

Improving Roll Forming Operations Through Effective Shop Floor Control

Introduction

The metal fabrication industry is a fast growing, highly competitive field. A manufacturer needs to consider the latest computer technology as a practical means of improving both the quality of the end product and efficiency of the operation.

This paper will consider the unique aspects of metal fabrication. It will outline some practical objectives of an upgrade project. Applicable computer technology will be explained and the impact of this technology on the manufacturing process will be discussed.

Metal Fabrication Manufacturing

The roll forming industry is defined as manufacturers of metal components that typically have the following common characteristics:

- Most parts are made to order instead of made for stock.
- Material costs are high relative to labor.
- Highly skilled labor is required.
- Most parts are fabricated in a single operation then packed for immediate shipment or use.
- A high price is paid for any mistakes made.
- Last minute changes are common.
- Manufacturing operations are very capital intensive

Most of the products previously mentioned are manufactured on roll forming machines. For simplicity, this paper will be limited to this type of machine. The principles covered are generally applicable to other types of manufacturing processes.

Objectives

The objectives of any upgrade of the manufacturing process should be to improve the quality of the finished product and to reduce the cost of the process. Computer technology can achieve both objectives.

Improved Quality

The most obvious way to improve the quality of goods produced is to add safeguards to insure that the correct product is shipped to the customer. Most manufacturers have experienced the wrong length, the wrong quantity, the wrong gauge, or the wrong color being shipped to a customer. These are caused by human errors and can be reduced

by minimizing the number of data entry points in the manufacturing process. An alert human can enter data with better than 99% accuracy. However, that 1% error rate can have very expensive consequences. Short shipping only one building panel can cause expensive delays at the job site, possible back charges and a great deal of expense in shipping and handling that one piece.

There are ways to verify the material used against the material specified on the order. A link between the machine and an inventory control system can insure the proper material is being used.

Most manufacturers depend on the diligence of the machine operator to detect flaws in the material or roll formed shape. There is emerging technology that will automatically detect flaws and take corrective action.

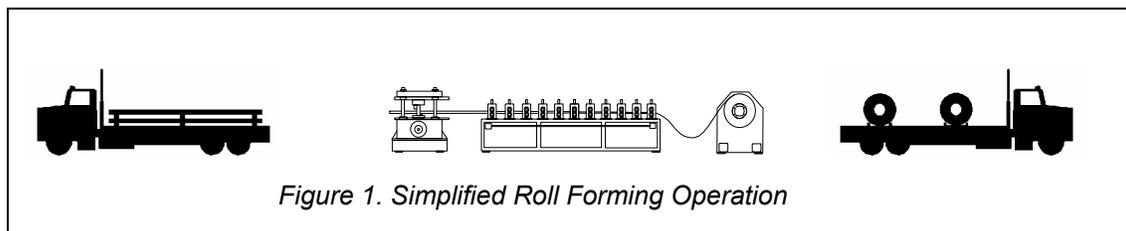
Product quality can also be enhanced by adding identification to each part produced. This identification can be done to insure proper routing or can be an aid at the job site. Such identification can enhance the value of the product and may command a higher price.

Improved Efficiency

Metal construction manufacturers look at the total number of man-hours needed to produce 1000 lineal feet of product as a figure of merit in gauging the efficiency of a plant. This parameter not only measures the efficiency of the machine operator but all other plant personnel. Computer technology can increase the running time of a machine that will increase the footage produced per hour. It can also automate some record keeping that may be presently entered manually. This would not only benefit machine efficiency but would also reduce clerical labor if this data needs to be entered in the office computer system.

Applying Computer Technology

Figure 1 shows a simplified diagram of a roll forming operation. Coils are received and placed in inventory. Coils are selected from inventory and loaded on the roll former. The material is roll formed and cut into specific lengths to fill orders. The cut sheets are crated and loaded on a truck. In this simple process, the roll form machine operator is a key figure, often involved in all steps. By concentrating on this employee's job functions, benefits of computer technology can be significant.



There are many ways roll forming companies handle the flow of data in their process. Most companies encountered have computers for accounting purposes but do not tie the computers to the manufacturing process. In this situation, a typical flow of data is as follows:

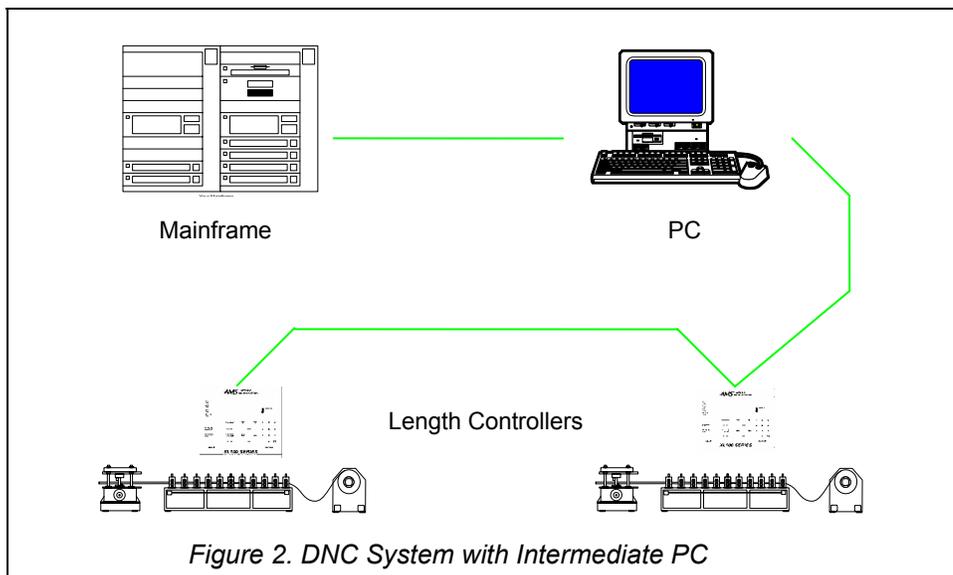
1. Order is taken by a sales person
2. Cut list is keyed into office computer by a clerk
3. Computer prints out a work order describing quantities, lengths, profile, and material
4. Machine operator keys in quantities and lengths into the roll former length controller
5. Machine operator manually labels the finished product
6. Machine operator fills out an operator's log indicating the order run, inventory coil used, and amount of material used
7. Office clerk updates inventory and generates invoices based on operator's log

In this process there are five steps that involve manual data entry. This means five opportunities to make mistakes in five time consuming tasks. The objective of computer technology is to reduce these manual data entry steps to only the initial entry of the order.

Direct Numeric Control (DNC)

In order to eliminate the many data entry steps, a method to get data to and from the roll forming machines must be established. With present technology, the most efficient method of communications is Direct Numeric Control or DNC. With DNC, a communication network is established between the office computer and a computer located at each machine. The roll form machine's length controller is a computer in most cases and can serve a dual role as machine controller and interface to the office computer.

A diagram of a DNC system is shown in Figure 2. In this configuration, an intermediate



PC has been added to standardize the system. There are a wide variety of mainframes in use and establishing a universal computer interface to the machine controllers would be impossible. However, most mainframe systems have established networking tools for connection to a standard PC. This PC can also serve as a workstation for a scheduler or production supervisor.

The DNC system performs the following tasks:

1. Download cut lists to the machines
2. Verify material used on the order
3. Upload data on the time and material required to complete an order
4. Monitor the present status of each machine from the supervisor's office

Download Orders

With DNC, the cutting list for an order is loaded into the machine controller automatically. There is no opportunity to enter the wrong quantity or length.

Since the operator does not have to key in the cutting list, the machine has less down time. Many manufacturers are surprised to find out just how inefficient their roll form machines are. A typical building panel line may only run two hours in an eight hour shift due to frequent coil changes, low quantity cutting lists, and packaging delays. It has been reported that downloading of orders can add one additional hour of actual running time to the machine. This is, in effect, a 50% increase in production.

Verify Material Used

Each order should specify a material to be used. Normally, a standard code number is established that identifies the type, gauge, width, color, and finish. This will be referred to as the Material Identifier (MID).

A plant may have several coils that fit this material code. Each coil needs a unique identifying number for inventory control. This number may come from the supplier or may be created when the coil is received. This number is referred to as the Coil Identifier (CID).

Normal practice is for the order to specify a MID, not a specific CID. This gives the operator the flexibility to select the most convenient coil to meet the order requirement. Otherwise, if the CID were specified, that particular coil may be on the bottom of a stack or may be damaged.

By letting the operator choose the coil, it becomes necessary to enter the CID each time the coil is loaded. This number along with the order number and MID can be sent to the office computer for verification. If the CID is not valid or the MID of the coil does not match the MID of the order, a warning can be sent to the operator.

Upload Production Data

The length controller on the roll forming machine precisely measures all material passing by the length transducer. As a computer, the length controller should be capable of keeping accurate time records. With these two features, an accurate record of time and material usage can be maintained.

The data collected by the length controller can be uploaded to the office computer. This data should include the following information in order to give a comprehensive picture of the activity at the machine:

1. Quantity and length of good parts produced.
2. Length of any scrap encountered
3. Date and time of production start
4. Date and time of production stop

With this data, the office computer can do the following tasks:

1. Mark items complete and automatically generate customer invoices
2. Reduce footage remaining of inventory coils based on usage
3. Compile scrap reports
4. Analyze running time versus down time

In addition, a permanent record of all of the machine's activities is obtained in a computer data file for any future reference. If a customer should complain of a short shipment, this data can be printed out to either substantiate or counter the claim.

Production Monitoring

In the configuration shown above, each roll forming machine is connected to the office PC via the LAN. This gives the opportunity to monitor the status of each machine from a central location. Such items as the current order, current material, line speed, and total footage for the shift can easily be displayed for each machine. A supervisor can track orders and detect production delays before they cause serious problems.

Identification Systems

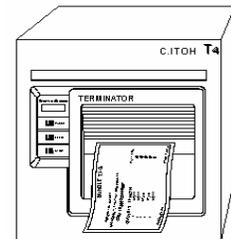
In many cases, machine operators must manually identify roll formed parts as they are being produced. They either mark each piece or fill out a shipping ticket for each bundle of goods produced. New computer technology makes available several devices which can automate this process.

Bundle Ticket Printers

If a bundle of parts must be identified as to its contents, the options are to manually write the ticket, use tickets printed on an office computer, or print the ticket at the machine as the bundle is being produced. Writing the tickets by hand is time consuming and can create problems of legibility.

Using preprinted tickets solves these problems but it reduces the flexibility at the time of production. Preprinted tickets means the contents of each bundle is predetermined. Often, breaking an order up into reasonably sized bundles requires human intervention from an experienced operator. Also, several bundle tickets would be present at any given time at the machine. This increases the possibility of losing a ticket or putting the wrong ticket on a bundle.

Printing the bundle tickets on demand at the machine solves these problems. The operator can set contents of a bundle and print a ticket reflecting his decision. Since

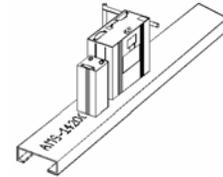


only one ticket should be present at the machine, the possibility of a mix up is eliminated.

The downside of printing bundle tickets at the machine is the expense of adding multiple printers. Also, machine-running time may be diminished if frequent changes of printer stock are required.

Ink Jet Printing

In some cases, it is necessary or desirable to mark each piece produced. Ink jet printers are ideal for such applications if the printing requirements are limited to less than 50 alphanumeric characters.



Ink Jet printers have a series of nozzles which spray a fast drying ink directly on the part as it is being produced by the roll former. The pulsation of the nozzles is timed to the movement of the material, forming coarse block letters.

There are two types of ink jet printing systems, drop-on-demand and recirculating ink systems. In the drop-on-demand system, the ink is stationary at the nozzles, waiting for a command to spray. This system produces large characters ranging from about ½ to 2 inches in height and is seen most commonly on many shipping cartons. In the recirculating ink systems, the ink is constantly moving from the reservoir past the spray nozzles and back to the reservoir. When printing is required, the stream of ink droplets is diverted onto the metal. This system produces small characters ranging from about 1/8 to ¼ inch in height and are most commonly seen on the bottoms of can goods.

The advantages of the drop-on-demand system of ink jet printing is the lower initial cost and large characters readable from a distance

In the metal fabrication industry, the need for large, readable characters in the field usually dictates the use of the drop-on-demand system.

Bar Code Scanning

Bar code scanners are commonplace in the retail industry. They are beginning to be seen in the metal construction industry as well. Any instance requiring fast, accurate input of predetermined data is ideal for bar code scanners. The most common usage is the reading of bar codes on coil tags since most suppliers now print bar codes on their tags. Bar codes are also being used input complex instructions to the controller while the operator is away from the control console. For example, if the controller has a function to make an extra piece if a defect is observed, a bar code for this instruction can be printed on a sheet located where the operator normally stands to stack finished parts. When a defect is seen, the operator scans the code for this defect without returning to the console.

One thing to consider when choosing a bar code system is the location of the scanner. Most scanners have a limited length cable and a longer cable may be difficult to maintain and may be a safety hazard. The operator may need to scan bar codes at the uncoiler, operator's console, and at the stacking station. This may cover a span of over 100 feet.

A solution to this problem is a wireless scanner that uses a radio frequency transmitter. Scanners are available that cover a 75 foot radius and do not require an FCC license to operate. Operators carry them in a holster or attach them to a vest with Velcro.

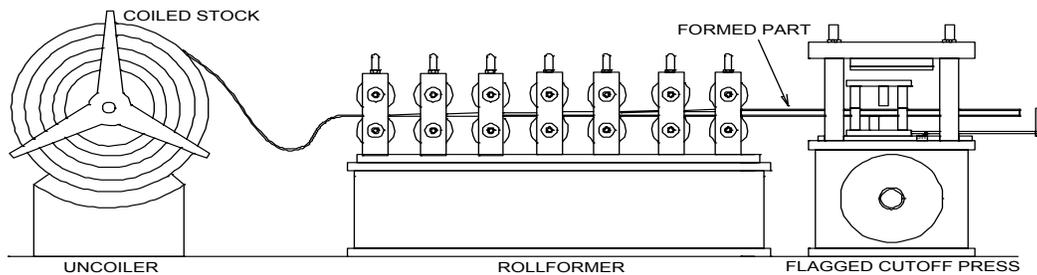
When selecting a bar code scanner, be sure to specify one with a rugged case. Most scanners specify a maximum drop distance on a concrete floor without damage.

Automatic Inspection Systems

As technology improves the roll forming industry, new challenges must be faced. As production rates increase, new machinery for handling the finished product will be required in order to take full advantage of the gains in speed. The ultimate solution is a fully automated bundling system. However, such equipment will remove the only quality control mechanism on the machine, the watchful eye of the operator.

In the next few years, emerging technology will be available for automatically inspecting roll formed products. These systems will check for length, profile, twist and camber. In the case of painted material, optical sensors should be able to detect paint flaws and take corrective action. Demand for such equipment will hasten its development.

Closed Loop Die Accelerator Systems



Simple Roll Forming System

If the roll former is coil-fed, a cutoff device must be added to the exit end of the machine. Some type of measuring system is added to size the parts and activate the cutoff press.

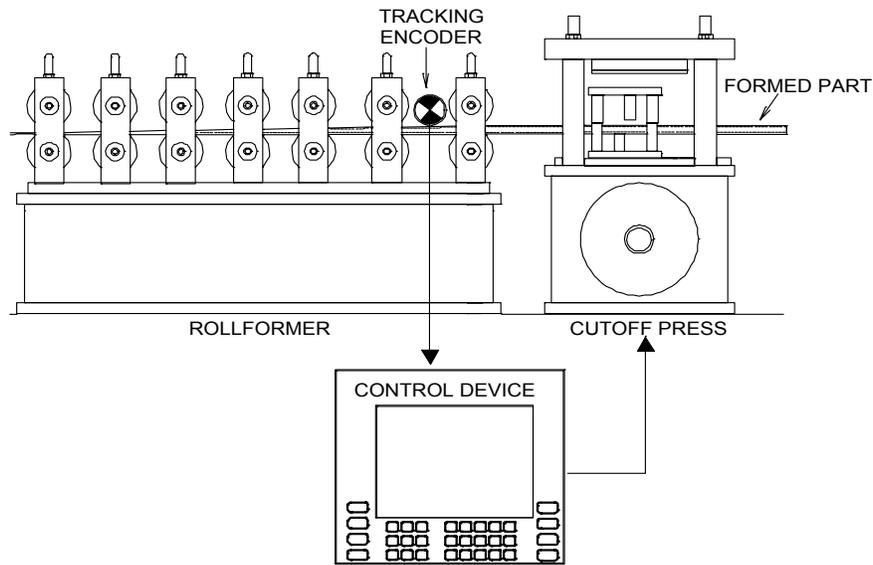
It is possible to stop the metal so that a stationary cutoff die can be used but this is inefficient for most applications. The roll former has too much inertia for rapid indexing to be practical and productivity would suffer from repeated halting. The vast majority of roll forming machines use a flying die so that the material can be fed at a continuous speed and productivity is maximized.

Die Accelerator Methods

In order for a flying cut to be made, the die must be traveling at the same speed as the material. Thus every machine needs some means of accelerating the die from a speed of zero up to the material speed for each cut.

Die Acceleration by Engaging Material

The simplest form of die acceleration occurs by allowing the material itself to push the die forward. This is done by abruptly engaging the die to the material. One way this is

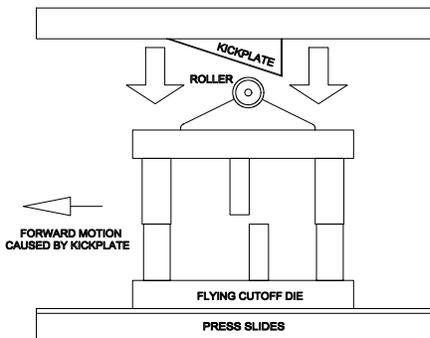


Electronic Length Control Using a Control Device and Encoder

Whether using the “Material Engagement” or “Die Engagement”, in both cases of material acceleration the impact on the material is abrupt. Applications are limited to very low line speeds or very stiff profiles. At higher speeds, the end of the part can be damaged or bowing can occur. Furthermore, the repeated impact can cause excessive wear and damage to the die.

Acceleration by Mechanical Kickers

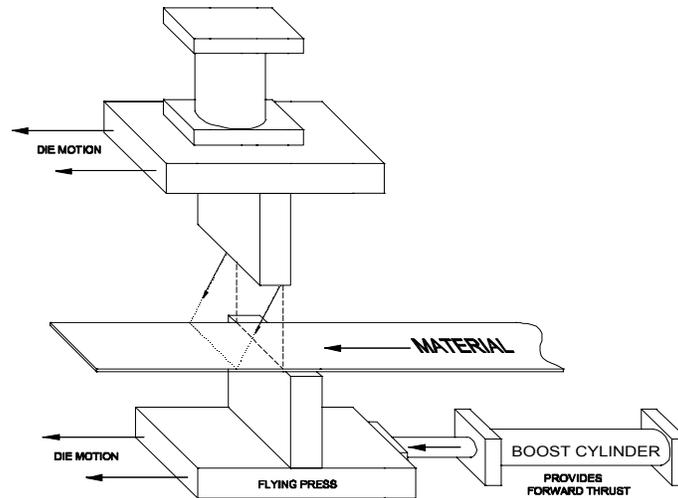
It is possible to accelerate a die with mechanical “kickers”. A ramp is located on a fixed position of the press. As the press closes, a roller on the die contacts the ramp and the die is pushed forward. A spring or air cylinder returns the die to the home position. This system is simple and inexpensive to install. However, the angle of the ramp must be carefully adjusted to match the material speed. Any mismatch of speed will cause damage to the part or the die.



Kicker Die Put into Motion by Inclined Kick-Plate and Roller

Acceleration by Die Boost Cylinders

To alleviate the impact of the die on the material, boost cylinders can be employed. These are either pneumatic or hydraulic cylinders that push the die forward with each cut. The cylinders are activated just prior to or at the same time as the cutoff. The same cylinder is used to return the die to its home position at the end of the cut. The advantage of such a system is that it is inexpensive, easy to implement, and effective as a die accelerator. The disadvantages of such a system are that it is difficult to control the boost rate and there can be a substantial amount of inaccuracy introduced by this device.

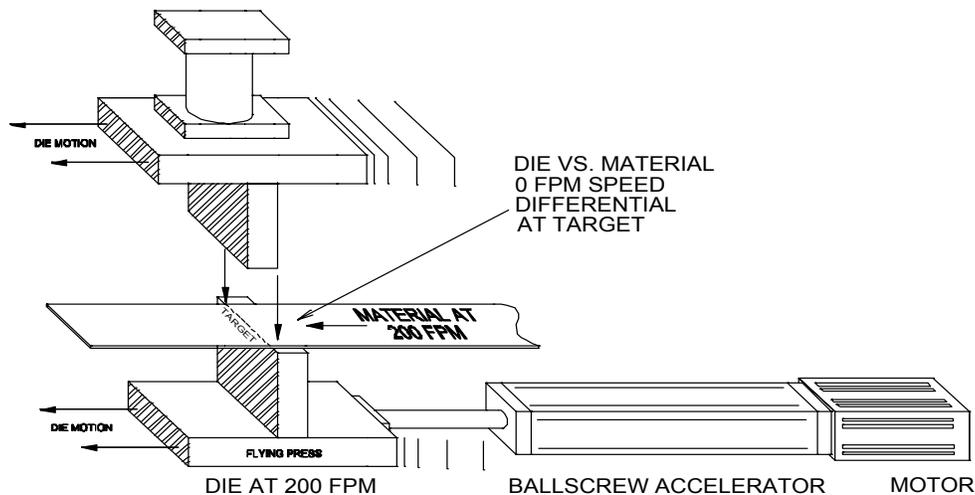


Flying Die with a Boost Cylinder

The Closed Loop Die Accelerator System

The previous methods of die acceleration place a mechanical strain on the material that can greatly limit performance of the machine. A closed loop die accelerator eliminates this strain and allows substantial improvements in the part quality and productivity.

A closed loop die accelerator system uses a positioning device that can accurately control the position of the die across the entire stroke length of the press. When a cut is made, the positioning device moves the die so that it is directly over the desired cut point and traveling at the same speed as the material. Tracking continues throughout the entire press cycle. Once the material is cut, the positioning system returns the die to its home position and awaits the next target. Since the die and the material are traveling at the same velocity, each cut is made at virtually zero speed, just as if it was a standing cut. This results in a clean cut with no strain on the material or on the die.



Die Accelerator matching Speed with the Material

The key to the performance of the closed loop die accelerator is the electronic control system that measures the material movement and drives the positioning device. This is a closed loop system as opposed to an open loop system. An analogy for an open loop control system versus a closed loop control system would be an artillery shell versus a guided missile. Once a shell is fired, control is lost. Changes in wind or in target location cannot be compensated for once it leaves the cannon. With a guided missile, course corrections are made all the way to the target. Similarly, an open loop system is vulnerable to speed and press fluctuations once the press is activated. With a closed loop system, adjustments are made throughout the press cycle and better accuracy is achieved.

Advantages of the Closed Loop Die Accelerator System

The main advantage of a closed loop die accelerator is that it provides a foolproof method of acceleration that is effective over a wide variety of conditions. It completely eliminates the collision between the material and the die, improving the quality of the parts produced and extending the life of the cutoff die.

The closed loop die accelerator creates a condition where the die and the material are moving at virtually zero relative speed. It is now possible to dramatically increase the line speed without damaging the parts and greatly increasing the number of parts produced without any additional labor.

With a mechanical gauge bar, the part is confined between the target and the die. This can create dangerous pinch points that are hazardous to personnel and produce the possibility for jam ups. With the closed loop die accelerator, the part exits the machine without constraints. This can reduce the amount of down time, free up costly floor space, and increase production.

A closed loop die accelerator system is one of the most accurate methods of length control. It can produce results similar to a gauge bar without the speed constraints and virtually no setup time for length changes. Furthermore, the closed loop system can produce accurate part lengths over a wide variety of machine conditions.

Disadvantages of the Closed Loop Die Accelerator

The main disadvantage of the closed loop die accelerator system is the high initial cost of the equipment. This is due to the precision die positioning system required. Depending on the weight of the die and line speed, such a system can cost between \$25,000 and \$75,000 to retrofit on an existing machine. However, higher line speeds, scrap savings, and reduced down time may likely justify the investment.

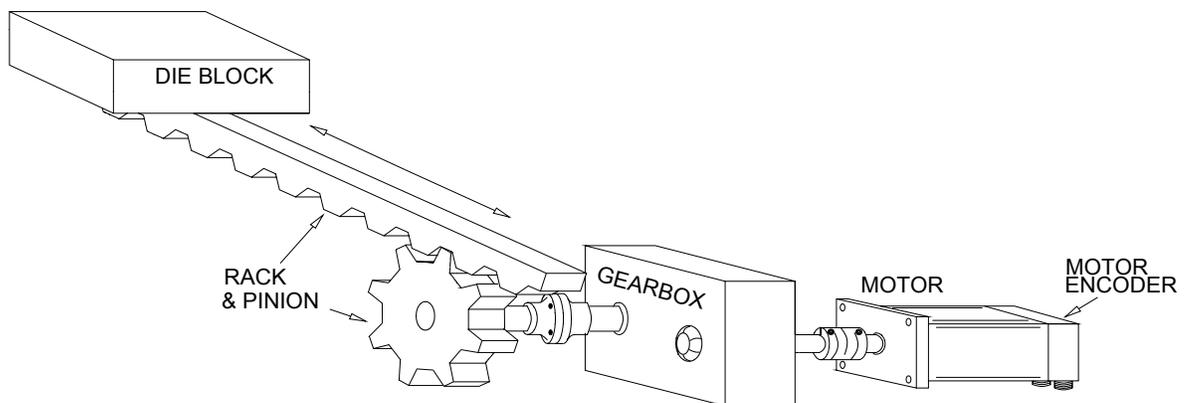
On any roll forming machine, the cycle rate of the cutoff press limits the minimum part length that can be run at a given line speed. A closed loop die accelerator further limits this speed by lengthening the cycle rate of the cutoff operation. Before a cut is made, the die must be accelerated up to line speed. After the cut, the die must be decelerated to a stop. Then the die is accelerated in the reverse direction then decelerated as it approaches the home position. The result is that shorter parts must be run at lower line speeds as compared with other accelerator methods. However, since a closed loop die accelerator adapts easily to line speed changes, the machine can be slowed down for short lengths and sped up for longer lengths with no deterioration of accuracy.

Types of Closed Loop Die Accelerator Systems

The key element of a closed loop die accelerator system is the linear actuator that accurately positions the die in line with the flow of the material. There are three types of linear actuators available. These are the hydraulic cylinder with servo valve, the rotary electric motor with a rotary-to-linear conversion device, and the linear motor.

The hydraulic system is one of the oldest types of closed loop die accelerators. It is ideal for heavy dies and high line speeds. However, it is difficult to maintain and contamination of the fluid is a constant problem. Tuning the system often requires a skilled technician.

Most closed loop die accelerator systems today use rotary servomotors with rotary-to-linear converters. Brushless DC servomotors with computerized drive systems offer high performance at relatively low cost. They require little maintenance and are easy to tune.



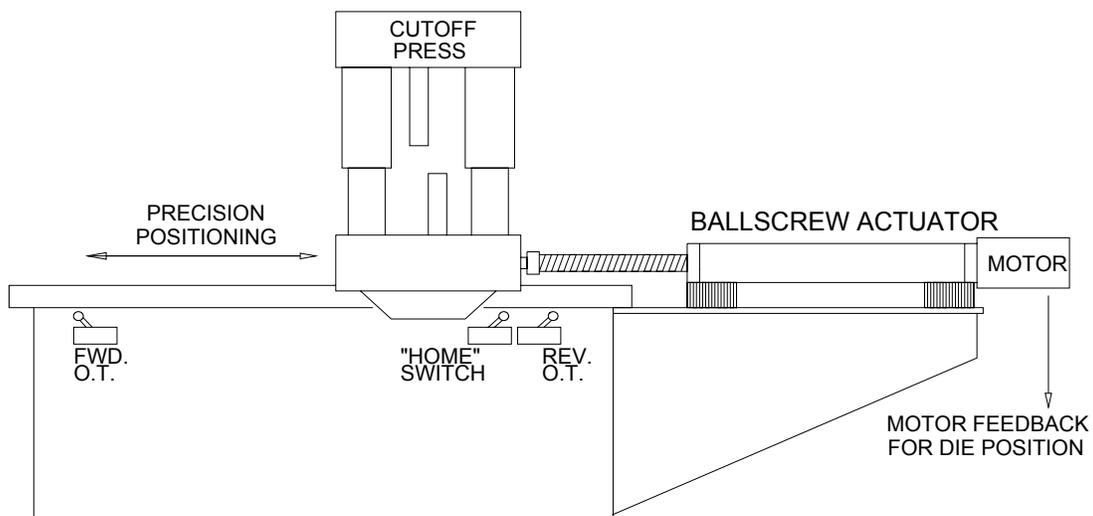
Rotary Servomotor Converted to Linear Motion

The future of die accelerator systems may lie in linear motors. A linear motor is essentially a rotary motor that has had its rotor and stator split and pressed flat. The two components are placed in parallel with each other with a close spacing. One is attached to the machine in a fixed position and the other is attached to the die. Electrical currents in windings cause the two plates to attract and repel each other in a controlled fashion that causes the die to move in the direction of material flow. The main advantage of linear motors is the elimination of the need for a linear actuator. Also, inertias are low and high accelerations are possible. The technology is new and there are only a few installations but linear motors have great potential as closed loop die accelerators.

Linear Actuators

With a rotary servomotor, a linear actuator must be added to convert the rotary motion of the motor into linear motion of the die. There are several types of linear actuators in use. They include the ball screw, the rack and pinion, and the timing belt. Feedback for the position of the die is normally taken off of the shaft of the motor. Any errors in the linear actuator will be outside the loop and cannot be compensated.

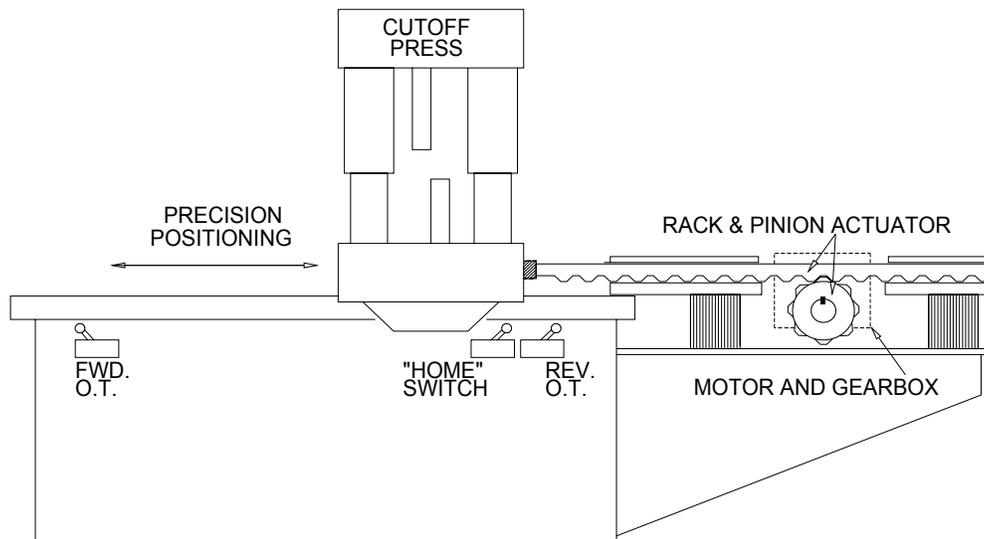
The ball screw is the most precise type of linear actuator. The ball nut moves a precise distance for each rotation of the screw with virtually no backlash. Due to the pitch of the ball screw, the servomotor can be directly connected to the ball screw without the need for gear reduction, in most cases. The ball screw is ideal for applications with lightweight dies and low speeds that require highly accurate parts. Ball screws are not suited for speeds in excess of 250 FPM due to a whipping action of the screw at high speeds.



Closed Loop System Driven by a Ball Screw Actuator

Rack and pinions have been used, as linear actuators in many applications with high speed and high die weights. Normally, the pinion gear cannot be connected directly to the servomotor. A gear reducer with low backlash is required in most cases so that the motor can run at near full speed. The rack is located parallel to the material flow and acts as the die pusher. The contact point between the rack and the pinion gear is critical

for this application. This can be a point of wear and breakage that can require extensive maintenance.



Closed Loop System Driven by a Rack and Pinion

A timing belt creates a versatile linear actuator for a closed loop die accelerator system. Two pulleys are located in line with the material flow. A bracket is attached to the belt that is coupled to the die. A servomotor is coupled to one of the pulleys through a gear reducer. This system is capable of high line speeds and moderate die weights. Timing belts are not made with high precision but repeatable results can be achieved if the cutoff occurs in the same general position each time.

Design Considerations and Productivity

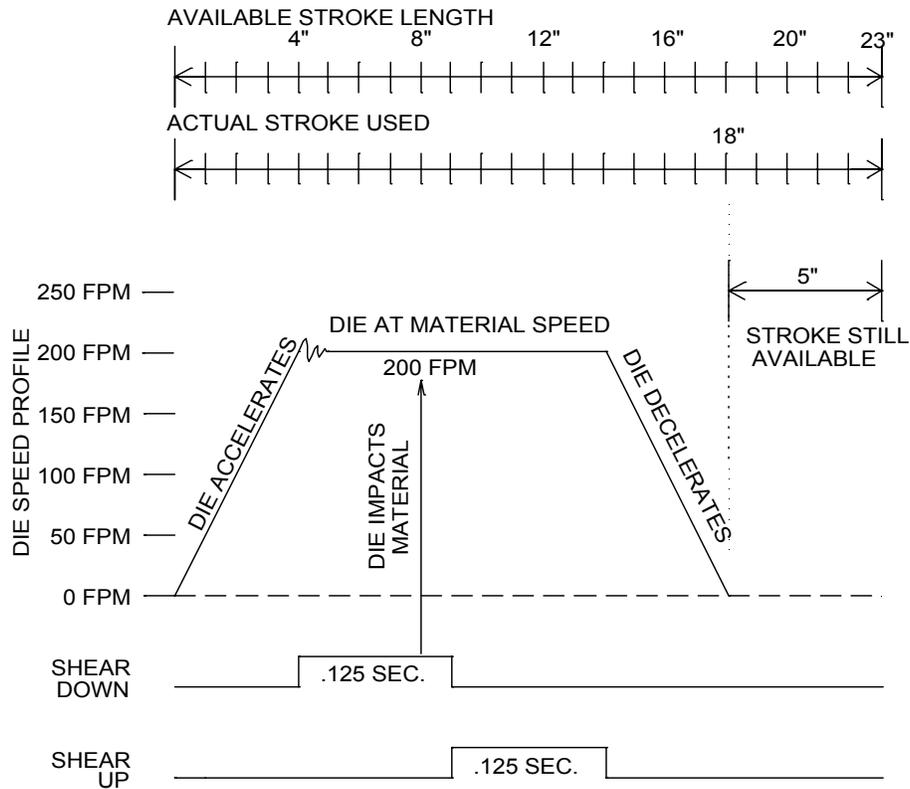
In sizing a closed loop die accelerator system, a number of factors must be considered. Four of these factors dictate the size and productivity of a specific system. These include:

- Weight of the die
- Speed of the material
- Length of available die travel
- Time required to cycle the cutoff press

With these four factors, a system can be designed and expected productivity can be calculated. This can best be explained by using an example, consider the following:

A line running at 200 feet per minute uses a 400 lb. shearing die in a mechanical press to cut the part. The line speed is limited to 200 FPM due to the fact that the material experiences damage when hitting the backstop or die at speeds higher. The cycle time of the press is .25 seconds (.125 seconds down and .125 seconds up). The available die travel is 23 inches between over-travels. Using a Ball screw actuator, the maximum

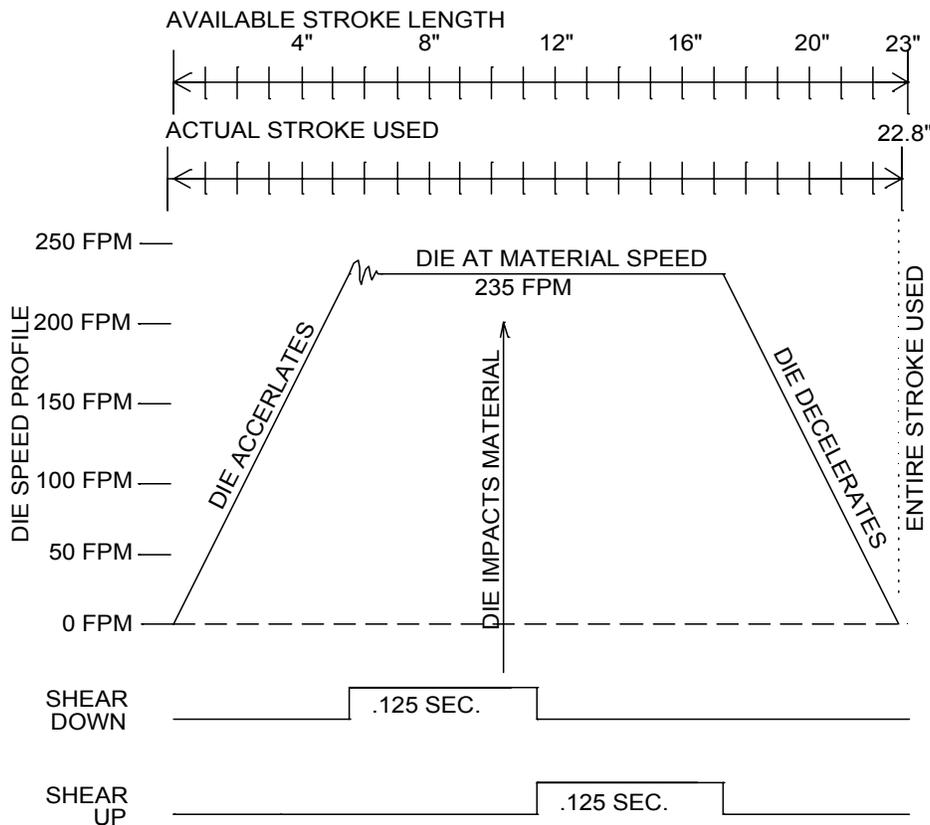
recommended acceleration rate for a die this heavy is about ½ g (193 inches/second²). With these numbers realized, the following chart can be graphed.



Example of a Die Accelerator Tracking a 200 FPM Target

Note that the die accelerates from a resting position to full line speed in .1 seconds. The die locates the target and maintains the same speed as the line throughout the press operation. With both the die and the material moving at the same speed, the press operation occurs just as if the press was making a standing cut with no stress on the part on or on the die. Once the cutoff is performed, the die decelerates to a stop and returns to its rest position.

As the graph shows, an additional 5 inches of travel is available still. Since the line speed was previously limited due to stress on the material, the line speed may now be increased. With the additional 5 inches of travel remaining, a line speed of 235 FPM should now be attainable. The higher line speed will require more time for the die to accelerate to and to decelerate from, and will require more travel distance while the press is firing, although the press time itself stays the same. Any item that requires more time or travel will reduce the amount of die travel remaining. The following example shows the new speed profile when running at 235 FPM.



Example of a Die Accelerator Tracking a 235 FPM Target

Note that nearly the entire available stroke is now being used to boost production by 35 FPM. In a 60% efficient production environment (run time), this equates into over 10,000 feet of additional product in an 8-hour shift. Product that has precision accuracies, minimal setup time, and edges that are as good as the die can cut without stress points and buckles.

The amount of thrust required for a die accelerator system is the acceleration, in g's, times the die weight. The 400-pound die with ½ g acceleration would require a thrust of 200 pounds. This determines the size of the motor and strength needed for the mechanical components.

Hydraulic, rack and pinion, and belt-driven linear actuators can often be run at higher accelerations. This can help to shorten the cycle time and shorten the required die travel, thus enabling higher line speeds. It may be worthwhile to consider changing the cutoff press to one with a faster cut cycle. Another consideration should be the design of the cutoff die. Minimizing the weight of the die will improve performance and reduce the requirements of the accelerator system.

Conclusion

Computer technology is available to greatly improve the quality and efficiency of the metal construction industry. The key to success is the fast, accurate flow of data from customer to shop floor and back to the customer. Controlling the flow of information is what computers do best.

In addition, every roll former with a flying cutoff press must have some method of accelerating the die to line speed for each cut. A closed loop die accelerator provides a positive means of such acceleration that can greatly enhance the performance of the machine. Part quality is improved both in the length accuracy and the profile since the cut is made with no strain on the part. Productivity can be increased because speeds can be increased without sacrificing quality.

When retrofitting a roll former with a closed loop die accelerator, die weight, available die travel, line speed, and press cycle time are important factors in the design of the system. Changes to these machine characteristics should be considered in order to optimize performance and take full advantage of the benefits of a closed loop die accelerator system.