel fixtures, and crush or kill personnel.

Roll Forming Machine Physics

In the roll forming industry, there are a few basic formulae that are important to understanding control systems and machine performance. Troubleshooting and installations can be impossible tasks without a basic understanding of these mathematical concepts.

Speed Conversion

Speed is a critical variable in most equations. Most machine speeds are expressed in feet per minute (fpm). When running calculations where fractions of a second are important, line speeds in fpm must be converted to inches per second (ips).

There are 60 seconds in 1 minute, and 12 inches in 1 foot, therefore:

$$\frac{60\ \text{s}}{1\ \text{min}} \div \frac{12\ \text{in}}{1\ \text{ft}}$$

When dividing two fractions, always invert one fraction and multiply the two together:

$$\frac{60\ \text{s}}{1\ \text{min}} \cdot \frac{1\ \text{ft}}{12\ \text{in}}$$

Next, simplify the equation:

$$\frac{5\ \text{s}}{1\ \text{min}} \cdot \frac{1\ \text{ft}}{1\ \text{in}}$$

The final product is the conversion factor:

$$\frac{5\ \text{s(ft)}}{1\ \text{min(in)}}$$

It's usually acceptable to drop the nomenclature from the conversion and use the constant "5" when performing a conversion. When converting from fpm to ips, divide by 5. When converting from ips to fpm, multiply by 5.

Speed, Time & Distance

In roll forming, speed, time and distance are critical factors. Length (distance) control is an important quality control. Variations in time and speed can result in variances in length.

In any application, the relationship between speed, time and distance is always linear:

$$s \cdot t = d$$

s = speed
t = time
d = distance

AMS controllers use distance and time to calculate speed. If there is an error in the distance measurement, the calculated speed will be wrong, and time critical operations will be off their mark.

In certain applications, length consistency is dependent upon timing consistency from the press. In this case, any fluctuation in timing will result in a length error. Consider the following example:

> An open loop flying cut-to-length line runs at a constant 200 fpm. The shear press is hydraulically actuated. After measuring several pieces, the total variance of the finished part lengths is 1" (± 0.5"). Assuming all the other possible reasons for length variance have been eliminated as potential causes, a variance in the timing of the press reaction is suspected. Calculating the variance:

$$s \cdot t = d$$

s = 200 fpm = 40 ips
t = ?
d = 1"

$$40 \text{ ips} \cdot t = 1''$$

$$t = 1''/ 40 \text{ ips}$$

$$t = 0.025 \text{ s}$$

> A 25 ms time variance can cause a 1" length variance at 200 fpm. In this particular example, the press reaction time could be measured using high-speed proximity sensor and an oscilloscope. Such a variance might be caused by a sticky valve, or an under-charged accumulator.

The distance equation, or variations of it, are used throughout roll forming. Several uses are explained within the context of machine applications later in this document.

The Loop

There are two general methods of machine control in roll forming machine applications; open loop and closed loop. The word “loop” refers to a communications loop between the control apparatus and the equipment.

In open loop applications, the communication is one-way, from the material. The control system (controller) measures the material and fires presses based on time, distance and speed calculations. If the equipment doesn’t actually do the job, the controller can’t measure the error or do anything to correct for error.

Closed loop applications provide the controller a means, through a servo system, to change tooling speed and position to match that of the material. The servo system also provides feedback to the controller. By comparing servo feedback from the tooling to the feedback from the material encoder, the controller can measure and correct for error.

Open Loop

In the open loop system shown as *Figure 1-8*, an encoder rides on the material and provides position information to the controller. Once the material has moved the programmed distance, the controller sends a signal to a solenoid valve to allow air or hydraulic fluid to flow. The valve controls the actuation of a press. The press might or might not fire in the desired position. If the tooling is out of position in relationship to the material, the controller cannot sense the error, nor can it do nothing to correct the error, because it has no communication (feedback) back from the press tooling. Accuracy cannot be measured by the controller and must be measured by another means, such as the machine operator.

In *Figure 1-8*, material position is fed to the controller from an encoder riding directly on the material. The controller’s output is sent to a press as the material flows through the tooling. When the controller turns on its press output, it expects the press to fire, though it has no way of measuring where the tooling contacted the material. If the press is slow to react to the press fire signal from the controller, or if the press reacts in an inconsistent manner, part tolerances will suffer.

In this example, the material carries the tooling forward as the cutting operation is performed. When material strength is low, a boost cylinder is typically used to help “shove” the tooling up to material speed.

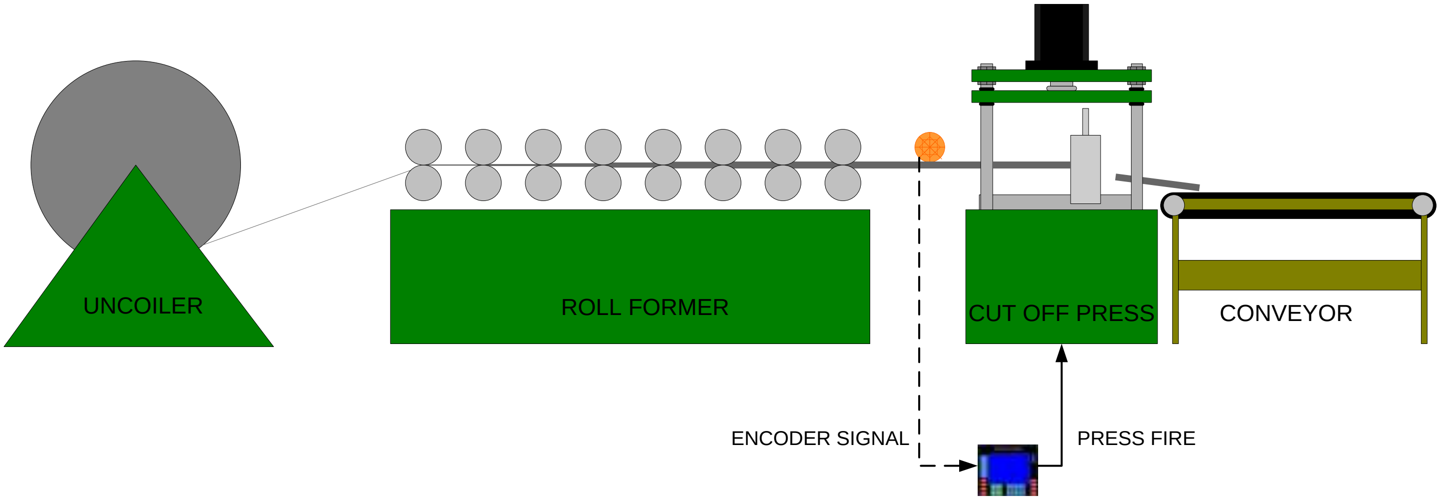


Figure 1-8 – Open Loop System

In the open loop machine application, accuracy and repeatability is directly tied to the performance capabilities of the equipment. If the roll former can't maintain a constant and consistent speed, if the press reaction time fluctuates, if the tooling does not come back to exactly the same home position every time, then the overall tolerance and repeatability of part lengths will vary.

Closed loop applications provide a method for tracking the tooling. Through the use of a servo system, the controller can accurately monitor the position of the press tools and move them, as necessary. The controller commands the servo drive to move the motor. As the motor moves, it reports its position back to the drive, which in turn sends that position data back to the controller.

Figure 1-9 represents a closed loop flying shear system. As in the open loop model of *Figure 1-8*, a material encoder sends material position data to the controller. The two systems are identical except that in *Figure 1-9* the die is moved by an actuator that is controlled by a servo system. The servo motor is mounted to the back of the actuator (a ballscrew actuator is represented) and the servo drive is shown as another link in the chain.

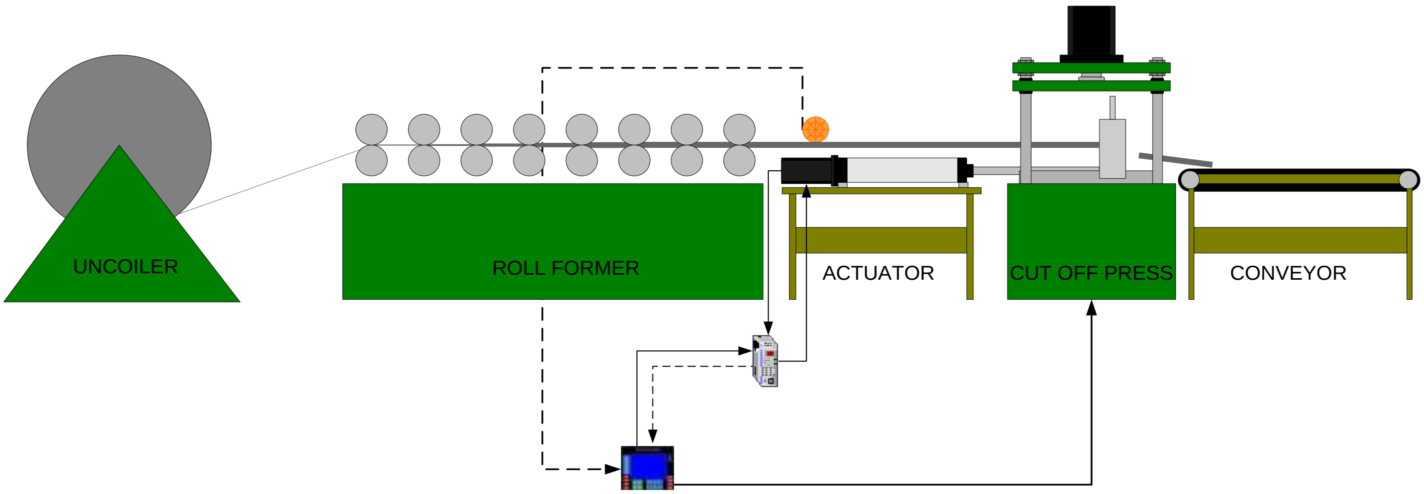


Figure 1-9 – Closed Loop Die Accelerator

Figure 1-10 shows a close-up of the relationship between the controller and servo system. The controller sends its analog command signal to the servo drive. The command signal controls motor position through velocity changes. The drive monitors current draw from the motor and the position of the motor shaft through the resolver feedback from the motor. The drive, through software and hardware, the resolver feedback from the motor is converted into an emulated encoder signal which is fed back to the controller.

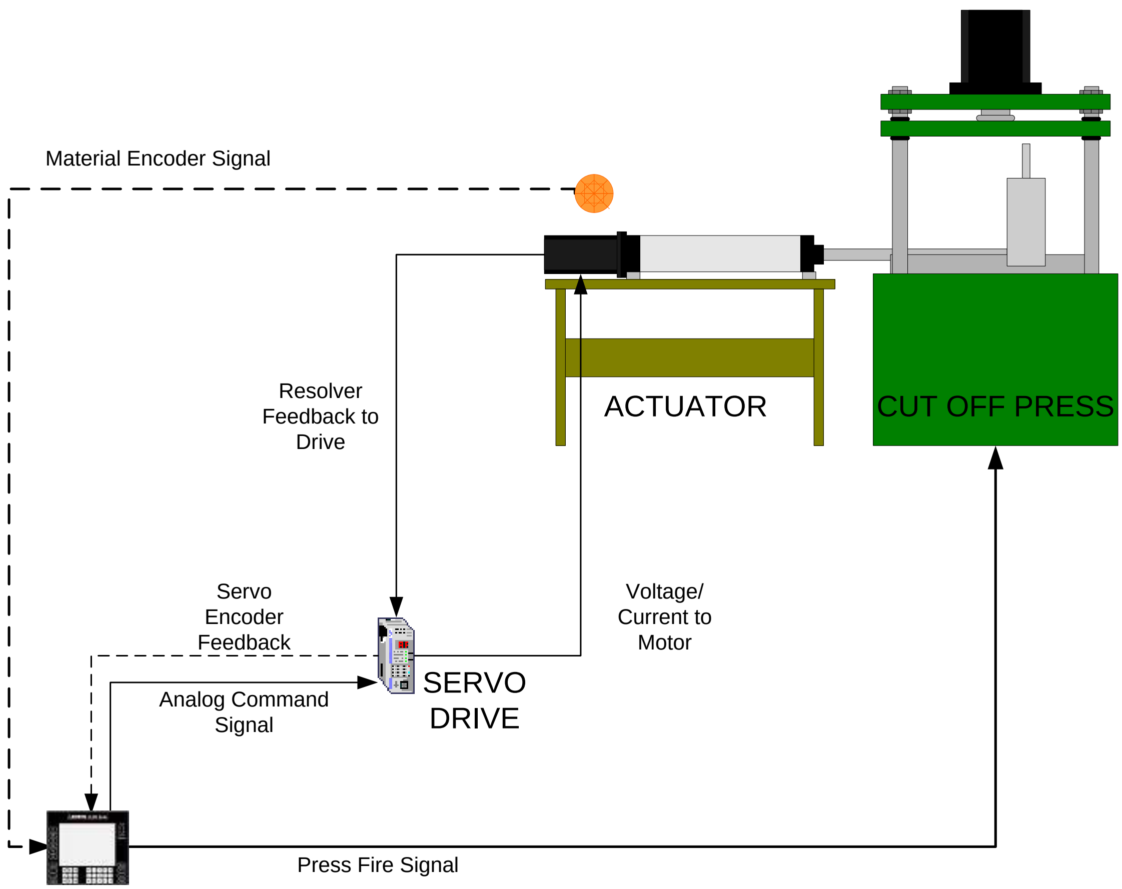


Figure 1-10

PID Loops

PID is short for *Proportional Gain*, *Integral*, and *Derivative*. In order to utilize a PID loop, some form of feedback to the driver (control system) is required.

The controller is monitoring the direction, speed, and position of the material through the line encoder. When a target comes into range of the tooling, the controller will try to make the tooling match speed and position with the target for the period of time required to perform the press operation. The tooling is controlled by a servo motor that sends encoder pulses to the controller. The controller uses the encoder pulses from the motor encoder to calculate speed and position of the tooling so the material and tooling speed and position can be matched.

As the servo motor spins, it acquires energy. Let's imagine that the controller can see through the feedback that the motor is slightly ahead of the target. The amount of speed change required to move the motor into position with the target would be the *Proportional Gain* (Gain). The controller commands the servo to change speed (slow down) to match position; however, the inertia of the motor will likely cause it to overshoot its target speed. When the controller sees this overshoot it tries to correct for the error and commands the motor to increase its speed again, causing another overshoot because of inertia. This creates a sort of ripple effect.

The loop also includes a *Derivative* portion. Derivative is a rate of change. So, as the controller tries to position the motor through speed changes, the derivative tells the controller how quickly or slowly to make the change. This allows the controller to adjust the amount of overshoot and make the ripple effect smaller.

Finally, the *Integral* is a summation of error over time. The integral tells the controller how much error it should correct over a given time period. If not for the integral, it is possible the controller might not attempt to correct for error if the error is small enough. Over time, the error is added up for each time increment of the integral and eventually forces a change to occur.

Inner and Outer Loop

When talking about the "closed loop" of a controller/servo system, it is important to understand that there are actually two closed loops in the system. The primary loop is the inner loop between the drive and the servo motor. The loop between the controller and the servo drive is the outer loop. The controller closes its loop *around* the servo loop.

Figure 1-11

Figure 1-11 demonstrates the inner and outer loop. The inner loop of the servo system is shown with larger arrows to indicate the importance of that loop. If the inner loop is properly tuned, the outer loop is less important to the overall performance of the system and is used as a "fine tuning" for the purpose of maintaining tight tolerances.

The tuning of the inner loop also influences how much of an effect tuning the outer loop has on the system. If greater flexibility is desired from the end-user point of view, it is desirable to “de-tune” the inner loop, slightly, to allow a greater range of tuning capability in the controller.
For all intents and purposes, the drive is typically ignored with respect to the loop. The controller really doesn’t “see” the servo drive. From the perspective of the controller, the motor feedback comes directly from the motor, and the controller’s speed and position commands are being sent directly to the motor. Thus, in most discussions, the drive is ignored.

Initial Controller Settings

Before parameterization of the control system can begin, certain specifics about the application must be known. Typically, it is sufficient to set the system up for a “worst-case scenario”. The idea being that if the system can perform well under the most extreme circumstance, it will typically perform well under any lesser circumstances.

The basic information required for parameterization is as follows:

- Maximum Line Speed
- Minimum Part Length at Maximum Line Speed
- Press Dwell (Down and Up)
- Acceleration

Maximum line speed and press dwell are the two most important variables. Minimum part length and acceleration are usually set and determined by maximum line speed and press dwell. Acceleration will be limited to the physical capabilities of the servo system.
To help understand the process by which the variable are calculated, the following example data will be used:

- Maximum Line Speed: 300 fpm
- Press Dwell: 0.18 s
- Minimum Part Length at Maximum Speed: 80”

Analog Command Signal

The controller uses an analog voltage to control the servo system. This voltage has a range from -10 VDC to +10 VDC. The actual voltage applied to the motor from the amplifier is typically 300 VDC to 700 VDC depending on the application and the incoming 3-phase power requirements. Servo drives are more aptly termed amplifiers, because they amplify the command signal from the controller to the servo motor. This document prefers the term “drive” in reference to servo amplifiers, since it denotes a motion aspect to the servo system, i.e. the amplifier *drives* the servo motor.

The analog circuit on the controller (and that of most servo drives) is a differential circuit. Differential signals tend to be immune to the effects of electrical noise. In order to correctly measure the voltage of the signal, the leads of a digital volt-ohm meter (DVOM) must be applied to both signal wires. The signal should not be read with respect to ground.

An oscilloscope is a better piece of equipment for monitoring the analog command signal, since it displays the signal over time. Viewing the analog signal on an oscilloscope will allow the complete motion profile to be seen at one time, as well as any potential disturbances in the signal. A disturbance in the command signal indicates the controller is attempting to compensate for a problem in the servo motor feedback.

When the drive is enabled, the controller commands the servo motor to 0 rpm. At this point, the motor is under “holding torque”. Because of the natural drift of a servo motor the controller is required to offset the drift through a slight increase in the command signal voltage. Therefore, 0 rpm usually does not equal 0 VDC on the command signal.

When the controller applies a positive voltage to the system, the motor spins in the “positive” direction. When the controller applies a negative voltage, the motor spins in the opposite direction. The greater the voltage applied (with respect to 0 VDC) the faster the motor should spin in either direction. Thus it is possible to test for problems in the control and servo systems by forcing the drive to “enable” (prepare to accept a command voltage and respond to that voltage) and apply a battery to the command inputs to simulate the controller function. This “battery test” is useful in troubleshooting the nature of servo/controller problems. The battery test is described in full in the Troubleshooting section.

Resolution

Resolution describes the amount of movement for a given measurement increment. In terms of a TTL encoder, it is the distance per pulse from the encoder.

As an encoder shaft turns, the encoder sends pulses to the controller. Encoders have a set number of pulses they can produce for 1 revolution of the encoder shaft. If the linear movement of 1 encoder revolution is divided by the number of pulses per revolution, the resolution can be calculated.

For example; the shaft (1” diameter) of a servo motor is connected to a 7:1 gearbox. The output shaft of the gearbox is connected to a 5.45” diameter pulley. A timing belt is wrapped around the pulley and an identical, idler pulley a few feet away. Resolution is calculated as follows:

$\text{resolution} = (C/r_g)/(m_{ppr})$

C = circumference = πD
D = pulley diameter

r_g = gearbox ratio
m_{ppr} = post-quadrature encoder pulses per revolution of the motor

5.45” · π is the linear movement of any given point on the timing belt for 1 revolution of the pulley. The input shaft of the gearbox must turn 7 times to get one full revolution of the pulley. Therefore, (5.45” · π)/7 is the amount of linear movement for one full revolution of the motor shaft. The servo drive has been programmed to emulate 5000 pulses per motor revolution. The resolution of the servo encoder is ((5.45” · π)/7)/5000, or 0.00048919” per pulse. 489 micro-inches is less than one half of one thousandth of an inch.

When calculating resolution, it’s important to keep in mind that the more couplings and gears involved in the mechanical movement of the tooling, the more likely the calculated resolution will be off. Once the calculated value is entered in the controller parameters and the system has been initialized, true tuning should not progress until a physical measurement has been taken and compared against the distance displayed on the controller screen. The larger the error in distance, the larger the error in speed and position match.

Feedback

Feedback is the term used to describe the reporting of the motor’s current position. The servo motor reports its position to the drive and the drive then reports that position to the controller. Often, a motor will use a resolver to report position data to the drive. A resolver is a sinusoidal waveform generator that allows very precise measurement. Some servo manufacturers are capable of tracking the position of a rotary motor down to 7.6 micro-inches (0.0000076”).

Since the controller cannot accept a resolver input, the drive converts the resolver signal into an encoder pulse through hardware/software emulation. The encoder signal is a series of TTL, 0 – 5 VDC square waves (also a differential signal). In digital drives, the encoder emulation can typically be set to whatever the user desires within the range of the equipment. AMS Controls typically tracks motor position to within a few hundred micro-inches, though the controller is capable of tracking position to 40 micro-inches.

If the feedback signal to the drive or controller is distorted or missing, the servo system will behave in an extremely erratic manner. Minimally, position loss will occur which can cause some machine types to slam the moving parts into hard stops.

Runaway

When recovering from a power up or E-Stop condition, the controller is in an idle state. The analog command signal is at 0 VDC (or whatever capacitive value is sitting on the line) and the Drive Enable output on the controller is inactive.

There are 4 conditions that cause the controller to move the motor:

- Putting the controller into Run
- Initiating the Die Test
- Giving the controller a Manual Shear input
- Giving the controller a Jog Forward or Jog Reverse input

Any of the above conditions cause the controller to begin a routine for initializing the servo system to accept a command signal. The controller does some internal checks based on which of the four conditions began the process (i.e. checking to see if orders have been programmed if it received a Run input).

Assuming all the internal checks for the given condition pass, the controller turns on the Drive Enable output. Once the output has been turned on, the controller waits for a certain amount of time for the drive to prepare itself to receive the commands. Once that time has passed, the controller sets its analog command signal to a specific voltage in an attempt to get an encoder count back from the servo motor. When that count comes back to the controller, it is tested to see if the count was in the direction the controller expected.

Any time the servo system fails to do what the controller expects, the controller increases its analog command signal in an attempt to force the motor to do what it expects it to do. Once the analog command signal reaches 10 VDC for 30 ms, the controller turns off the enable output to the drive and generates a “Drive Not Responding” error. “Drive Not Responding” is a generic error. Since the controller doesn’t actually communicate to the drive, there is no way for the controller to determine the nature of the problem. The controller can only tell that the motor is not doing what it expects the motor to do.

When the controller does not get the feedback from the servo system that it expects, a runaway condition can occur. There are really 3 types of runaway condition.

1. If the controller commands the servo motor to move in one direction, and it receives feedback indicating the motor is moving in the opposite direction, the controller will increase its analog command signal in an attempt to “force” the drive to move the motor in the correct direction. If there is a wiring problem (such as an inverted encoder signal from the drive), then this in essence tells the drive to turn the motor faster.

   As the counts continue to feed back to the controller in the wrong direction, but at an increasing rate, the controller very quickly ramps its analog command signal to the maximum output of the circuit (10 VDC).

2. If no counts are received from the motor, the controller will leave its analog command signal at the current setting and continue to wait for an encoder count. If the controller never receives a

count, it will wait in this state until something changes. If the condition that caused the controller to enable to servo system was a Jog command from the user, another Jog command will cause the controller to increase the analog command voltage. The more times the Jog button is pressed, or the longer the input is held on, the higher the analog command voltage will be increased until it reaches 10 VDC for 30 ms.

This condition will manifest itself in a less violent manner than if the encoder counts are not in the correct direction, but the motor will continue to turn which can drive tooling into physical stops. This problem can “look” like an inverted encoder signal if the Jog inputs are what initiate the problem, and the operator holds his finger on the button. Decoupling the motor from the load and quickly “tapping” the Job button one time should cause the motor to turn at one consistent speed if the problem is a total lack of feedback.

3. Electrical noise can distort the encoder feedback from the drive to the controller. The controller must see a clean transition on the square waves coming back from the drive. If the square waves are so deformed that they begin to look like a saw-tooth waveform, the controller will throw those counts out because they are not a clear low-to-high transition. The effect will be that the motor moves the tooling farther in one or both directions (typically the problem manifests in only one direction during an instance, since it’s typically one edge of the wave form that is distorted).

   The reason is the controller must see the encoder counts for distance and speed calculations. If it doesn’t get enough counts, then it thinks the motor is traveling too slowly, and that it hasn’t traveled as far as it should. Everything the controller knows about the servo motor comes from the encoder feedback.

   This particular problem usually does not result in the “Drive Not Responding” error from the controller because noise usually does not deform enough square waves over a period of time to cause total loss of control.

The servo system itself can have problems with feedback from the motor to the drive. This almost always results in drive generated errors, though, which are typically easy to identify and troubleshoot. In the case of a problem with the servo feedback, a battery test will reveal the problem in the servo system.

Control and Direction on Startup

When starting up a new servo system for the first time, one of the first things that must be done is to ascertain control and direction of the servo motor. Before attempting to put the system into motion, the tooling should be disconnected from the servo motor. The motor body should be strapped to a solid surface or mechanically fixed in position.

Once the motor is secure, jog the servo motor by applying a momentary Jog input to the controller. For ease of use, all servo controlled axis should have Jog Forward and Jog Reverse switches installed that give the controller a momentary input on the appropriate terminals.

There are a set of rules for gaining control and direction of a servo motor that are always true. Sometimes, it is necessary to apply more than one rule. When this happens, always follow the rule that applies to that particular problem, even though it may seem to contradict the first.

1. The servo motor spins and never stops, or it spins out of control, but no counts are displayed on the controller screen.

   NO ENCODER FEEDBACK

   The controller is not receiving counts back from the motor.

   - Make sure the drive is set up to emulate encoder counts to the controller.
   - Check wiring connections between the drive and controller.
   - Some drive encoder circuits require a 5 VDC supply in order to function and some do not. If the signals are driven from the drive circuit, make sure the 5 VDC from the controller is not connected. If the drive requires 5 VDC from another source, make sure the controller's 5 VDC output is connected to the proper terminal on the drive.
   - Use an oscilloscope to see if the signals are coming from the drive at all. If no signal is present, the drive's encoder emulation circuit might be damaged. If the signal is present, but the controller does not register counts, the encoder circuit on the controller could be damaged.

2. The servo motor spins out of control, but only turns in one direction, regardless of which Jog input is used.

   INVERTED ANALOG COMMAND SIGNAL

   The analog command signal to the drive is backwards.

   - Use the DIP switches on the controller to change the polarity of the analog command signal. Optionally, the wires for the analog command signal can be swapped in the terminals.
   - Check to be sure one side of the analog command cable is not shorted to shield. Since this is a differential circuit, receiving only one side of the signal will always cause the servo drive to run in one direction.

3. The servo motor spins out of control, but changes direction depending on which Jog input the controller receives.

   INVERTED ENCODER SIGNAL

   One channel of the servo encoder is backwards.

   - Use the DIP switches on the controller to change the direction of the servo encoder. Optionally, the wires for one channel of the servo encoder can be swapped in the terminals (for instance, swap A+ with A-).

4. The servo motor spins in control, but the motor turns in the opposite direction from the desired direction.

   INVERTED ANALOG AND ENCODER SIGNALS
   The analog and the encoder are backwards.
   - Use the DIP switches on the controller to change the polarity of the analog command signal, and the direction of the servo encoder signal. Optionally, the wires for the analog command cable and the wires for one channel of the servo encoder can be swapped in their respective terminals.

Drive Tuning

Depending on the manufacturer and model of the servo drive, tuning can include anything from adjusting individual potentiometers with a screwdriver to connection of the drive to a laptop and interfacing through the drive manufacturer's (or a Windows component) HMI software. This document assumes the drive is a newer, digital drive that has its own HMI software. This software should already be installed and some familiarity with navigating the software and changing parameters might be required. It is the responsibility of the end-user to have the requisite PC, cables, and software in-hand and ready when tuning begins.

Drive Imposed Limitations

Programmable digital servo drives often include many internal parameters for limiting aspects of the motor control. The first adjustments to the drive parameters should be to open up any limitations on motor velocity, positioning velocity, and acceleration.

When the controller commands the motor to move, it expects the motor feedback to exactly match its analog command signal. The *instant* the motor feedback does not match the analog command signal the controller increases the command signal in an attempt to regain control of the motor. This happens very quickly and in real-time. If the drive has a preset acceleration limit, and the controller acceleration parameters are set higher than the drive limit, this will cause control problems and likely controller error codes and machine shutdown.

The drive must be a "dumb drive" in that it simply does whatever the controller commands it to do. Any preset acceleration ramps should also be disabled or removed from the drive parameters.

Gain

Since the servo loop is the primary (inner) loop, tuning should begin in the drive. Parameters in the drive are going to have a greater, more significant impact on the functioning of the system than the parameters in the controller. Current technology allows for some auto-tuning or auto-parameterization of the servo system. This is usually accomplished with software inside the drive when the drive is first connected to a motor. Manufacturers can place RAM chips inside their motors so the drive can set itself up once it reads the data from the motor.

This can be a help or a hindrance. Servo manufacturers often produce and supply their own general-purpose (non-roll forming specific) controllers to interface to their equipment. Because of this, the auto-tuning features try to create a tightly tuned loop between the drive and the servo motor. If the inner loop is “tight”, the outer loop or *control loop* must stay “loose” or the motor will be thrown into a state of *instability*. Instable refers to a system that becomes more stable as tuning parameters are increased or decreased to get the desired performance. At some point, a technological limit will be hit, and the system will become unstable. This instability typically manifests as a hum or growl from the motor because the motor is actually oscillating at a high frequency.

Integral

The integral is a summation of error over time. If the amount of error in the system isn’t enough to trigger the gain to adjust the system, integral will put the system into motion. With each iteration of the time integral, the amount of error is added to the error from the previous integral. This way, even when the error is small, the error will eventually add up and force an adjustment.

Sometimes, oscillation can be resolved through increasing the integral time constant inside the drive. A larger value tends to “smooth out” the entire system since the error isn’t being summed as often.

Gain and integral are closely related and sometimes it can be difficult to tell which parameter is the source of an oscillation. In general, it is best to open both parameters up a little bit in the drive. The controller has its own integral and gain parameters. As with the gain parameter, “loosening” the tuning on the drive’s integral allows a greater range of tuning through the controller.

Scaling Factor

The most significant control setting in the drive is the scaling of the analog voltage to the motor rpm value. This single parameter will make the largest difference in tolerance and system performance in servo systems that use an analog signal to control velocity.

> As an example, imagine that a specific servo motor has a maximum speed rating of 5000 rpm. The controller has a range of 0 – 10 VDC to control the motor in one direction. With the default settings, 10 VDC from the controller equals 5000 rpm from the motor.

If the controller changes the analog command signal by 0.1 VDC, the motor speed will change by 50 rpm. The controller can adjust the actual value of the analog command signal to several decimal places, so it will eventually force the motor to the desired speed.

Now consider that for the application, the motor will never need to run faster than 1800 rpm. If we change the scaling factor in the drive so that 10 VDC equals 2000 rpm. Now, a 0.1 VDC change from the controller will change the motor speed by 20 rpm. By scaling the signal in the drive, the motor has become more than twice as responsive to the analog command signal as it was before.

Troubleshooting

Length Calibration
Understanding the Part Queue
Testing Inputs & Outputs

Formulas

Important Formulas and References

Roll Forming Line Speed Conversion Constant:

When converting from feet per minute to inches per second:

(1ft / 12in) / (1min / 60sec) = Conversion Constant

(1ft/12in) · (60sec/1min) = Conversion Constant

(1ft / 1in) · (5sec / 1min) = Conversion Constant

5sec(ft) / 1in(min) = 5

Line Speed Conversion:

$$s_{fpm} / 5 = s_{ips}$$

s_{fpm} = speed in feet per minute
s_{ips} = speed in inches per second
5 = Speed Conversion Constant

Distance Equation:

$$s \cdot t = d$$

s = speed in inches per second
t = time in seconds
d = distance in inches

Resolution Correction Equation:

$$R_2 = R_1 \cdot M / E$$

R_2 = New Resolution
R_1 = Old Resolution (Current in Controller)
M = Measured Distance or Measured Part Length
E = Expected Distance or Expected Part Length (What the controller expected)

Acceleration Distance:

v2 / (2a) = d

v = velocity in inches per second
a = acceleration in inches per second^2
d = distance required to accelerate to velocity
2 = Constant

Time to Accelerate:

v / a = t

v = velocity
a = acceleration
t = time

Acceleration of Gravity

9.8 m/s^2

386.09004 in/s^2

Maximum Velocity Achieved During a Triangular Move

v = **2d** / **t**

v = maximum velocity achieved during the move
d = distance to be covered during the move
t = time available to move the distance

Acceleration Required to Achieve Maximum Velocity During a Triangular Move

a = **4d** / **t^2**

a = acceleration required to achieve maximum velocity
d = distance to be covered during the move
t = time available to move the distance

Circumference Equation:

C = πD

C = circumference in inches
π = pi or 3.14159265358979323846264338327950
D = diameter of a circle in inches

Encoder Resolution Equation:

R = C / ppr

R = resolution in inches per pulse
C = circumference in inches or linear distance per revolution of the encoder shaft
ppr = pulses per revolution from encoder feedback device (post-quadrature)

Press Reaction Equation:

$$((D_{FIRST} - D_{SECOND}) / s) \cdot 5 = \text{reaction time}$$

D_{FIRST} = distance to first press operation
D_{SECOND} = distance from first press operation to second press operation
s = speed in feet per minute
5 = conversion constant (5secft / 1inmin)

Servo Encoder Resolution

Ballscrew Actuator

R = P / ppr

R = resolution in inches per pulse
P = pitch of the screw – linear distance traveled per revolution of the screw
ppr = pulses per revolution from encoder feedback device (post-quadrature)

Correction Formula:

$$d_{MEAS} / d_{PROG} = \text{correction percentage}$$

d_{MEAS} = measured distance
d_{PROG} = programmed distance

Shortest Part Equation for Die Accelerators (basic version):

$$d_{MINP} = v(2(((v / a)2) + (t_{SU} + (t_{SD} - t_{SR})) + ((d_{MIN} - d_{MINC}) / v)))$$

d_{MINP} = Shortest part length possible given the following variables:

v = maximum speed in inches per second
a = acceleration in inches per second^2
t_{SU} = programmed shear dwell up time
t_{SD} = programmed shear dwell down time
t_{SR} = programmed shear reaction time
d_{MIN} = programmed minimum die distance
d_{MINC} = calculated minimum die distance
2 = Constant

Shortest Part Equation for Die Accelerators (advanced version):

$$d_{MINP} = (v(((v / a)2) + (t_{SU} + (t_{SD} - t_{SR})) + ((d_{MIN} - d_{MINC}) / v))) + (((v(((v / a)2) + (t_{SU} + (t_{SD} - t_{SR})) + ((d_{MIN} - d_{MINC}) / v))) - ((v_{RET}^2 / 2(a_{RET}))2)) / v_{RET}) + (v((v_{RET} / a_{RET})2))$$

d_{MINP} = Shortest part length possible given the following variables:

v = maximum speed in inches per second
a = acceleration in inches per second^2
t_{SU} = programmed shear dwell up time
t_{SD} = programmed shear dwell down time
t_{SR} = programmed shear reaction time
d_{MIN} = programmed minimum die distance
d_{MINC} = calculated minimum die distance
2 = Constant
v_{RET} = programmed maximum return velocity
a_{RET} = programmed return acceleration

Shortest Part Equation

Advanced Version with Triangular Return Profile

$$d_{MINP} = (v(((v / a)2) + (t_{PU} + (t_{PD} - t_{PR})) + ((d_S - d_{ACC}) / v))) + (v(\surd(a_{RET}(4(v(((v / a)2) + (t_{PU} + (t_{PD} - t_{PR})) + ((d_S - d_{ACC}) / v)))))))$$

d_{MINP} = Shortest part length possible given the following variables:

v = maximum speed in inches per second
a = acceleration in inches per second^2
t_{PU} = press dwell up time
t_{PD} = press dwell down time
t_{PR} = press reaction time
d_S = acceleration distance including settling distance
d_{ACC} = acceleration distance
2 = Constant
a_{RET} = return acceleration

Conversion of Angular Degrees to Linear Distance:

$$(\theta C) / 360° = d$$

θ = angle in degrees
C = circumference of circle in inches
360 = Constant (360° in a circle)
d = linear distance in inches

Thrust Force:

$$\mathbf{F_t = m \cdot a}$$

F_t = Thrust Force
m = mass (weight)
a = acceleration in g force

Example:
A 1200 lb mass must accelerate at 140 in/s^2

a = 140 in/s^2 / 1 g
a = 140 in/s^2 / 385.8in/s^2
a = 0.363 g

F_t = 1200 lb · 0.363 g
F_t = 435.6 lbf

Frictional Force:

$$\mathbf{F_f = m \cdot \mu}$$

F_f = frictional force
m = mass (weight)
μ = coefficient of friction for the sliding surfaces

Example:
A 1200 lb steel mass will move along a greased steel slide.

m = 1200 lb
μ = 0.12 (estimated coefficient of friction for hard steel sliding along another hard steel surface that has been greased)
F_f = 1200 lb · 0.12
F_f = 144 lbf