Automation of VFFS Machine

High Performance and Modular VFFS Solutions for OEM

This paper provides an overview for a primer guide on the VFFS machine application and key automaton solutions.

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Executive Summary

As a machine builder, you are challenged to differentiate yourself amidst global competition and rapidly evolving technology. Product packaging demands Vertical Form Fill and Seal (VFFS) machines that combine high production output, consistent reliability and product quality with low manpower requirements and low maintenance costs. The machines also need to be flexible enough to adapt to variations in bag dimensions and sophisticated designs.

Lower your Total Cost to Design, Develop and Deliver® VFFS machines with Rockwell Automation® Mid-range solutions

Whether measured from a business, commercial or technical perspective, Rockwell Automation can help improve your VFFS machine performance with solutions and services to lower the Total Cost to Design, Develop, and Deliver® machines and meet your customers' requirement.

What may start out as an "order-by-order" relationship, can eventually develop into a mutually beneficial business relationship because we strive for a holistic approach that focuses on your machine and business performance.

Consider Rockwell Automation your VFFS machine automation supplier for each stage of your machine's life cycle from design, throughout development, to customer delivery and beyond.

Introduction

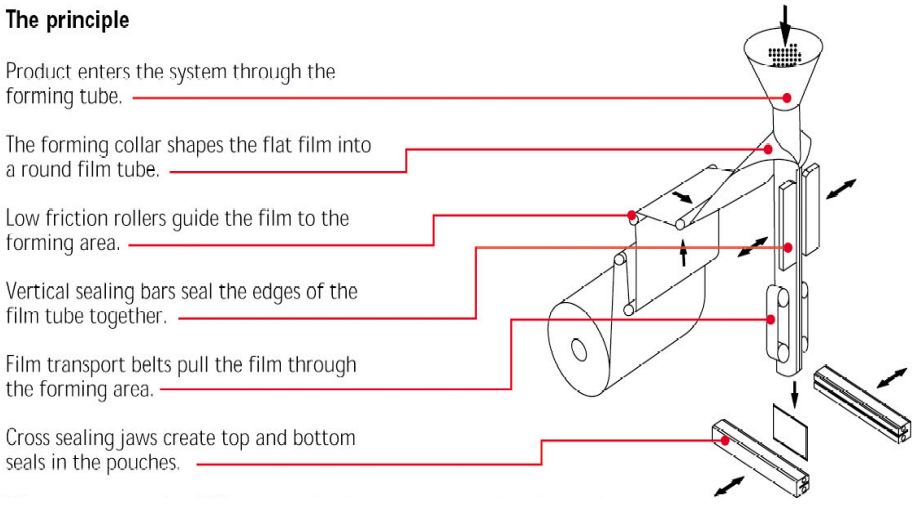
Vertical Form, Fill and Seal (VFFS) machines are automated assembly line packaging systems used in packaging liquids and solids. VFFS machine can be intermittent or continuous motion. Intermittent motion machines operate on the principle that vertical bag seals are made when the film is moving and horizontal seals occur when the film stops. Intermittent motion machines offer a suitable solution for applications where speed is not absolutely paramount. On continuous motion machines the vertical and horizontal bag seals are applied without stopping the film and therefore higher production rates can be achieved.

Vertical Form, Fill, and Seal (VFFS) machines are used in the consumer products industry for a wide variety of packaging applications. Various products like salt, tea, sugar, spices, snack foods, wafers, detergent and candies are placed into formed pouches and then sealed. The pouch material is flexible and typically heat-sealable plastic. Paper is also used and sealed by glue

Fully automatic VFFS machines require limited operator intervention. The operator need only replenish product by loading supply hoppers or changing packaging film drums. For machines that are semi-automatic, operators are required to perform part of the packaging operation.

VFFS machines can be intermittent or continuous motion. Intermittent motion machines operate on the principle that vertical bag seals are made when the film is moving and horizontal seals occur when the film stops. Intermittent motion machines offer a suitable solution for applications where speed is not absolutely paramount.

Continuous motion machines operate on the principle that both vertical and horizontal bag seals are made when the film is in motion. These machines operate at the highest attainable speeds and require a reciprocating sealing jaw motion format.



Principle of a how the mechanism works

Generic VFFS Machine Process

A roll of film is unwound and formed into a tube over a forming collar. A vertical overlap seal is applied to the tube by the vertical sealing bars. A bottom seal is created by the horizontal sealing bars in the cross jaws.

The formed pouch is then filled with correct amount of product while the film tube is being fed by the film transport belts. Often a precision scale or an auger ensures that the proper amount of product is placed in the pouch in a consistent manner.

After the correct length of film tube has been fed, a top seal of the filled pouch is created by the horizontal sealing bars, while the filled pouch is cut from the descending film tube by a knife in the cross jaws.

If the film is pre-printed, a registration sensor is added to the system to correct the film position in order to maintain the correct print position relative to the end of the pouch.
The bottom seal creation of the empty pouch, top seal creation of the filled pouch and cutting of the filled pouch all occur at the same time.

Product enters the system through the forming tube.

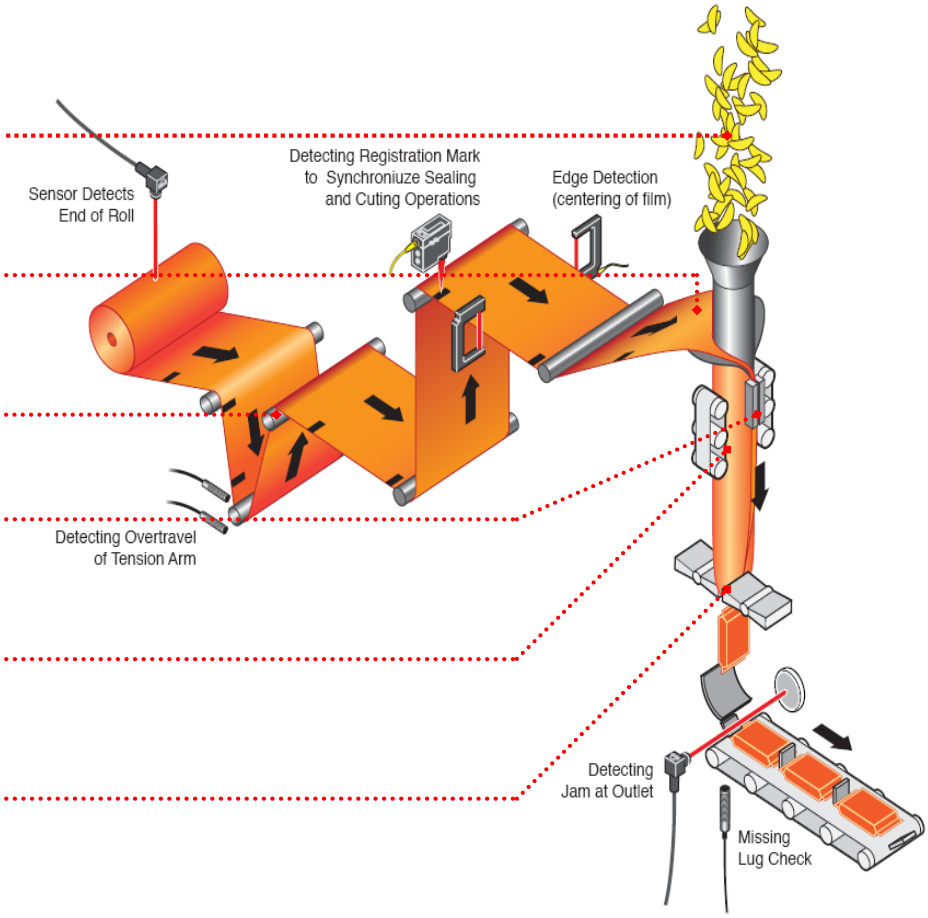
The forming collar shapes the flat film into a round film tube.

Low friction rollers guide the film to the forming area.

Vertical sealing bars seal the edges of the film tube together.

Film transport belts pull the film through the forming area.

Cross sealing jaws create top and bottom seals in the pouches, and cut the filled pouch from the empty pouch.

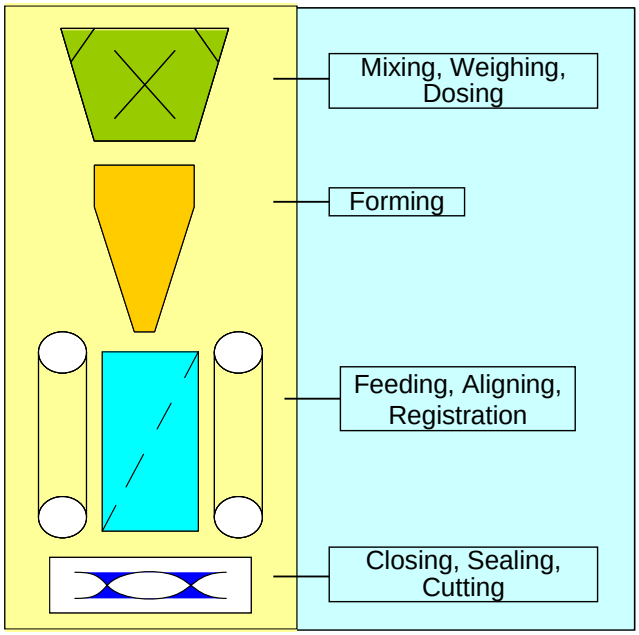


There are two major process advantages for a continuous motion machine over an intermittent type:

• Faster cycles times. On a continuous motion machine the cross jaw moves with the film and can perform the horizontal sealing application while the film is still moving. The typical intermittent machine operates at 60 to 80 packs per minute (ppm) maximum, while a continuous machine can operate up to speeds of 180 ppm. The highest machine speed attainable is determined by the weighing mechanism.

• Control over the cross jaw along the vertical plane provides additional bag making possibilities.

The VFFS machine can be divided into four functional areas: (1) mixing, weighing, dosing; (2) forming, (3) feeding, aligning, registration; and (4) closing, sealing, cutting.



Typically, roll-fed flexible packaging film is unwound from a feeder roll. A dancer roll would be used to maintain a constant tension on the unwinding web of film. The unwinding motor and dancers are required for maintaining tension and maintaining critical accuracy in feed.

The film is threaded up over a forming collar and then down, forming the web into a chute-like tube. For perishable food products, gas flushing is executed to prolong the shelf life. The process involves injecting an inert gas, like carbon monoxide, into the package cavity before it is sealed. A vertical overlap seam and bottom seal are applied. The pouch is then filled and a top seal applied while a knife cuts the sealed pouch from the descending web of film.

There are two machine formats:

Single Lane

Has a single lane tube form to shape the pouch at each cycle

Suitable for many different sized pouches

Most common configuration

Multi-Lane

Has multiple lanes of tube to form multiple pouches at each cycle

Mostly used for small packets such as sugar and salt packets

Packaged Product Types

The type of products to be packaged influences the type of application schematic required for the machine sections. Products characteristics such as size, consistency and weight are important details which influence the control system application modules. Product mis-feeds can lead to product jams in the sealing section for example. Suitable jam detection sensors would be required to detect this early.

Product Type	Example	Machine Sections	Application Needs
Liquid	Sauce	Dosing	The machine must manage the measurement and insertion of product into the pouch, which requires tight coordination with the scales, augers, and mixers. For perishable product, the machine needs to be washed down for sanitary purposes. For food products, gas flushing with inert gas or O_2 extraction is required to extend food shelf life.
Fine granules	Sugar, Salt	Dosing, Mixing	
Coarse granules	Cereals, Spices	Dosing, Mixing	
Powders	Detergent	Dosing, Mixing	
Solids	Candy, Pharmaceuticals, Hardware	Weighing	
Fresh produce	Vegetable	Dosing, Gas Flushing for product protection, Wash down	
Perishable	Meat, Fish	Dosing, Gas Flushing for product protection, Wash down	

Packaged Material

Packaging material selection is based on the type of products packaged. Plastics and paper based films are widely used in most packaging machines. The packaging material used can generate unique application requirements.

Packaging Material Type	Application Needs
Plastics	Film tension must be maintained. Sealing and cutting jaws must take action after the product is received, completing the process of bag formation. There may be multiple designs for these components but there is one general requirement—film velocity and jaw sealer velocity have to be identical. Any disturbance in timing can damage the bag and waste both packaging and product.
Plastics performed	
Plastics multilane	
Paper	
Composites	

For instance, high static charges are generated when plastic packaging film is fed from a wind-off roll. The static charge attracts powder and lightweight dust from the filling product onto the internal film surface, thus preventing effective sealing. A static eliminator bar or contaminant spray can be used to reduce this problem.

Film Unwind

Film unwind is responsible for unwinding film into the machine, providing operator ease-of-splice (optional), roll change-out features (optional) and film tension. Many unwind sections are static mandrel (un-powered) types and use either a pneumatic brake or friction brake to control unwind action and provide applicable film tension. Although, occasionally the unwind mandrel will require VFD, Servo or DC gear motor type control.

In the unwind section often there are roll change features, such as dual mandrels, roll lifts and vacuum splice bars. A vacuum splice bar is a horizontal bar with a vacuum manifold built in and a small horizontal slot (suitable to accommodate a utility knife blade) through the middle of the bar. The unwind section will also include the film tension and / or dancer. The dancer can provide a speed feedback (analog or discrete) to the unwind control circuit, as well as a film accumulator area for bag index purposes, especially on an intermittent type machine. Additional options possible for the unwind section are functions like zipper applicators and breather inserters.

Film Registration

This section includes the film registration sensor and placement adjustment mechanisms. The film registration is used on film with graphics or pre-printed information. Printing process variations, film stretch, film slippage during acceleration and other factors can allow the graphics to drift away from ideal cosmetic / marketing placement on the finished bag. The registration mark provides a method to make minor adjustments to the actual end placement of the seal and cut on a bag. When there is no printing or graphics on the bag, the process is defined solely on length. Also located in the film registration section, it is common to have the film alignment / tracking adjustment mechanisms. These are used to ensure the film stays in the correct place on the forming tube.

Forming Tube

The forming tube mechanics are often unique designs for different machines, films and products. However, the general description is an inverted cone with radius corners. This cone and the correct diameter tube (shapes can differ from round for special package needs) are combined to form the flat film into a tubular or tunnel type shape, which ends up being wrapped around the external surface of the actual forming tube. In order to provide extra film for the long or "back" seal, the width of the film will be greater than the circumference of the forming tube. The long seal is formed by several different heater mechanical configurations that are typically placed on the front of the forming tube and are eight to twelve inches in length. Linear film speed and type are factors in determining the correct minimum length of the long seal. There are two main types of long seal.

The first type of long seal is the static bar, which is a heated bar with heating element and thermocouple. This bar will be engaged into the film and forming tube only while the film is in motion with slight timing delays to prohibit melting of the film when stationary. There can also be two bars, but placed where they are facing one another in a manner to allow the long seal flaps to be placed in between the two bars. This method is used instead of the overlapping method used for single bar configurations. This can provide stronger seals / seams and the product ambient temperature (i.e. forming tube temperature) will have less of a factor on the loop control.

The second type of long seal is the dynamic belt, a single-heated stainless steel belt with two pulleys. A heated plate transfers the heat to the stainless steel band or belt and is engaged into the film and forming tube while the film is in motion. Like the static bar type, there can also be dual dynamic belts / bands. The benefit of dynamic belts is they can move with the film and also be adjusted to operate faster than the base film speed or even slower. These are process decisions made based on many product, machine and material factors.

Film Pull Belt(s)

There are typically two film pull belts—right side and left side. They are typically vacuum belts, which allows for better gripping control in dusty, high moisture or cold operating environments. The belt mechanics are often powered by VFD motors with encoder feedback, servo axes or perhaps stepper motors. Occasionally there will be only one motor that is mechanically transferred to the separate belts, but the general practice is to eliminate the additional special mechanical costs in lieu of the additional, but more flexible, controls cost. The film pull belts provide the actual force to pull the film through the machine and are used to maintain good film tension on the forming plow and tube. Often code is used to monitor position and velocity error to ensure that slight mechanical differences are not allowing one side to pull more than the other.

Cross (Sealing) Jaw

The cross jaw is responsible for three major functions—to seal the top of the previously filled bag, to create the bottom seal for the soon to be filled bag and to cut or separate the completed bag from the bottom of the new bag.

The front and back cross jaws operate as a pair. The front and back jaw will both have a top seal area (horizontally) and a bottom seal area. Additionally, either the front (typically due to maintenance reasons) or the back jaw set will have a knife which runs horizontally in the middle of the jaw face. This knife is recessed and is activated by a pneumatic actuator. The opposite jaw set will contain the anvil for the knife.

Each jaw will have one or two heating elements as well as a thermocouple for temperature control. Additionally, the cross jaw section can have options like product wipers, bag deflators, bag hanger punch, gusset (single & double) creation mechanics and flat bottom bag mechanics to name a few. Cross jaws are typically configured mechanically where the front and back jaws interpose each other and therefore meet in the vertical centerline of the bag and forming tunnel. However, there are also

versions where either the front or back jaw is stationary and the opposite jaw is moveable. Servo drive/motor combinations, VFD drives with induction motors and high power pneumatic cylinder actuators are used to close the jaws and provide the necessary sealing pressure to provide a suitable bag seal. It is very common for the jaws to contain built-in springs to allow for some closure error as well as a default force. Often, position and torque data are monitored for the cross jaws. This data can easily be used to detect product in the seal or between the jaws. Anytime there is product in the seal, these two bags should be discarded due to potential seal / seam leakage.

The previous sections are typical for an intermittent VFFS machine; however a continuous machine will often contain a section called the rotary or vertical jaw, depending on the bagger type.

Rotary Jaw

The first type of continuous bagger is the rotary / "D" jaw. For a rotary type bagger, the horizontal plane motion for the front and back cross jaws is replaced with a rotary type motion. This is accomplished with special mechanisms, orbital gearboxes and/or four-bar type linkages. In general each jaw is attached between two gears. Each jaw end gear is actuated by a driving gear. Along with some orientation linkages, these jaws will operate in a “mirrored” fashion so the jaws maintain the same distance to the vertical plane as they rotate in a top-to-bottom and around fashion. The main benefit of a continuous type bagger over the intermittent is that since the cross jaw is now moving along the vertical plane as well as the horizontal plane, the sealing process can occur without stopping the film completely.

Vertical Jaw

The second type of continuous bagger is the box or square jaw type. This differs from the rotary jaw in that there are now two mechanical movers for the overall cross jaw - one is the horizontal-only plane and the other is for the vertical-only plane. Although this adds increased controls and mechanical costs, it can also provide additional bag making process options, longer bags with fewer constraints and more control for product sweeping type functions. Mechanically, the cross jaw mechanics and motor are contained on a carriage. This carriage is controlled and moved along the vertical plane via the vertical mechanics and motor.

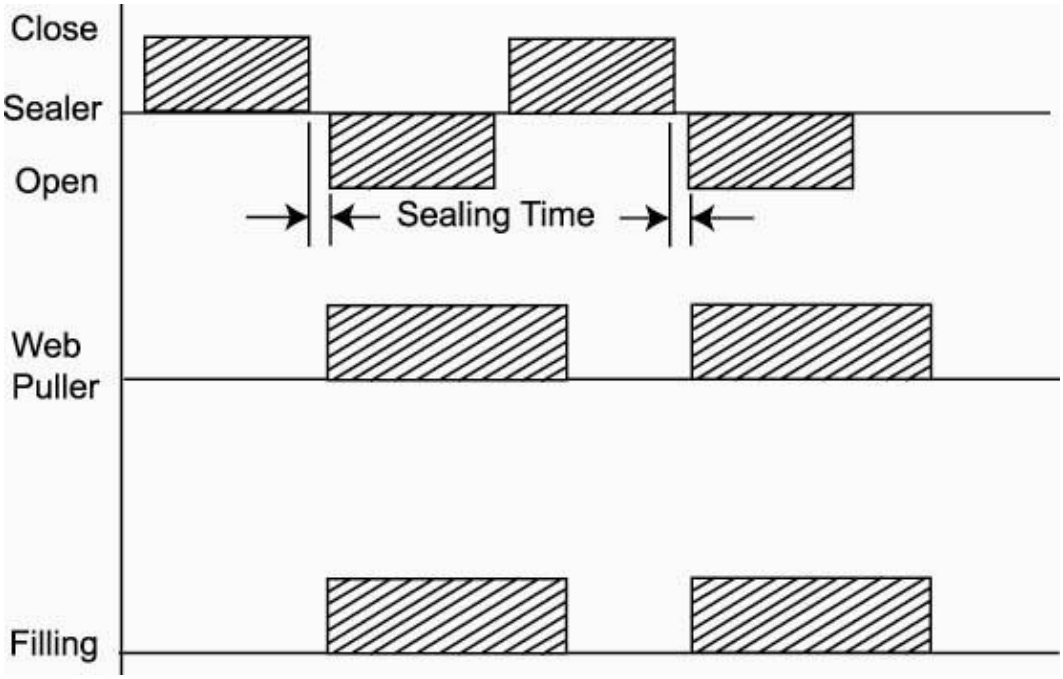
Machine Speed

The speed of the VFFS machine is the rate at which it is able to (1) form the pouch (bag, sachet, etc.); (2) fill it with product; (3) seal it; (4) cut it; and (5) transfer the package for shipment or further end-of-line packaging such as a case packer, over wrapper etc. The speed of the machine is one of the main attributes in many end users’ buying criteria. Machine builders will design their machines to operate at the highest speed possible

Challenges

- How to design the mechanics of the machine to operate at high speed and maintain the correct tension of the film feed in order to maintain the quality of the packaging.
- How to position the film accurately based on eye mark registration.
- How to design the optimum sequence of machine operation. Refer to the timing diagram below for an example of a Form, Fill and Seal operation in intermittent duty cycle.

This is an example of typical VFFS machine with an auger screw filling system.



Machine Functions Application Needs

Mixing/Dosing/Filling

Mixing/Dosing/ Filling Methods	**Characteristics**	**Application Needs**
Time & Gravity	Simple filling technology Dependent only on gravity to drain a product from a hopper and stopping the bagging into the pouch over a set period of time Low cost and easy to setup Suitable for a uniform and consistent product like water	Saving scrap bags when product is not being dropped
Volumetric Cup Fillers	Dependent on time and gravity Series of tubes/cups with a set volume attached to a rotating plate. Suitable for dry product and consistent product such as grains, sugar, pet foods, detergent	
Auger Weigher	Measures the product dosing volume using screw-like auger for a predetermined number of revolutions to displace product from hopper to pouches Suitable for powders or paste	Use of load cells for weight of products
Multi-head Weigher	Product is fed into weigh buckets. Its control system calculates the best combination for discharge to pouches High precision and accurate dosing Suitable for meat parts, cereals, candies, noodles	

Filling Method Machines:

Auger Weigher

Multi-head Weigher

Volumetric Cup Filler

Feeding

Feeding Method	**Application Needs**
Product fed intermittently	Material feeding based on auger screw, piston-based suction and ejection
Product fed continuously	High speed bulk head feeders, servo drive auger screw systems

Forming

Forming Method	**Application Needs**
Forming tube	Laminate / Film driven by friction roller
Film fed to a plough	Length controlled by VFD with clutch/brake or servo-based motion Calculation of process parameters for different pack/pouch length Keeping consistent film tension

Aligning

Aligning Method	**Application Needs**
Film registration	Tracking the exact target lines for a variety of bag types because film changes often affect registration mark positions. Maintaining accurate film positioning as the speed of the machine increases.

Closing

Closing Method	**Application Needs**
Closing	Closing jaws with heater coils will linearly move towards and away with pneumatics or mechanical CAM driven by AC motor

Sealing

Sealing Method	**Application Needs**
Sealing jaws	Use of electrical elements to provide heat to contact surface to melt packaging material Sealing time, pressure and temperature control Coordination with cutting section

Cutting

Application needs
Additional pneumatic actuated blade fitted within sealing jaw

End Users expect VFFS to be:

- **Productive:** Optimize packaging process to achieve maximum possible machine speed; maximize throughput with highest quality; high accuracy and shorten recovery time.
- **High performance:** Satisfy strict accuracy requirements at high machine speeds and variable bag lengths.
- **Flexible:** Release the burden of manual adjustment of film registration sensor position by introducing software adjustment scheme; improve changeover time.

  Easy to use: In spite of machine complexity, machines must be easy to maintain and operate.

Machine Builders expect VFFS to be:

- **Modular and scalable**: Mix and match VFFS machine functions that are ideally suited for specific customer applications; customized functions to develop a new machine that is localized to market demands.
- **Standard**: Develop and document mechanisms common to VFFS machines that can be easily redeployed with minimum modifications, despite different machine sections/conditions that result in more complicated sequencing and interlocking, so that machine design and development time can be reduced.
- **Cost-effective:** Machine integration, mechanical, electrical optimization and wiring start up time costs are reduced.

Solutions & Benefits

There are several good solutions which can be used for VFFS machine applications. The main determining factors will be:

1) Controller /Programming Preference
a) Micro800® controller
b) CompactLogix™ /ControlLogix® controller

2) Continuous/Intermittent Motion
a) Electronic Gearing /Camming
b) PowerFlex® VFD / Servos

For instance, for a basic intermittent VFFS machine there will be some sort of timing axis or PLS channel to coordinate the dosing section (multi-head scale, auger, volumetric cup filler…) with the bag making process. The film pull belt axis will be indexed at either specific lengths and stopped or stopped based on the registration mark and a calculated stop distance based on control variables and machine dynamics. Once the film pull belts have stopped, the cross jaw can commence the sealing process.

The Film Unwind control is handled as a separate function based on dancer position and whether the film is in motion or not. If a VFD or stepper control is desired for the film pull belts, then a Micro800 can be used to drive the VFD via ModBus, control discrete or analog I/O and monitor the position via an encoder and the high speed counter channel. Additionally, (third party) stepper modules could be used to drive Stepper drives, Kinetix® 3 for controlling the cross jaw.

For continuous type machines, the required coordination of the cross jaw axis (or axes for a box jaw) creates additional control functionality needs, such as position camming and virtual axes. This type of machine would use:
a) CompactLogix with integrated motion
b) ControlLogix with integrated motion

Additional control elements would/could include:
a) PanelView™ Plus - with language switching and recipe management functionality
b) Safety products - door interlocks, safety relays
c) Discrete I/O

Servo Based Solution

The Rockwell Automation Integrated Architecture® with integrated motion is ideal for VFFS machines which require speeds of 100 packs per minute and above.

A servo axis on the roll of film is used to maintain tension in the process, so the exact amount of film material can be used with minimal waste. This servo axis will feed the correct length of film into the formed film tube, based on the recipe provided by the operator. If the film is pre-printed, a registration sensor adjusts the film position to maintain the correct print position.

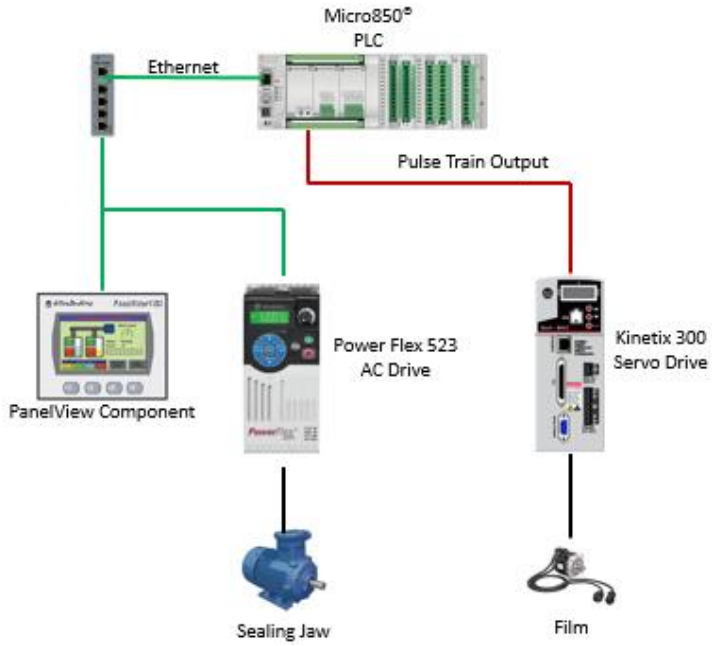
As the feed servo axis pulls the film down, the goods to be packaged are gravity-fed into the tube, often by a precision scale, which ensures that the proper amount of goods are placed in the pouch in a consistent manner. Before product is put into the pouch, the cross jaw servo axis seals the bottom of the pouch. It is then filled and indexed. The cross jaw servo axis now seals and cuts the pouch, with the product placed between the end seals, to form a pouch.

Built-in PID functionality provides accurate control of the film unwind mechanism by controlling such devices as unwind brakes or motors, as well as accurate temperature control of a variety of devices. Native math capabilities in the Logix processor provide a powerful environment for creating complex algorithms. Registration inputs to the Logix processor are able to record not only the position of any physical axes independent of the process, but also the time the input occurred. This time can be used to determine precise positions for all other physical and virtual axes in the system to help control accurate film positioning.

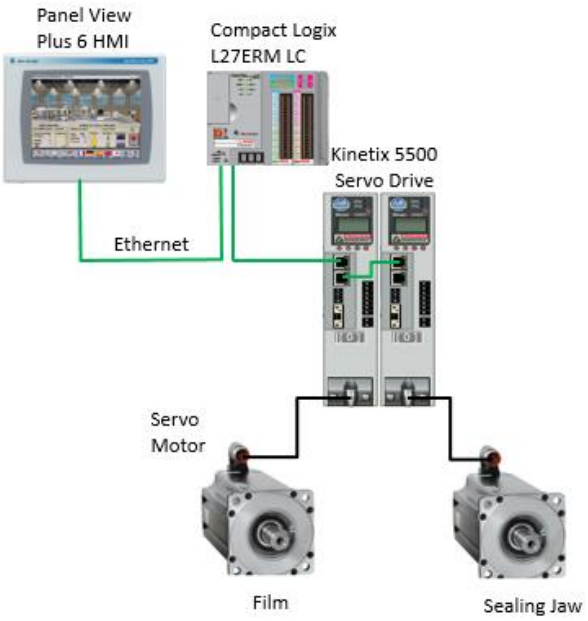
Pending cams on an otherwise continuously recurring cam motion bring the bagging hands to a stop and restart them within half a product cycle to control dwelling when product is unavailable. Plant-floor operators can select appropriately sized cam profiles by entering parameters from the operator terminal or calculate profiles on the fly with the MCCP instructions.

Below are typical architectures for VFFS machines using Rockwell Automation solutions.

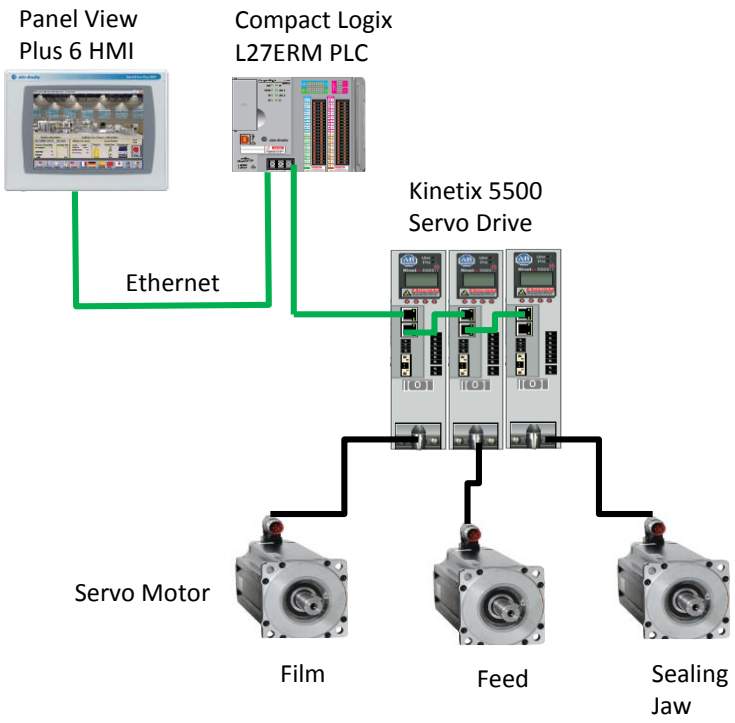
Intermittent motion, machine speed <= 70 packs



Intermittent motion, machine speed <= 100 packs



Continuous Motion



Substitution of mechanical machine elements

- Flexible, electronic synchronized drives replace rigid mechanical systems with main shaft, gears and cams
- Extended machine lifecycle and noise and vibration reduction by decoupling mechanical components

Increased flexibility
- Easy synchronization to upstream or downstream machines or processes

Increased productivity
- Increased cycle rates by replacing mechanical transmission components with servo technologies
- Automated format change by means of recipe storage

Increased product quality
- Phase correction by use of registration mark control improves seal and cut accuracy

Reduced downtime

- No homing after downtime (in case of product jams or power failure) by using servo motors with absolute encoders

Global Solutions – Locally Delivered

Whether you're around the corner or around the world, our Services & Support network can provide the skills and resources you need to optimize performance and utilization of your automation equipment, helping you meet your business objectives.

- Global emergency support 24/7
- Offices and agents in more than 80 countries
- 35,000 distributors and agents
- 1000 service engineers, consultants and project managers worldwide

Summary

Rockwell Automation solutions deliver improved production capabilities and reduced total cost of ownership by providing unparalleled functionality, flexibility and scalability. Machine builders can respond more quickly to customer or market demands, reduce maintenance costs and downtime and easily gain access to actionable plant and production information for improved management and decision-making.

For VFFS machines, the Logix Control Platform is a powerful system of control, networking, visualization and information technologies that delivers a lower total cost to design, develop and deliver machinery. Unlike conventional control architectures, it provides fully integrated, scalable solutions using a single control platform and a single development environment. This enables machine builders to efficiently re-use engineering designs to reduce development time and cost and greatly enhance business performance.

Resources

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Publication OEM-WP004B-EN-P