

# Feed-To-Length System

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A feed-to-length application is one where a specific amount of material is to be fed a known distance and stopped, then followed by another process (see Fig. 1). There are no stipulations on the size and type of material, and no limitations on the process once the material has been fed. Materials range from fine gauge wire, to slabs of steel, to sheets of plastic. Post-feed processes include cutting, welding, scoring, and stamping, to name a few.

Some processes feed material via an unwinder attached to a roll or spool of material. Other machines send material to a feed-to-length system from a continuous process feeder. (As the material is made in one part of the machine, it is continuously sent to the feed-to-length system.) Still other methods use a hopper of folded or coiled material to store and supply the product to the process.

Common methods of feeding material in a feed-to-length application include the use of conveyors or pinch rolls. The walking beam approach is sometimes used. Another uses a gripper to pull the product to the desired length.

*Figure 1*

## Cut-to-length

A feed-to-length application for a cut-to-length system is shown in Fig. 2. Usually the material to be cut is wound on a roll or spool. To ensure that the force at the feed rollers is relatively constant and of a manageable magnitude, an unwind mechanism is used. In this example, an unwind motor keeps a loop of material ahead of the pinch rolls, which minimizes the force seen by the feed motor. There needs to be as much material in the loop as required by the longest index. To maintain this loop, its size is monitored by a simple dancer arm assembly. As the material is fed by the pinch rolls, the loop gets smaller, causing the dancer to rise. When the dancer signals that the loop is getting too small, the arm contacts the limit switch, which activates the unwind motor until the loop is acceptable again. This process keeps a known force level on the material in process, and also keeps the inertia of the supply roll from being reflected back to the feed rolls.

The feed controller accepts input from the operator. The input includes the length of material to be fed and possibly a batch number (indicating the number of cuts required). The length of the piece to be fed (usually entered as user defined units) is converted into a move distance on the motor. This distance command is sent to the motor and the material is indexed. Once this index is complete, the controller sends a signal to a knife controller, signaling the knife to cut the material. After a fixed period of time (the tool cycle) the next index occurs.

*Figure 2*

In many applications, it is critical that the material feed very accurately, or that any jam in the system is detected before the process continues. This example system uses an encoder mounted to a roller driven by the material is used to close the loop and detect exactly how much material is fed. This data is fed to the controller which corrects for errors, or detects problems. In this application, the finished product is offloaded onto a stacker. As each piece is added to the stacker, it moves down one thickness, allowing more material to be placed on the stack.

## **Material Supply**

Material can be stored in many ways before it is fed into a feed-to-length system. Sheet material is most often wound on a roll. Stranded material like wire is most often wound on a spool or wound and placed loosely in a box in such a way that it unravels easily. Accumulators are often used to accumulate material from the supply roll and prepare it for feeding. This often means keeping a loop of material between the feed roll and the feed mechanism. The use of accumulators couples the unwind motion from the feed roll and the feed mechanism.

## **Accuracy**

All feed-to-length applications have accuracy requirements. The finished product or application will dictate the priority that accuracy will receive in the design. An example application where accuracy is important is the indexing of paper to eight-inch segments. The accuracy is specified at 0.001 in.. This guaranteed that the pieces are no shorter than 7.999 in. and no longer than 8.001 in. Many products that are processed in feed-to-length applications have to be at least as long as the length specified in order to conform with trade laws.

Some applications have to compensate for the system's inaccuracies by overfeeding the material to be cut, creating waste. The accuracy of the motor drive system and of the power transmission components (belts, pulleys, gear reducers, etc.) used between the motor and the material are major contributors to system accuracy; however, backlash in the gearbox is the largest contributor.

If a gearbox has been rotated in one direction for a reasonable distance and then the direction of rotation is reversed, there is a finite time that the input shaft is rotated and the output shaft remains stationary. Once all of the gears have fully meshed in the new direction, the output shaft begins to rotate.

The amount of rotation between the point where the input motion is reversed and the output motion begins is the backlash. It is also a factor when a high inertia load is stopped quickly. To reduce the effect of backlash low, and theoretically zero, backlash gear boxes are available.

Stretching and slippage of belts also cause system inaccuracy. Stretching of a belt is affected by the type of belt material used, and the length of the belt itself. Steel-reinforced belts stretch less and are therefore better than most rubber or plastic belts. Keeping the belts as short as possible also helps reduce stretching.

Slippage can be caused if a friction belt is not kept tight enough. Keeping the belt tight will not only reduce slippage, but will also reduce backlash. Slippage and backlash can both be improved by using a toothed belt instead of a friction type.

## **Closing the Loop**

To meet the accuracy specification, a positive feedback device may be required. This device, typically an incremental encoder, is mounted to a low-inertia wheel that is driven by the material being fed. As the material moves, it turns the encoder. The encoder generates electrical pulses proportional to the rotational distance traveled at a frequency proportional to the speed of the web. This allows monitoring of the actual length of material fed regardless of the motor/drive or mechanical components, since the material itself is driving the encoder. When the loop is closed with an encoder, the load can be positioned without regard to the mechanical components and motor/drive involved.

## **Repeatability**

Most applications are concerned with repeatability, which is easier to achieve than high accuracy. Repeatability deals with how closely the length of a given length feed will repeat itself time after time. For

instance, if material is being fed via a stepper motor and a set of pinch rolls, and 10,000 motor steps corresponds to 5 inches of travel, the five-inch travel will be within the accuracy specification when 10,000 steps occur at the motor/drive. If the accuracy is 0.1 inches, the length could vary from 4.9 to 5.1 inches.

Repeatability is different than accuracy in that it does not include non-cumulative errors that the accuracy specification includes. Non-cumulative errors are caused by factors like backlash and hysteresis. Because repeatability usually assumes that all travel is unidirectional (which it almost always is in feed-to-length applications) the effects of backlash and hysteresis are negligible. In the example above, a reasonable repeatability is 0.02 inches.

This means that while the accuracy specification dictates a range of 4.9 to 5.1 inches, if the actual feed is 4.95 inches the repeatability specification guarantees all of the 10,000 step feeds to be 4.93 to 4.97 inches. Since the expected feed distance can be adjusted based on a test feed, the repeatability specification helps guarantee a uniform length product after the adjustment.

## **Throughput**

Throughput, or the number of parts per second, minute, or hour that can be produced, is important in any project. System acceleration and top speed determine the throughput. If the moves are short, acceleration will be the dominating factor. Short moves are defined as moves where acceleration and deceleration times are longer than the constant velocity portion, as shown Fig. 3. Often, short moves have no constant velocity portion and the move profile is triangular. If the moves are long compared to the acceleration time, top speed will have the stronger influence. Increasing speed means a faster motor; increasing acceleration requires more torque. The driven inertia of the machine and load will also affect throughput. For a given motor drive system driving the feed mechanism, the higher the system inertia the lower the throughput. Increasing the power of the motor increases the throughput; however, acceleration, speed, and inertia also affect the motor and drive system.

*Figure 3*

## **Slippage / Stall Detect**

Tension must be controlled at the web in a feed-to-length application. Three contributors to inaccuracies in feed length of material are material slippage, slippage of mechanical couplings in the feed mechanism, and stalling of the feed motor. All of these cause unexpected variations in feed length. Stalling or slipping causes significant problems with quality of production and/or catastrophic damage to the machine.

Slippage of the material occurs when the pinch rolls or grippers are not contacting the material firmly enough, allowing the material to slip between them. If this occurs during normal operation, the force between the pinch rolls or grippers needs to be increased. Unforeseen circumstances can cause the couplings to slip or the motor to stall. If there is an unexpected increase in the force needed to feed the material that the feed rolls or grippers can handle, the disturbance is transmitted to the mechanical components of the feed mechanism and to the motor.

All of the problems mentioned above can be detected by mounting an external position feedback device to the load, typically an incremental encoder, as detailed earlier.

## **Stretching and Tearing**

All materials have some amount of elasticity associated with them. In most feed-to-length applications, materials like thick steel slabs, which have a high modulus of elasticity, don't stretch much and will only deflect a minute amount when put under stress by the feed mechanism.

Other materials—thin plastic sheets, for example—stretch when put under loads often found in feed-to-length applications. As long as the material stretches within its elastic limit, it will eventually return to its natural shape. If the material is over-stressed, it reaches what is known as plastic deformation, meaning the material will not return to its original shape. It is important to keep the drag force due to friction in the feed mechanism as low as possible, and to keep acceleration of the feed material low enough so the product does not permanently deform or tear.

*Figure 4*

Acceleration profiles that are parabolic or sinusoidal in shape (see Fig. 4) reduce the load on the material, which reduces stretching. In essence, these acceleration profiles provide gentle forces near zero speed and top speed while making up for the lost ground in the middle.

The other problem associated with material stretching is that it contributes to reduced accuracy. This can be overcome by either compensating for the stretch in the controller if the amount of stretch is predictable, or installing a position verification device (encoder, etc.) between the feed mechanism and the post-feed process.

## **Kerf, Registration**

The kerf is the material lost when a cut is made by a saw or other cutting device. The wider the cutting device, the larger the kerf. Therefore, if you have a device that makes a 0.1 inch cut and you want a ten-inch piece of material, you actually have to feed the material 10.0 inches to get the proper length.

In many feed-to-length applications, the length of the feed is not specifically defined at the start of the move. This is the case when cutting or performing other operations on pre-printed webs. It is more important that the cut be in the proper position with respect to the printing than to the last cut. This on-the-fly adjustment to the final positioning is called registration. The moves required are called registration moves. Performing registration moves is sometimes called indexing on-the-fly.

In motion control terms, registration provides the ability to execute a preset move with reference to an external event while the motor is executing another move. This is done by providing an external trigger input which causes the current move to be aborted, and a new move, the registration move, to be started.

## **Operator Interface**

One of the most important considerations to make is the selection of an operator interface. The simplest choice is a push button system. An operator pushes a start button to begin material feed, and pushes the stop button when the feed gets to the proper length. If better accuracy is required, a thumbwheel is recommended. A consideration on any operator interface is the need for an emergency stop mechanism—either a button on the control panel that is wired into the controller in a fail-safe manner or into the system's power circuit, or simply easy access to the machine's power plug.