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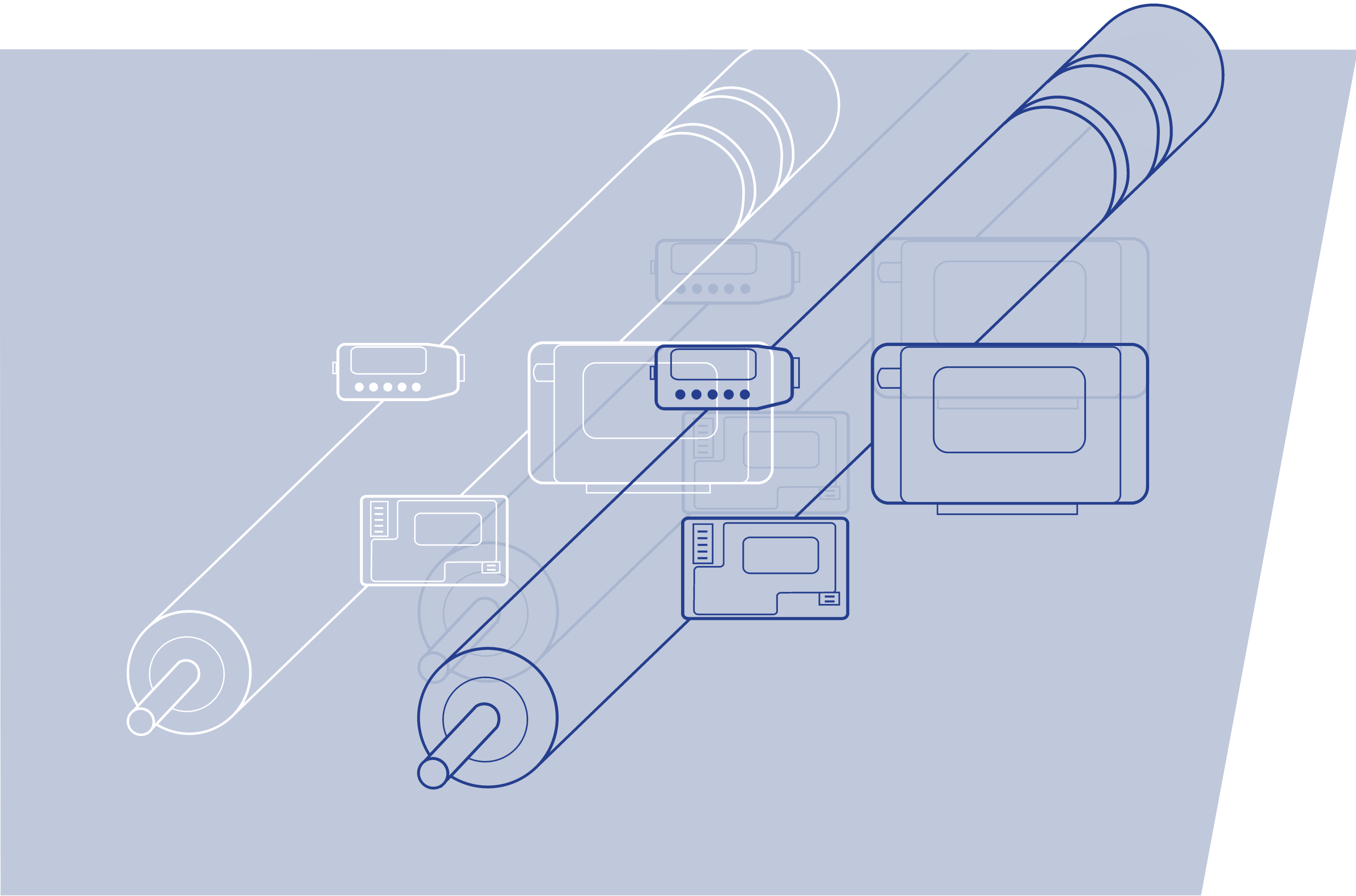
An InfiniDrive™ Motor Manufacturing Company

24 Volt DC Motor-Driven Roller Conveyor Primer



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- **Distribute I/O Catalog**

Holjeron MDR and ZoneLink® Pricing Guide

24 Volt DC Motor-Driven Roller Conveyor Primer

Who Should Read this Primer:

You are a professional charged with the technical responsibility to envision, design, and implement a conveyor system for merchandise in a factory or warehouse. The installation may be in a brand new facility or it may be an expansion/update of existing infrastructure. You have in-depth knowledge of the organization's physical plant and logistical needs: capacity, throughput, material handling requirements, and more. Now it is time to "put pen to paper" and design a system specifically for the application at hand.

You should read this primer if your conveyor plans include:

- Practical constraints on floor space, power or compressed air distribution
- Requirements for zero pressure accumulation as the product passes over curves, inclines, declines, merges, diverters or transfers
- Potential future expansion or re-routing of the conveying system
- Processes that encompass preventive maintenance and performance monitoring of plant equipment
- A "cost-of-ownership" analysis

This primer will discuss the technologies found in today's roller conveyors, and will guide you through the power requirements, control architectures, motors, and other considerations affecting a system design. With a particular focus on Brushless DC (BLDC) rollers and related control technologies, this primer will give you the background to begin planning an efficient conveyor system that meets your needs.

Introduction

Conveyor systems come in many shapes and sizes, dictated by the applications they serve. But all powered roller conveyors fall into one of two basic categories:

- Systems using centralized multi-horsepower AC motors to drive shafts, belts, or chains that in turn move banks of rollers. These are known as Belt-Driven Live Roller (BDLR) and Lineshaft conveyors. An example is shown in Figure 1.
- Conveyors based on distributed rollers with internal DC "micro-horsepower" motors that drive a localized segment of passive rollers. These are known as Brushless DC (BLDC) roller conveyors, shown in Figure 2.

Figure 1 AC motors powering a BDLR conveyor

Figure 2 Motorized rollers in a BLDC conveyor

Each type has its strengths. Light, responsive BLDC elements can transport packages quickly with no collisions—a key consideration for electronics, glass and plastic items, and similarly delicate merchandise. BLDC systems are suitable for products of almost any weight. AC motor-driven conveyors, too, can handle a broad range of product weights and sizes. Historically they have been the preferred platform for the heaviest load weights.

The Belt-Driven Live Roller Conveyor

The Belt-Driven Live Roller system has long been a workhorse in factories, warehouses, and shipping depots around the world. For decades, the BDLR was the only effective solution for moving many types of merchandise around the premises. At this writing, BDLR is still the most common powered roller conveyor architecture. It is serving in applications ranging from backroom conveyors just a few feet long to warehouse-wide systems with literally miles of conveyors.

In a BDLR conveyor system, a powerful AC motor drives a transfer medium (a belt, chain, or a line shaft) that delivers the motor's motion to a series of rollers. The motor runs continuously, and pneumatic actuators determine when the motive power is actually applied to the rollers. By this means, the product traveling on the conveyor can be held back or moved forward as conditions on the line permit.

Of course, it's impractical (at best) to use a single AC motor to power the massive of conveyor lengths common in today's large commercial settings. Therefore BDLR conveyors deploy multiple AC motors, each driving its own rank of rollers via a local shaft and pneumatic apparatus.

Supporting all this is a centralized Programmable Logic Controller (PLC) that controls the state of the entire conveyor line. As it happens, this is a big job. The PLC provides all the intelligence to control the activity of the rollers, which must start and stop at precisely the right time if collisions between adjacent packages are to be avoided. The PLC also monitors inputs from sensors on the conveyor; these detect objects on each conveyor section. This information helps the PLC decide whether to move the product ahead or hold it while the line ahead clears. Point-to-point wiring harnesses (one for each conveyor section) carry commands and sensor data between the PLC and the functional elements of the system.

The BDLR conveyor is a proven, reliable tool. But there are some tradeoffs in its implementation.

The AC motor runs continuously, whether the conveyor rollers are actually moving merchandise or not. That adds up to constant noise, heat, and wear. And because of the power, torque, and momentum involved, there is a safety risk for those working near the moving elements. A roller that catches a loose sleeve won't tend to stop; it will pull the sleeve in. In addition, the high-voltage service (usually 220 volts or more) at each AC motor adds cost and exposes workers to further risks.

The BDLR system requires compressed air for the pneumatics on each conveyor section. Installing and maintaining this subsystem adds a layer of complexity that must be considered when evaluating the true cost of the conveyor apparatus.

While BDLR architectures are still a cornerstone of conveyor technology, today's rigorous goals of throughput, productivity, cost-effectiveness, and enterprise automation have given rise to alternative approaches. Chief among these is the brushless DC roller conveyor.

The Brushless DC Roller Conveyor

The brushless DC conveyor system (BLDC) system takes an entirely different approach from its BDLR predecessors. Leveraging advances in motors, networking, computing, and control, BLDC technology is designed to deliver maximum efficiency along with reduced complexity and lower cost of ownership.

The BLDC system is built around the interaction of several key components: drive rollers with self-contained brushless DC motors; intelligent local control modules; and networking based on industry-standard bidirectional communication protocols.

The enabling technology behind the BLDC system is the motor-driven roller. A 24 VDC brushless motor and planetary gearing are contained entirely within the roller cylinder. This makes possible a modular scheme of installation and control. The concept is scalable to essentially any size. A conveyor section is simply a frame that situates one or more motorized rollers and several passive rollers joined mechanically to it. There are no shafts, external motors, or pneumatics required to execute the basic stop and go commands.

The BLDC roller motor remains stationary until it receives a start command, and then it runs only for a second or two. Unlike the AC motor-based systems, little heat or mechanical noises are generated when the rollers are idle. Net power consumption is lower than BDLR systems.

In effect, the horsepower needed to do the work is divided among many small motors rather than a few large, powerful motors. No single BLDC roller has enough torque to threaten the safety of those working in proximity; it can actually be stopped by hand. The power supply voltages present at the motor—only 24 VDC—are not unduly hazardous to personnel.

There are several control methodologies. The most efficient uses a central PC or PLC to track items but uses distributed intelligence to control conveyor functions such as accumulation, merges, diverts and transfers. These modules receive information from the local sensors and react accordingly. There is minimal interaction with the central controller/PC. It is a simpler and less costly approach that that of the BDLR conveyor, which relies on individual multi-conductor harnesses to carry data back and forth to the conveyor segments. And because so much of the processing is handled at the local module level, bandwidth issues between the controller and the machinery are a thing of the past. Figure 3 illustrates these trends.

Working with local processing intelligence, the rollers' internal motors can participate in a predictive maintenance regime, alerting the controller to heat, wear, and length of service conditions.

Perhaps most importantly, the BLDC scheme innately simplifies "Zero Pressure Accumulation" (ZPA) implementation. The small local DC motors can start and stop directly. There are no added complexities due to pneumatic actuators or I/O networks. With distributed intelligence, adjacent zones are aware of each other's conditions and product can be indexed through the zones at very short intervals with little risk of collisions or backups.

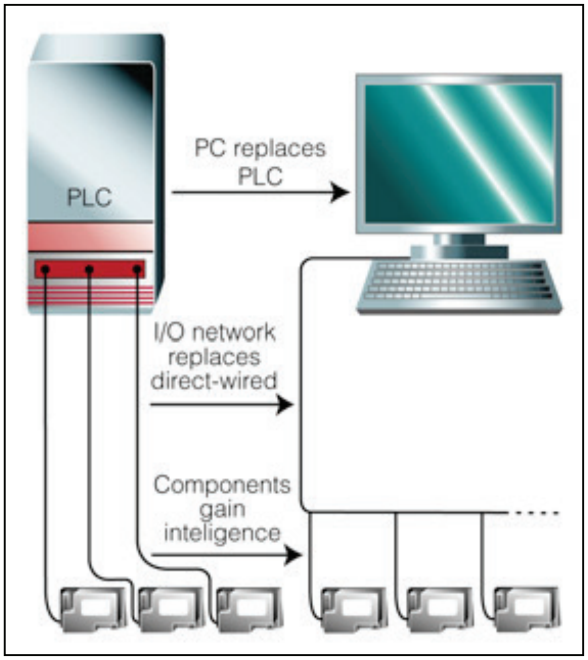

Figure 3 The landscape of conveyor control is changing

More and more conveyor users are choosing BLDC systems for their applications. The architecture lends itself to advancements in automation and control technology. Most conveyor manufacturers and integrators, even those entrenched in the BDLR market, now offer BLDC products. The brushless DC motor conveyor has a bright future in modern commercial applications.

About Holjeron Corporation

The Holjeron Corporation designs and manufactures a range of solutions for industrial automation applications. Holjeron's innovative conveyor transmission and control products are based on hardware components such as Holjeron MDR motorized rollers and ZoneLink™ controllers, and on industry-standard software protocols including Controller Area Network (CAN) and DeviceNet™. Holjeron conveyor systems employing these technologies maximize system throughput and efficiency while reducing the cost of ownership.

The balance of this document will present background information to support planning and design of a motorized roller-based conveyor system.

Understanding Motor-Driven Rollers

Abstract: This section will explain the mechanics and operation of motor-driven rollers, and then go into detail on the motor-related factors you must consider when planning a BLDC conveyor. Issues relating to the control of these motorized rollers are treated in Section 3.

Motor-driven roller conveyors have unique solutions to all of the challenges posed by conveyor applications. To fully realize the benefits, it pays to understand the underlying technology.

Anatomy of a Brushless DC Motor-Driven Roller (MDR)

DC motors consist of a rotor, a stator, and a commutator. In conventional DC motors, the rotor is a wound copper coil on an axle and the stator is a permanent magnet. The rotation of the motor depends on rapidly alternating forces of attraction and repulsion between the wound rotor coil and the magnetic stator.

Commutator brushes, a legacy of the earliest electric motor designs, maintain a constant friction contact with the rotor and cause a reversal of the current flow in the rotor during each revolution, switching its polarity. Thus, the rotor is drawn first toward one magnetic pole and then the other, sustaining the rotation. Unfortunately, brush commutators are subject to wear and must be replaced periodically.

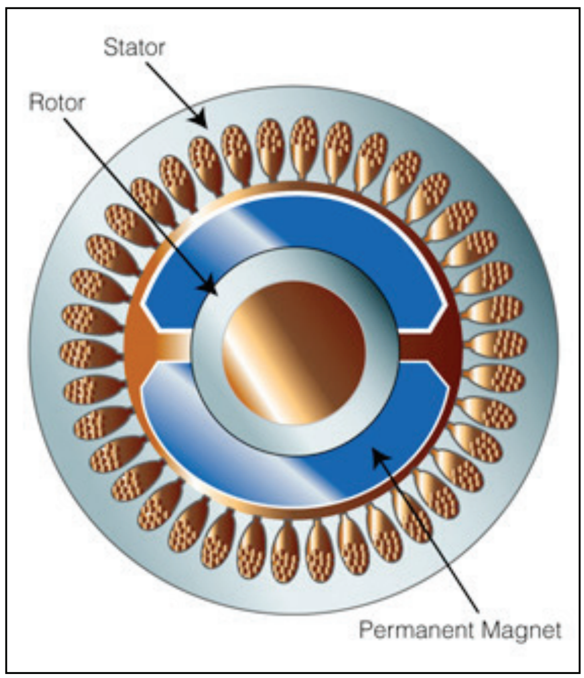

Figure 4 Anatomy of a Brushless DC (BLDC) motor

At the heart of a modern motorized roller is a *brushless* DC motor of the configuration shown in Figure 4.

As their name implies, these motors don't rely on mechanical commutator brushes. The brushless motor's stator is wound and the rotor is attached to the permanent magnet. The stator receives the commutation current from Integrated circuit (IC) devices designed to deliver the correct polarity and amount of commutating current at the correct time. The timing is determined by the state of Hall Effect sensors that monitor the rotor position. The net result is the same continuous rotating motion that a mechanical commutator provides, but without the wear. Figure 5 depicts this scheme. The “Driver” component is an external unit that feeds DC power to the motor and houses the circuitry that drives the commutation elements.

24V BLDC MDR

- Generates torque through a fully-enclosed, self-lubricating planetary gear
- Offers a variety of torque-speed combinations
- Drives only one zone in a conveying system
- Can be covered in a variety of rubber or urethane coatings to provide grip or protection

It’s All about Torque

Torque is the key parameter that defines BLDC roller motors. Its complement is speed. Torque can be thought of as force in a circular direction. BLDC roller motors have innately high starting torque as well as very linear speed vs. torque characteristics. The starting torque provides the “leverage” to overcome the inertia of the load on the roller—that is, the motorized roller itself, those coupled to it, and the cargo on the conveyor.

The linear speed vs. torque characteristic is also important in conveyor applications. To support a consistent flow of product on the conveyor, the motorized rollers must be able to maintain their rated speed under load, and deliver their rated torque at speed. A linear speed vs. torque characteristic ensures predictable performance and response times on the conveyor. It provides the information to predict the conveyor’s reaction to differing load weights and supports the instantaneous speed corrections that a dynamic conveying environment requires.

The motor delivers its energy to the roller by means of planetary gears that also reside within the roller. BLDC motors typically can deliver a constant torque across a large range of operating speeds. The planetary gear system multiplies the torque and reduces the speed according to the gear ratios, making it possible for one type of motor to meet a range of performance requirements.

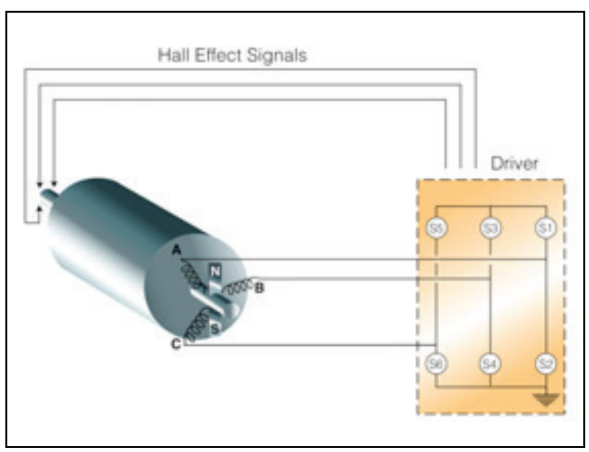

Figure 5 Brushless Motor Commutation

Figure 6 is a cutaway view of a motorized roller. It shows how the planetary gears attach to a flywheel that transmits their torque to the cylindrical housing that is the roller itself.

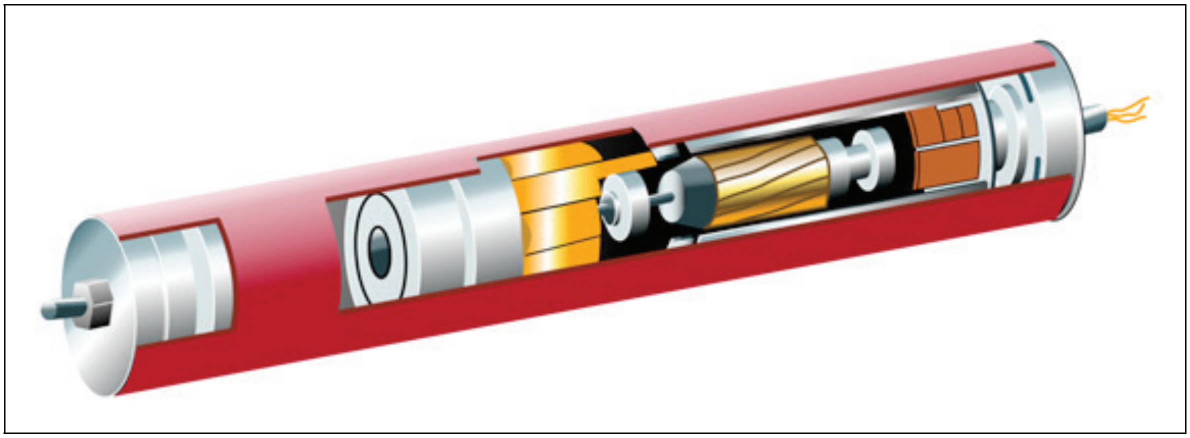

Figure 6 Motor-Driven Roller (MDR) Cutaway View

Note that industry specifications differentiate roller motors based on overall power expressed in watts (the voltage rating is standardized industry-wide at 24 volts). Because the net torque of the roller package as a whole depends on the planetary gears, the power rating is just a starting point for planning your roller configuration.

The cost of the underlying technologies (ICs, Hall Effect sensors, power semiconductors) that support BLDC motors has decreased dramatically in recent years, expanding the range of applications that can benefit from motorized roller implementations.

Choosing a Motorized Roller for Your Application

Making the right choice in motorized rollers is a matter of doing the math and weighing the needs of "What must be moved" against the specifications of commercially available rollers. As explained earlier, planetary gears enable a wide range of speed/torque combinations. In addition, suppliers offer motors in several increments of power; Holjeron Corp, for example, provides 22-watt and 35-watt motors matched to a variety of planetary gear ratios and cylinder diameters.

Those accustomed to working with BDLR conveyors and the AC motors that drive them know that motor power requirements derive directly from classical horsepower calculations in which one horsepower is equivalent to 33,000 ft.-lbs. per minute. Influences to the calculation include factors such as coefficient of friction, the conveyor length ("*l*") and load weight. In any case, the motor isn't just moving the

24V BLDC MDR

- Motive power is distributed across many small "zones"
- Calculate required torque and cross-reference to available speeds at the required torque to select the best roller for the application

rollers and the cargo; it's also continuously spinning a shaft or drive belt that consumes power. The standard horsepower calculation implies that a substantial motor is needed to power the mechanics and transport, say, a 200-lb. object a distance (*l*) of 60 feet in one minute. Motors of 3 HP, 5 HP, and more are commonly used in conveyor systems.

In a BLDC motorized roller application, a different mindset applies. In a basic system, the motive power is distributed among many small roller motors. The "l" term in a conveyor is the total length of the conveyor powered by a single motor. In a basic BLDC system, *"l"* is typically 2-3 feet, the length of a single zone. In a sense, the BLDC conveyor divides the work of moving the load into many small, manageable pieces. Each motorized roller runs just long enough to move the item across its own zone. In this scheme, the motors are quiescent (and incidentally, cooling down) whenever they are not moving the product. Unlike the AC motor-powered BDLR conveyor, no single motor carries a continuous load[1]. No single motor normally sees more than one unit of load weight at a time. While there are recommended margins to ensure the needed performance under worst-case loading scenarios, there is no need to over-design.

Sizing the Motor

Calculating Torque

The first and most important calculation for a motorized roller is torque.

The terms involved in the torque calculation are simple requiring just three factors: the weight of the intended load, the coefficient of rolling friction, and the radius of the roller.

The weight is a given that depends entirely on the application. The coefficient of rolling friction can be determined by measurement, or estimated, from a reference such as Table 1.

Table 1 Coefficients of friction for commonly used roller and cargo materials

	Load Material			
Roller Material	Steel	Plastic	Wood	Corrugated
Steel	0.02	0.04	0.05	0.1
PVC coating	0.02	0.04	0.05	0.15
Kastalon (sleeve)	0.02	0.04	0.05	0.15
Urethane (sleeve)	0.03	0.04	0.06	0.15
Urethane (molded)	0.02	0.04	0.05	0.15

[1] This assumes a "basic" BLDC conveyor. It is possible to configure systems in which multiple synchronized rollers contribute more power to move a heavier load across the zone.

The tangential force is the force on the conveyed object in a direction parallel to the moving surface, as shown in Figure 7.

Tangential force must be calculated for use in the torque equation. The formula for tangential force is as follows:

$$W_{lbs} * E_{fr} = F$$

Where:

- W_{lbs} = load weight in pounds
- E_{fr} = coefficient of rolling friction between the roller and load materials (provided by a source such as Table 1).
- F = tangential force in pounds

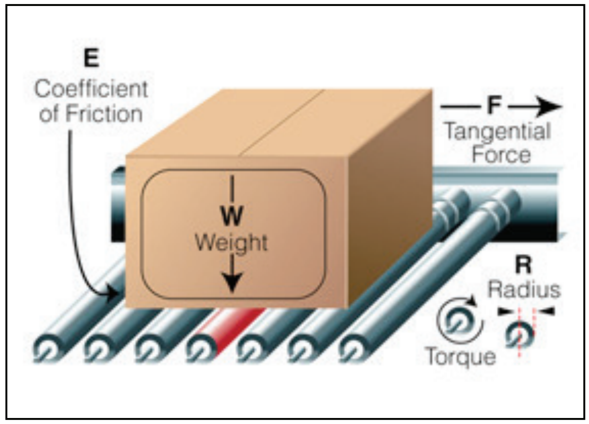

Figure 7 Calculating Tangential Force

Next, the minimum torque is simply the product of the tangential force and the radius of the roller:

$$F * R = / Torque_{in./lbs}$$

Where:

- F = tangential force, and
- R = roller radius in inches

Note that these equations produce minimum acceptable figures. For each idle (passive) roller coupled to the motorized roller, approximately 2% of the available torque is lost and must be accounted for.

Equally important, performance margins are essential in any mission-critical application such as a conveyor. The performance margin provides additional headroom to accommodate extraordinary loading conditions. Most Equipment manufacturers recommend margins such as these guidelines published by Holjeron Corp.:

- 1.5X margin to be applied to all calculated minimum tangential force and torque requirements
- 2.0X margin to be applied to all calculated minimum tangential force and torque requirements when:
- Speed is critical
- Loading may exceed design parameters
- Only one roller is used per zone

Calculating Required Torque

Assume a requirement to convey a 12” x 18” 70 lb plastic tote at 120 fpm using 1.9 in galvanized rollers.

Assumptions:

Coefficient of rolling friction = 0.04
Zone size = 24”
Rollers on 3” centers yields 7 idle rollers per MDR
MDR placement in center of zone
Margin factor = 2.0

Calculations:

70 lbs * 0.04 = 2.8 lbs tangential force required
2.8 lbs * 1.9 in/2 = 2.7 in-lb torque required
2.8 in-lbs * 2% * 4 rollers = 0.2 in-lbs
2.8 in-lbs + 0.2 in-lbs = 3.0 in-lbs minimum torque required
3.0 in-lbs * 2.0 = 6.0 in-lbs torque required

Selecting the Correct Roller

Appendix 1-2 shows the PMR-AD-48-xxx-30-xxxx Holjeron MDR provides sufficient torque (10 in-lbs.) and linear velocity (120 fpm) to meet the application requirements.

Reducing the margin factor to 1.5 yields a required torque of 4.5 in-lbs. the PMR-AD-48-xxx-40-xxxx Holjeron MDR provides more than adequate linear speed (238 fpm) but would provide insufficient torque (4 in-lbs.) for this application. Reducing the Holjeron MDR speed would do nothing to help meet the torque requirement.

Torque and Speed Go Hand-in-Hand

A BLDC motor is inherently able to generate a fairly flat torque response across a range of motor rpms. Due to the internal planetary gears, every motorized roller trades torque for speed, or speed for torque. A specific gear ratio can provide a specific maximum continuous torque. Varying the motor speed can produce a range of linear speeds for the items being conveyed, but it is the gear reduction ratio that determines what that range is.

The load weight is a factor in the torque calculation. After computing the torque, you must cross-reference the needed conveyor speed (expressed in feet per minute, or FPM) against the speed ranges available for the required torque. Armed with this information, you can select an MDR that’s right for your application.

Figure 8 is a representative plot of the range of speeds and weights of specific 22 watt motor-gearbox selections when conveying a plastic tote. If instead the load was made up of corrugated boxes (with different behavior in terms of the coefficient of friction and weight variations), an entirely different range of MDR might be recommended.

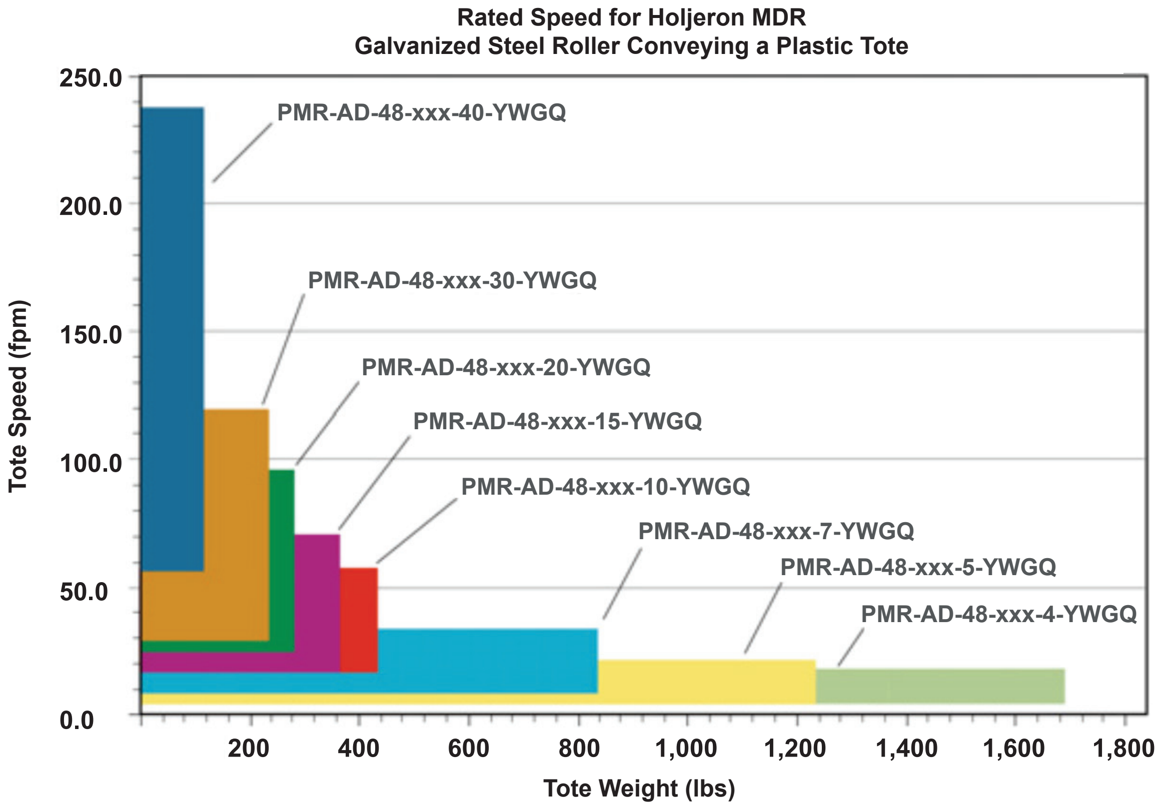

Figure 8 Speed abd Weight Ranges for Galvanized Steel Holjeron MDRs Conveying a Plastic Tote

Some applications demand both high torque and high speed. The solution lies in choosing a high-power motor such as Holjeron's 35-watt PMR-AD-40-YZGQ.

There is of course a finite range of torque vs. speed options to choose from. When yet more power is required at high speeds, the solution is to use multiple rollers per zone. With appropriate control technology, two motorized rollers can be synchronized such that they act like one doubly powerful roller.

Other Considerations

Rollers are available in various diameters, although "off-the-shelf" models are limited to industry-standard dimensions. The most common diameter used in light industrial and warehousing applications is 1.9 inches, but diameters up to 2.38 inches are also widely used. A larger diameter provides higher linear speed for any given RPM but may require more motor torque. In addition, thick-walled rollers are available for applications expected to handle more weight or requiring wider spans.

The length of the roller itself is another variable that depends on “What must be moved.” A large item may require a wide conveyor made up of longer rollers. These longer, heavier rollers require more motor power to move them, irrespective of the cargo. In addition, there are weight limits to consider. A 4’ roller of 1.9” diameter should not be loaded as heavily as a 2’ roller of the same size. Roller manufacturers can supply data about these specifications. See Appendix 1-4 for more detail.

Roller lagging, or covering, ranges from plain galvanized steel to thick coatings of urethane. This latter formulation cushions the moving merchandise and provides more traction as well. See Appendix 3 for more information on available lagging.

Powering Roller Conveyors

Abstract: This section will discuss the prevailing methods of powering roller conveyor systems, and offer some simple guidelines for planning power distribution for a 24V Brushless DC motor-driven roller conveyor system.

Connecting and Delivering Electrical Power

Nowhere is the contrast between BDLR and MDR conveyor architectures more distinct than in their power connection and consumption. Again, applications in which massive, heavy objects must be moved are usually served by BDLR conveyors and their powerful centralized AC motors. Although 24V BLDC MDRs can be clustered to meet torque requirements of heavier loads, typically AC motor-driven conveyor is more suitable when the load consists of, say, engine blocks or pallets of bagged cement.

- MDR conveyor is powered by safe 24V DC power
- MDR conveyor offers substantial energy savings over BDLR or Lineshaft conveyor

Feeding large AC motors that drive BDLR with sufficient electrical power requires dedicated 220V or even 480V power drops. These are not wall outlets—they are fixed, hardwired installations that carry dangerous voltages and currents. It adds up to a substantial investment in special-purpose electrical infrastructure within the plant. And moving a conveyor, or even a single motor, means moving the elaborate electrical service behind it.

Compare this to the MDR conveyor. Cost-effective DC power supplies—a commodity available from any electronics distributor—drive the rollers. These power supplies connect to ordinary 117V drops, eliminating the need for a separate high-voltage service. Moreover, the conventional 117V service is compatible with cost-effective ancillary equipment such as uninterruptible power supplies and monitoring devices. Lastly, the 24VDC supplies can be had with full safety and EMC ratings, which simplify code inspections and regulatory compliance.

WARNING: Electrical power installation is subject to local codes as well as Federal and state regulations. Moreover, there are safety, shielding, grounding, power quality, and even EMI (electromagnetic interference) issues to consider, whether the conveyor is an MDR or a BDLR type.All high-voltage electrical power installation work MUST be carried out by licensed personnel in compliance with applicable regulations.

Equally important, the MDR conveyor is more efficient in terms of its power use. As explained in the example above, the powered rollers are off most of the time. With no chains, belts, or shafts to keep moving, the MDR rollers sit idle until they receive a signal from the controller or an adjacent zone (when standalone ZPA modules are used). Little power is used. When the signal arrives, the rollers run for a second or two— just long enough to index the product into the next zone. One major MDR conveyor user has found that rollers in its conveyor system, even though the facility runs 24/7[2], are active approximately 44% of the time. Other large MDR users have cited tens of thousands of dollars per year in power savings.

A Tale of Two Warehouses

A major grocery store chain operates a distribution center near Chicago. Cartons move around the site on a belt-driven roller conveyor system powered by large (10 HP) AC motors positioned strategically along the line.

The store's competitor runs a similar regional center near Milwaukee. At this site the wares move about on a 24V motor-driven roller conveyor (MDR).

Both facilities are equivalent in size and both handle about the same amount and kind of merchandise month in, month out.

But the Milwaukee warehouse, running its MDR conveyor, uses about half the kilowatt-hours of electrical power the Chicago competitor's AC motor system consumes. Why?

Could it be because the rollers that drive the MDR system, even when running at full capacity, are actually off most of the time?

This story is fictional, but is based on technical facts and real-world experience. It illustrates just one of the power issues—the cost of the actual kilowatts—that must be evaluated when planning a conveyor system. There are others: safety, installation and maintenance cost, ease of use, availability of standardized components, ability to monitor performance, and more. For many end-users, the way a conveyor is powered influences the choice of the conveyor itself.

[2] "USPS Ups Efficiency With 'Smart' Conveyor Controls," Packaging World magazine, October, 1997.

Planning for DC Power Distribution

Although power distribution is rarely the only factor that leads to choosing an MDR conveyor, it is important because it enables a simpler, more efficient power distribution scheme than does a BDLR system.

The MDR concept is one of small power supplies and motors distributed at appropriate intervals in a modular fashion rather than large, power-hungry motors driving longer fixed spans of conveyor. MDR power supplies are situated near the rollers they are driving. The lead length from any given DC power supply to the destination at the roller terminals is short; typically ten feet or less. This minimizes losses (the voltage drop that occurs when currents flow through the wire's resistance) between the supply and the rollers. Even when maximum current is being drawn, there is ample voltage at the rollers' input terminal to do the job.

- Build sufficient margin when design power distribution

The rollers in an MDR system are sometimes described as "micro-horsepower rollers." A quick comparison against the AC motor counterpart explains why. The five horsepower rating of a typical AC conveyor motor is equivalent to 3730 watts of power. MDR motors run on 24 VDC and deliver 22W or 35W of motive power, depending on the model (Note: the balance of this discussion applies to the 22W models but the same principles hold true for the 35W units).

Holjeron 22W motors are current-limited to 2 amperes of current, nominal. Turn-on surges exceed this value but are brief enough not to trigger the motor's internal current-limiting circuitry under normal circumstances.

Knowing the nominal current (2 amps per powered roller) that will be required of the DC power supply, selecting a supply is straightforward. A typical MDR conveyor configuration might use, for example, standard 1.9 rollers set on 3 spacing. This "typical" conveyor uses groups of eight rollers—one motorized roller driving seven unpowered "idlers." Five of these eight-roller "zones" equate to a 10' modular section.

Now, each of the motorized rollers draws a maximum of 2 amps of current when running normally. By assuming that this amount of current is drawn 100% of the time, you are building in a very comfortable operating margin. We will see why in a moment.

Simple arithmetic tells us that the five motors in the modular section will need no more than 10 amps of current. Therefore a proven 24V, 20A DC industrial-quality power supply such as the Mean Well SP500 will drive not just one, but two full ten-foot sections of the conveyor. By placing the supply at the point where the two sections join, no DC power cable need be longer than ten feet.

It is important to note that Holjeron ZoneLink™ systems operate on a floating DC signaling network. Signaling reliability can suffer when adjacent zones powered by different power supplies are not operating from a common ground reference. Therefore it is essential to connect the ground leads of any two adjacent power supplies to a common ground point as shown in Figure 9.

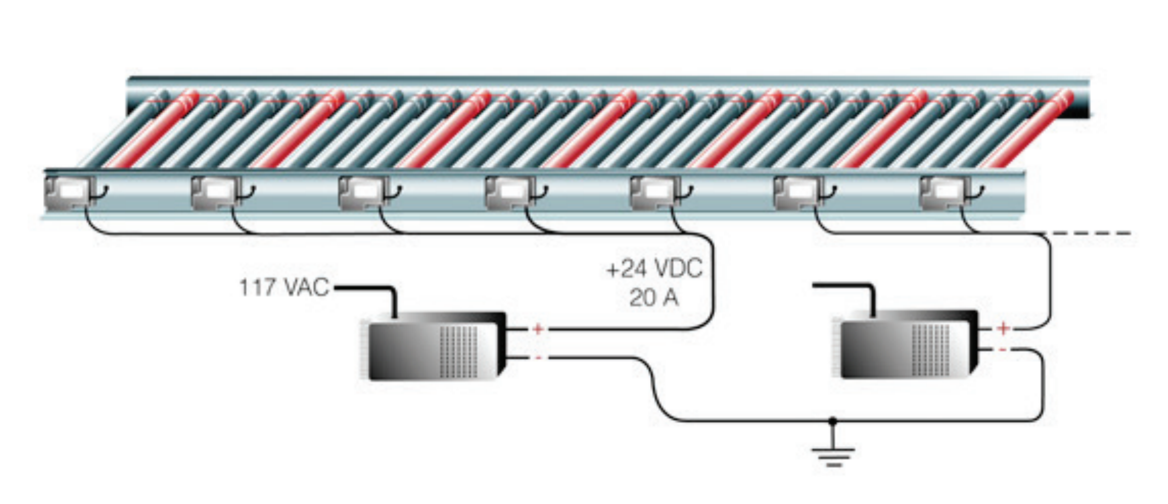

Figure 9 Typical MDR Power Distribution

Although wiring should be specified and completed by a certified technician, experience has taught us that solid wire may have a tendency to break in vibratory environments, such as a roller conveyor. Braided wire is usually preferred.

It is common industrial practice to over-design power supplies to preclude overloads in "worst-case" situations. By these standards, the power supply shown in Figure 9 would seem to be inadequate. Can its 20A current capacity really handle the 20A demand of ten motorized rollers?

Absolutely! Because of the on again, off again operation of the rollers, there is essentially no time during which all ten rollers are running and pulling 2A of current a piece. By definition, indexing in adjacent zones is a serial sequence, with one roller running, then the next, then the next, and so on. There may be some overlap between rollers several zones apart, but the reality is that the power supply never sees a full 20A load. Yet the design equation accounts for rollers running full-time. The 100% assumption provides ample protection against the dreaded worst case.

It is worth noting, too, that MDR rollers at rest are rollers that aren't heating up. In fact, they tend to cool off between operational cycles. As a result, there is less environmental heat produced, and less heat-induced stress on the machinery.

Tangible Cost Savings

As the foregoing discussions demonstrate, MDR power distribution and installation is less elaborate and expensive than the BDLR alternative. Day-to-day cost savings can be substantial as well.

The anecdote earlier in this primer is a fictional but not improbable look into the world of MDR conveyors. Remember, BDLR conveyor motors and the rotating elements attached to them run constantly, whether there is product in the zones or not. MDR conveyors run only when a sensor or controller tells them an item is present and needs to be indexed into the next zone. All the rest of the time—50%, 70%, or even 90% of the time—the MDR motors are at rest, consuming little power.

Some MDR users report a savings of 50% or more in the cost of electrical power to drive their conveyors. The United States Postal Service reconfigured the 11,000-ft. conveyor in one of its large regional processing centers in part to achieve savings of expected to reach $60,000 per year in electrical costs alone[3]. And these are savings that accrue year after year, joining other MDR economies in maintenance and operation.

Elsewhere in the MDR architecture, we have seen how diagnostic elements and indicators can alert operators to impending problems in the motors and controllers. Power supplies, too, have acquired diagnostic capability. Some full-featured 24V supplies have on-board indicator lights to call attention to low-voltage conditions and potential causes. Moreover, these smart supplies can be connected to the PLC to provide real-time information about the supply's status and fault history. Together, these diagnostic features can forestall problems and save troubleshooting time on the line.

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[3] "USPS Ups Efficiency With 'Smart' Conveyor Controls," Packaging World magazine, October, 1997.

Basic Control of 24V BLDC Motor-Driven Rollers

Abstract: This section provides a quick overview of the electro-mechanical interaction that powers a BLDC conveyor zone. An in-depth discussion of conveyor control commences in the next section.

Control Logic Drives 24V BLDC Motor-Driven Rollers

In Section 1, we discussed the torque and speed requirements that determine the selection of an appropriate roller configuration. Whatever their power and torque ratings, most industry-standard BLDC motor-driven rollers operate on 24V DC power, and this power is delivered to the roller motors by "driver" modules. At the heart of this driver is a group of MOSFET power transistors that deliver the required current to the motor winding when told to do so. In effect, the MOSFET is a switch whose Off/On state depends on the BLDC control logic, which in turn receives its instructions from an external controller.

- 24V BLDC MDR have no brushes to replace
- Uses a computer chip to commutate the motor
- A feedback loop keeps the motor speed stable

The external controller sends out the Run and Direction commands and accepts Fault notifications from the motor. It also accepts sensor signals from the conveyor line itself—separately connected signals that indicate whether material is within the zone associated with the motorized roller.

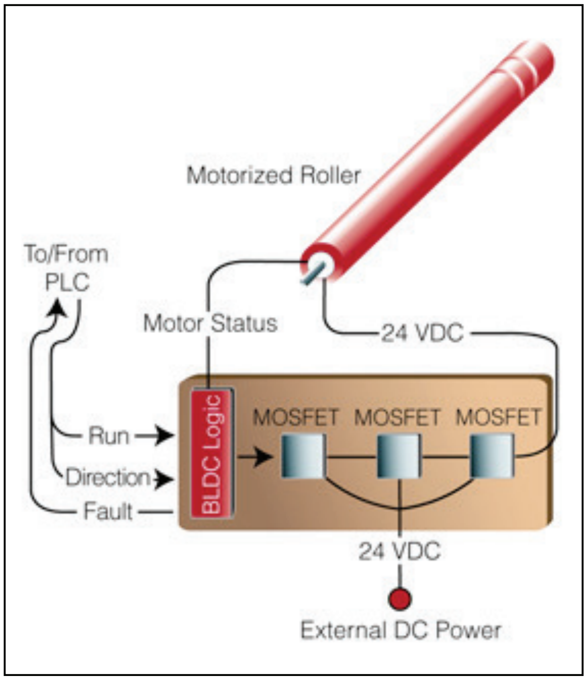

Figure 10 A basic MDR driver scheme

As shown in Figure 10, the most basic BLDC motors use three windings situated 120 degrees apart in phase. This is known as a "star" configuration. Within the motor, sensors (usually Hall-Effect devices) detect the angular position of the rotor and send pulses to the external driver accordingly. Inside the driver, a logic circuit detects the actual rotor position and causes the MOSFET power transistors to respond by sending current to the motor. This occurs in a timed sequence that keeps the rotor spinning.

The amount of current supplied to the motor is not constant; it is apportioned by a current controller to keep the motor's *speed* stable. A comparator circuit constantly checks the speed values provided by the logic circuit to ensure that the speed of rotation remains within its programmed range.

What is a Zone?

A conveyor "zone" consists of a motor-driven roller, a BLDC driver and at least one sensor. Typically, the motor-driven roller transfers power via round urethane belts to idler rollers ranging in number from seven to about eleven. The sensor defines the end of the zone. This, the simplest zone configuration, is depicted in Figure 11.

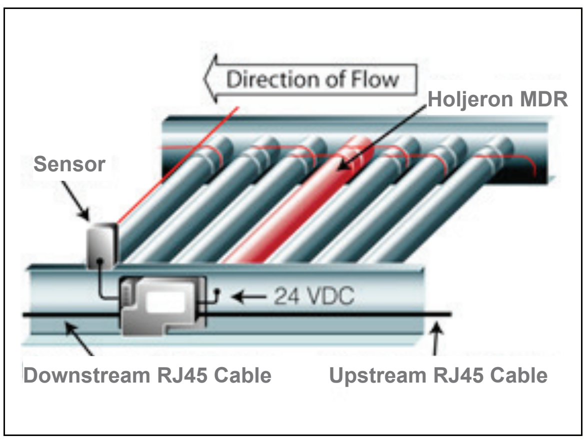

Figure 11 A simple straight-through zone configurations

A more complex form of zone is used for merges and/or transfers. There is a more sophisticated interaction among the controls and between controls and rollers. As shown in Figure 12, a transfer involves either indexing an item to the primary branch or activating an output that operates a lifting mechanism prior to indexing the item at an angle down a secondary branch.

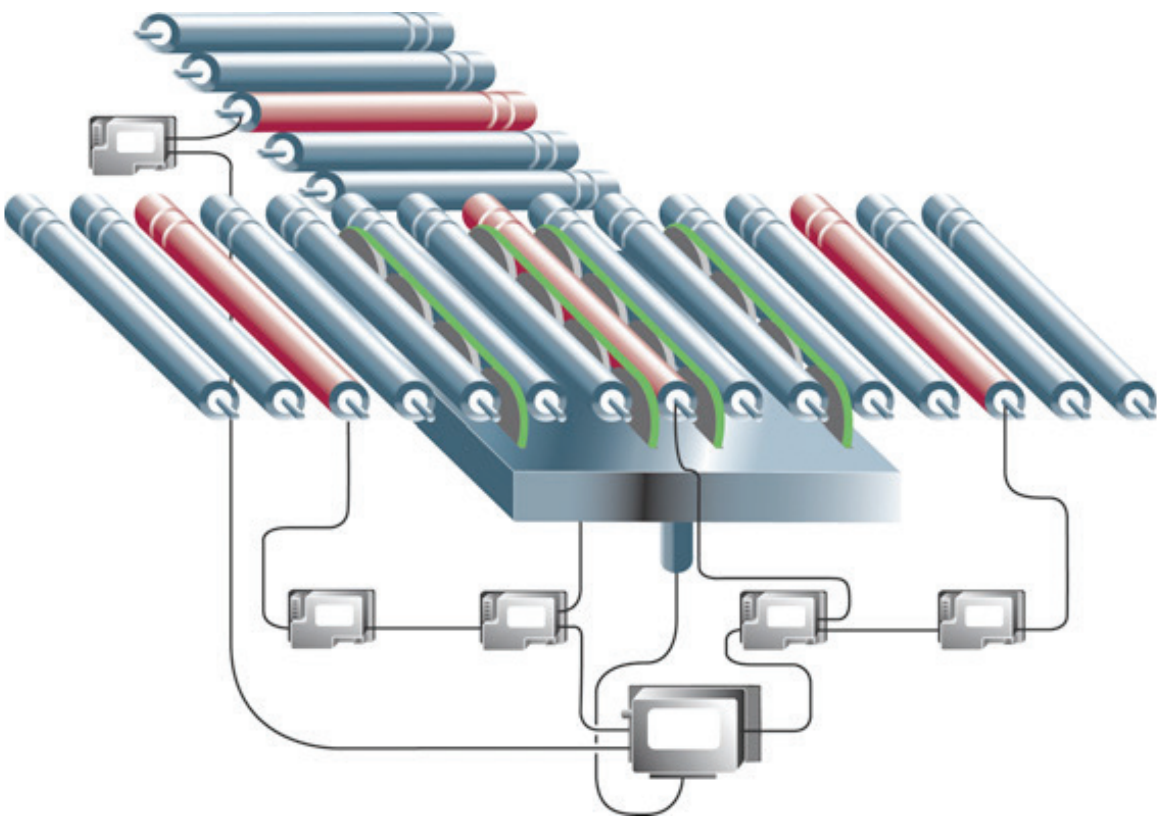

Figure 12 Basic right angle transfer

Control Networks

Abstract: Conveyor control has advanced tremendously in recent years thanks to the ubiquitous PC as well as the smarter, smaller, and more integrated silicon devices used as operating elements. This Controls section begins with an overview of enterprise-wide command and control architectures and goes on to examine the varied schemes (including distributed-intelligence approaches) used to control individual conveyor elements.

Trends in Material Handling Controls

- New technologies can distribute the computing power of the PLC to the conveyor rail

Figure 13 illustrates the plant-wide architecture prevalent in most enterprises. At the top tier, enterprise applications are gathering more real-time data and delivering information to support departments that have nothing to do with manufacturing or warehousing. The enterprise servers can be accessed by the accounting department, the CEO's office, facilities, marketing, or any other authorized corporate entity. For example, the application receives real-time confirmation from the System level via Ethernet that a particular carton, for example has been indexed all the way to the shipping dock. The Accounts Receivable process issues an invoice and the inventory system is informed that stock has been consumed.

The System tier intervenes between the Enterprise and Machine Control levels. It tracks cartons by means of RFID tags or bar codes. It is the system-level entity that directly controls the activities of the conveyor. In many installations, banks of PLCs still play the dominant role in controlling the conveyor's local drivers and mechanical elements. But that role is changing as new technologies emerge to share the workload.

The Machine Control level, in its basic form, drives the conveyor directly by means of voltages and currents sent to valves, actuators, diverters, and/or motors. It is here and in the actual conveyor mechanics that the most significant improvements in performance and capability are being applied.

In most conveyor environments, the boundaries of the Enterprise, System, and Machine Control levels are not as clear as Figure 13 implies. There may be overlaps and even redundancy among the levels. It is sometimes difficult to distinguish where one network begins and the others end. Conveyor vendors and integrators often differentiate their products by cultivating some technical advantage in just one of the three layers. These "advantages" sometimes come at the expense of truly seamless integration.

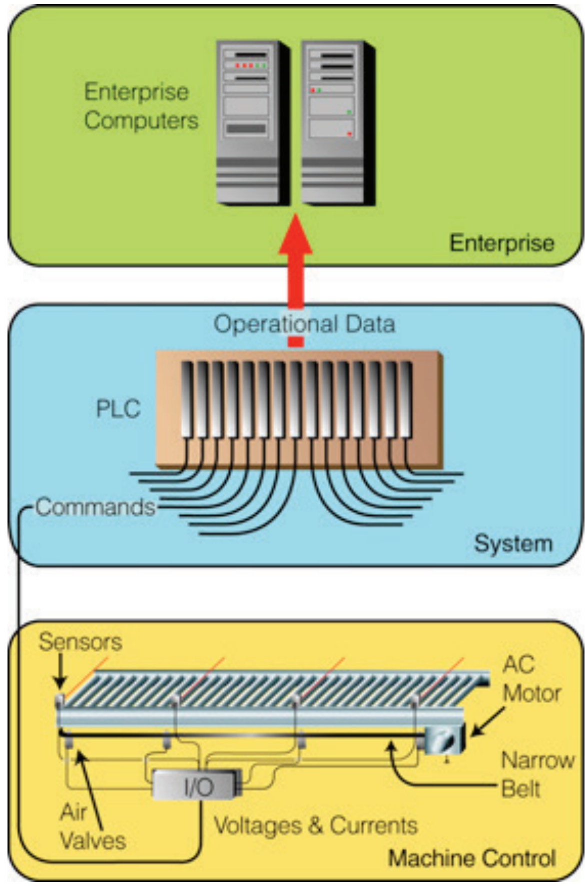

Figure 13 Industrial Control Hierarchy

In an AC-motor-powered BDLR system, it is complex and difficult to implement an ideal top-down architecture. Among other issues, it requires a huge number of ancillary sensors just to track items moving down the line. The PLC must receive confirmation (provided by a sensor such as a photo-electric eye) of a particular carton's progress through every zone. In addition, every operation beyond a straightforward index step requires actuating an array of air valves to control barriers, push thrusters, engage belts, etc.

Many conveyors in operation today still rely on control architectures that were designed for BDLR systems: centralized AC motors and discrete PLC channels connected to individual air valves, diverters, mergers, and sensors. These established implementations are complex and often unable to take advantage of developments in system monitoring and diagnostic techniques that can improve reliability and reduce cost. But there are some trends, both evolutionary and revolutionary, that are creating an environment that fosters higher efficiency and productivity.

For decades, the PLC has been the focal point of conveyor operation. The PLC, usually located remotely from the operating elements of the conveyor, is responsible for everything from controlling the basic indexing to interpreting (and acting on) data from bar code readers. The operational "intelligence" for the entire conveyor system resides within banks of PLCs and I/O cards.

It is certainly a workable scheme but it requires many PLCs, I/O cards and many connections and cables to control a substantial conveyor system. Custom "ladder logic" code must be written for every single operation and all foreseen variants thereof. Error handling must be planned. Coordination among disparate PLCs must be programmed.

The growing use of the BLDC approach with its motor-driven rollers and associated technologies is changing this scenario. The BLDC architecture is far more adaptable to modern monitoring techniques as well as item tracking. In addition, the motors can deliver status information, including throughput, faults, and even energy consumption to the higher tiers in the enterprise-wide system.

- Distributed, intelligent controls feed can feed operational data back to the Enterprise Network
- Holjeron controls and drivers reduce field wiring cost and complexity

But even in a BLDC system, this detailed level of control and monitoring can be hampered by cost of installing and programming the PLC resources to keep a constant watch on every single function and error indication. Ultimately, the problem lies in the complexity of implementing the system tier. There is too much reliance on the remote PLC and not enough independent "intelligence" distributed where the work is done—on the conveyor itself.

This brings us to another trend that stems from the use of motor-driven roller conveyor technology: the merging of functions from the System and Machine Control layers. Local driver and control modules are getting smarter, incorporating many of the decision-making steps formerly left to the PLC alone. This level of distributed intelligence, pioneered by Holjeron Corp. products, is the benchmark for conveyor efficiency.

These trends add up to a continuum in which conveyor operation becomes part of the institution's "big picture" encompassing costs, revenues, inventory, and operations. Theoretically the Enterprise can know not only the location of individual cartons on the conveyor, but also about a failing motor and when it may need to be replaced.

The balance of this Controls section will be devoted to explaining the distributed intelligence technologies that are enabling this transition toward enterprise integration.

The PLC communicates with driver modules and line sensors by means of cables running from the PLC itself to each module. A driver that can interpret certain basic commands (thanks to its internal logic) can take some of the processing load off of the PLC. This is the first step toward merging the System and Machine Control layers. Even this simple driver can boost system capacity and throughput and reduce cost with its economical use of PLC "bandwidth."

A Generation of Smarter Drivers

Section 3 discussed basic commutation employed by a BLDC driver. Some types of driver modules have acquired additional features that provide even tighter coupling with other elements above them in the control hierarchy. These features are made possible by a built-in microcontroller that replaces the BLDC interface component. The Holjeron

ZoneLink™ Series drivers, for example, apply the ".S" communications protocol to the driver module[4]. The modules in this series offer direct connections for the conveyor sensors and the rollers, as well as expanded fault monitoring and optionally, inputs and outputs for local manual control and braking.

Thanks to the enhanced internal motor monitoring, these drivers can perform highly accurate closed-loop speed control. The rotor speed is sampled 100 times per second and the results sent to the driver module. Speed corrections, if needed, are almost instantaneous within this self-contained loop. Thus, the conveyor's speed can be maintained with exceptional stability. The microcontroller also brings with it current monitoring and other tools to support predictive diagnostics.

With the advent of .S drivers, the concept of distributed intelligence really begins to pay off. With their ability to independently accept and respond to sensor signals while powering the roller itself, they dramatically simplify the interconnection between the conveyor and the PLC. Long cable runs to the sensors (and the processing load they represent), are eliminated. And more detailed diagnostic information is readily available.

Local Controller Manages Multiple Drivers

The efficiency of the .S drivers can be multiplied by adding a local controller that adds intelligence to monitor and control four drivers and interacts with a remote host. This scheme is shown in Figure 14.

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[4] For more information about the .S protocol, see Appendix 4.

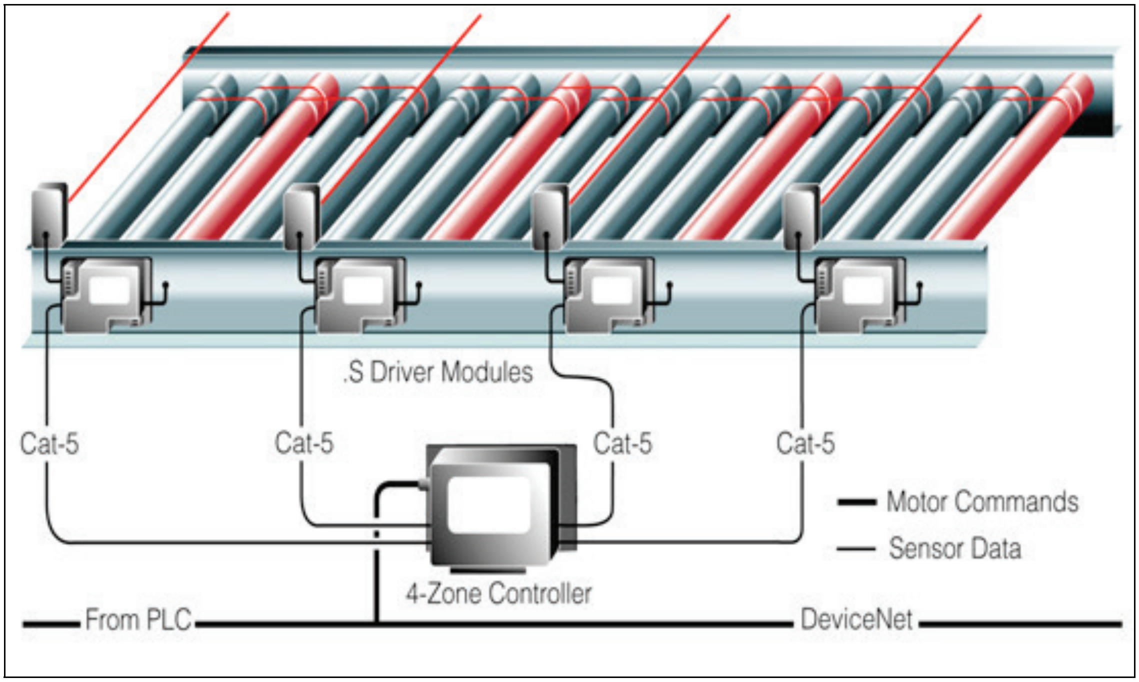


Figure 14 Supervisory Control of MDR Conveyor

Take particular note of the cabling from the driver to the DeviceNet[5] node. At this point we have eliminated all but one cable, supporting 3 outputs for run speed, bypass speed and direction and 2 inputs from the sensor and the fault line as well as power and ground for the motor power (there is an 8th line for carrying serial .S commands.) Gone is the complex harness of cables, or the "home run" between the PLC and individual driver modules. The one remaining cable is a common Cat-5 type, easily installed with snap-in fittings.

The Four-Zone Controller makes it possible to oversee the mechanics of more complex conveyor operations without intervention from the PLC. The controller can manage pressure accumulation, merges, diverts, and more. Working interactively with the ZoneLink™ .S driver module, the controller conveys predictive diagnostic information and fault notifications to the host. This includes warnings (derived from the speed, heat and current measurements) about impending roller failures. What's critical about this diagnostic process is that it too uses the controller's internal compute power to manage fault information. Rather than sending continuous status readings to the PLC and letting the PLC sort out the results, the Four-Zone Controller sends only the qualified diagnostic/fault data. This is another example of distributed intelligence used to reduce the burden on the System layer.

[5] For more information about DeviceNet, see Appendix 5.

The Four-Zone Controller also enables the conveyor speed to be set remotely from the central host, and it permits zone configuration from the host.

- Holjeron controls and drivers enable setting speed remotely
- Holjeron controls enable zero pressure accumulation and merge/divert/transfer control with no PLC programming required
- ZPA optimizes throughput without losses from collisions

A Simple Solution for ZPA

Zero Pressure Accumulation (ZPA) has been an elusive ideal in conveyor systems for years. It is a hurdle that has only recently been crossed—and again, distributed intelligence has made the achievement possible. Before we look at solutions available to implement ZPA, it's important to understand the background of the concept.

Accumulation and "Pressure"

The reason for installing a conveyor is to transport items from one processing point to another. In manufacturing, products are progressively assembled, tested and inspected at work stations at intervals along the conveyor. In warehouses and distribution centers, merchandise moves from pick locations to packing or shipping points. There are varying speed requirements as items travel among process points with differing throughput rates. An inspection step might take 15 seconds, while the packaging step that follows it takes a full minute. This points toward the need to manage *accumulation*—the backups and gaps, both intentional and unintentional, in the flow of the product – to optimize throughput and "balance" the line.

In a hypothetical passive conveyor system with no control over accumulation, everything on the conveyor line would have to travel at the speed of the slowest process to avoid backups and collisions. The slow workstations would pace the entire line, while fast workstations wouldn't receive merchandise soon enough to keep busy. An impractical approach, and a recipe for low productivity.

Zero Pressure Accumulation is the answer. ZPA means simply that the movement of items on the conveyor is controlled such that some minimum spacing is maintained under all circumstances. An item doesn't advance until the zone ahead is clear. The speed of the line and the throughput of the workstations along its span are among the factors that determine when a package moves to the next zone. There may be backups (accumulation), but these are intentional and controlled. There are no collisions.

Older conveyor implementations rely on pneumatically actuated barriers to stop items on the conveyor before they collide with those ahead of them. A sensor monitors the zone ahead and relays the information to the remote PLC, which raises the barrier accordingly. It is a workable scheme, but one that relies on noisy, complex mechanical operations.

And incidentally, there is nothing to prevent the merchandise from colliding with the barrier.

Motorized roller technology has changed all this. The responsiveness of motorized rollers makes it possible to move or halt conveyor-borne merchandise in fractions of a second, without barriers or buffers. However, the success of the ZPA implementation depends as much on the control elements as on the motors.

- No programming is required. However, operations can be configured to the environment. Set speed, ZPA mode as well as accumulation timers to set gaps and insure items completely index downstream.
- Holjeron ZPA warns of jams with configurable jam timers

There are two proven approaches to implement ZPA through distributed intelligence. The first uses the four-zone controller and .S modules already discussed. The controller has all the logic needed to support ZPA decision-making within its zones. Via DeviceNet, it connects to the PLC, which manages all of the four-zone controllers in the line. The node-to-node handshake is two simple lines of ladder logic. There is no requirement for a hardwired interface. The result is a tightly integrated ZPA scheme across the conveyor's full length with little interaction from the PLC.

Managing Pressure Accumulation without a PLC

There is a class of independent ZPA-capable drivers available. An example of such a module is the Holjeron ZL3.S-AH121, which is designed to control 22-watt rollers. Like the more basic driver modules, the ZPA module connects directly to the roller and supplies power by means of a MOSFET device and the commutation logic with a microprocessor. However, its microprocessor and logic are sophisticated enough to carry out flow management operations that would otherwise require a PLC.

The ZPA driver module implements ZPA through several user-selected modes:

- Singulation—individual items on the conveyor are deliberately separated, creating an intentional gap of one or more zones.
- High-throughput singulation – increase throughput with zero pressure accumulation but creating gap widths of less than one zone
- Train – release all items in the queue simultaneously
- Slave—two zone motors are synchronized to execute the same operations—start, stop—at the exact same time, permitting longer items to be transported

Each ZPA driver module knows about its connected companions on the conveyor line. Configurable parameters allow each serially-connected module to react to conditions observed upstream or downstream[6]. For example, the Jam Timer will cause the zone to stop and indicate a fault when a downstream sensor is blocked for a duration exceeding the programmed time value. Other configurable parameters include Transfer Timer, Sleep Timer, and Jam Timer as well as operating speed and acceleration or deceleration rates.

The entire array of ZPA driver modules operates independently of PLCs and other enterprise networking applications. However, it can be connected to an external PC by means of a serial interface component designed for the purpose. Connected via a USB the PC can be used to:

- Monitor motor diagnostics that predict early motor failure.
- Monitor motor current and temperature.
- Set individual zone speed and accumulation timers, including gap time and release time.

The ZPA module architecture confers many benefits on a conveyor system. One of the most significant is its efficient use of overall conveyor control capacity. Full-featured ZPA modules like the ZL3.S-AH122 liberate the conveyor from the PLC, distributing the ZPA intelligence over the entire system. The conveyor acts at its own discretion based on the loading and the programmed settings.

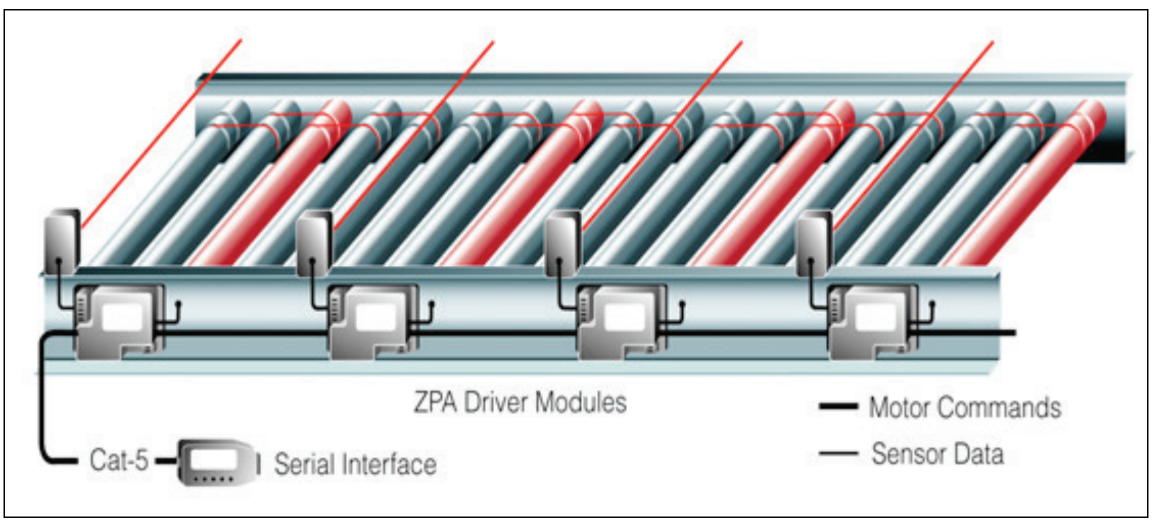


Figure 15 Stand-alone Zero Pressure Accumulation Control

[6] "Upstream" is taken to mean earlier in time; that is, in a zone the product must pass through before reaching the current zone.

“Rolling Up” the Operational Data

As explained earlier in this primer, there is a growing emphasis industry-wide to share information across the breadth and depth an enterprise. The acceptance of smart controllers and drivers, plus the use of motor-driven roller drivers that supply a stream of data about their status, is evidence of this trend. End-users are monitoring and measuring more points in their conveyor systems, tracking variables from energy use to motor speed. And they are relying on smart local controllers to help them verify, for example, quantities of individual products reaching the end of the conveyor line. Armed with this information, procurement can ensure that parts inventories don’t dip below specified levels.

Thanks to predictive diagnostic information from BLDC rollers and smart controllers, long-term conveyor performance is more stable. Early warnings such as over-current indications can be databased and tracked at the enterprise level, making it possible to schedule timely maintenance and prevent disastrous line shutdowns. Problem areas (such as overloaded zones) are easier to spot, analyze, and correct.

Could this be done without motorized rollers and smart controllers? Perhaps. But the job would require vast PLC resources and untold man-hours spent programming, debugging, connecting and maintaining the systems.

BLDC systems offer the real-time monitoring and the controllability to make the enterprise-wide information sharing a practical reality.

Maintenance and Operation

Abstract: Conveyor operation is moving from a discipline involving hands-on work with wrenches and screwdrivers to one of remote control and monitoring. Maintenance is moving from preventive replacement to predictive diagnostics. This section will explain how BLDC technology is accomplishing these necessary transformations.

Maintain, Monitor, Modify

In day-in, day-out operation a newly installed conveyor system is put to the test. The wisdom of one's platform choice (BDLR or MDR) becomes clear as the "actuals" of throughput and downtime begin to accrue. Productivity forecasts stand or fall based on real statistics about traffic, capacity, and efficiency. Up-front capital and installation costs are paid off and the real costs of ownership become apparent.

Functions such as preventive maintenance, on-site modifications and repair, and performance monitoring and control fall under the general heading of "operations." These activities set the pace of cost and efficiency in conveyor operation. In this section we will see how these disciplines play a role in the effectiveness of various types of conveyor systems.

- 24V BLDC MDR conveyors need little preventative maintenance
- Should unscheduled maintenance be required, an MDR can be changed within minutes, often without disrupting the flow of material.
- MDR conveyor's inherent modularity is flexible enough to quickly adapt to layout changes.
- Microprocessor-based BLDC drivers can download a system-wide speed value, enhancing ability to implement and tune a conveyor for optimal throughput.
- Microprocessor-based drivers can monitor motor operating parameters and predict impending motor failure, reducing unplanned downtime.

BDLR Maintenance and Operation: Lube, Oil, Filter

A BDLR or line shaft roller (LSR) conveyor system is often the platform of choice when substantial transport length is required. The basic mechanics of AC motors, belts, pulleys, actuators, and passive rollers are well proven in such applications, and a vast body of experience exists to serve the needs of the conveyor.

A large conveyor BDLR or LSR installation requires the skills of several trades to maintain and repair it and oversee its operation. Electricians are on hand for the installation phase, and are of course called in when a motor or solenoid fails. But more frequently the conveyor needs the services of a mechanic.

Routine maintenance tasks include belt maintenance, where tension and wear must be checked regularly. Spring-loaded tensioners are placed at periodic intervals along the belt, and these must be adjusted to ensure uniform contact and pressure between belt and rollers. The belt itself must be monitored for wear, particularly in environments with high temperatures or other hostile conditions.

Frequent lubrication of elements such as transfer chains (between the motor and the belt or shaft) and gears is also necessary. This may require removal of safety housings, prolonging the time spent on the task.

In addition, hardware associated with pressure accumulation and other forms of traffic control in BDLR/LSR systems must be maintained. Typically, these mechanisms are air-actuated by a complex of valves connected to a central compressor. The compressed air system is yet another area of responsibility for the mechanics. They must troubleshoot valve problems, change filters in the air lines and repair any failures in the compressor itself.

It is usually possible to avoid service interruptions by carrying out routine preventive maintenance work during off hours, though not all applications permit that. But unscheduled maintenance and repair work is a problem for BDLR/LSR conveyors. Repairing the compressor, for instance, necessarily entails shutting down the whole conveyor. Even repairing a single valve can disable an entire section, which may stop upstream traffic. Similarly, a motor or gear failure is disastrous because it can affect a wide swath of the conveyor, potentially impacting traffic throughout the system.

The Simplest Approach to Preventive Maintenance

With respect to preventive maintenance (and its costs), MDR conveyors have a noteworthy advantage over their BDLR/LSR counterparts: *there is no regular preventive maintenance.* Once an MDR system is installed and its "speeds and feeds" set up, it is essentially maintenance-free. At most, the urethane bands connecting the motorized rollers to their idle companions may need to be replaced if they experience damage or stretching. An MDR conveyor is far less complex than a conveyor system based on centralized AC motors. There are no chains, external gear boxes, or belts, and no air valves or solenoids to control accumulation. The MDR carries out complex operations without the complex mechanisms of a BDLR/LSR conveyor. Only an overt failure inside a roller can stop the MDR conveyor. And the use of brushless DC motors, 25,000-hour bearings and self-contained, self-lubricating internal gearing minimizes this problem.

What if a roller does fail? Even this need not be a catastrophic issue. A roller fault affects only one zone; just a few feet of conveyor length. Many motorized rollers (including all those offered by Holjeron) have snap-in shafts and can be changed by one person in just a few minutes. Interruption of product traffic is so brief as to be insignificant. In fact, since only one zone is affected, it is often possible to move the merchandise ahead manually during the minute or two needed for repairs.

Change is Constant

In today's manufacturing, distribution, and warehousing enterprises, the only constant is change itself. New products emerge quickly, driving the need for new or modified conveyor layouts. Just-in-Time logistical practices make unpredictable demands on distributors and shippers. These trends, and many more, make flexibility an important consideration when choosing a conveyor platform.

One key contrast between BDLR/LSR and MDR conveyors is their differing ability to adapt to these realities. A BDLR/LSR installation is best suited for pure transport in stable manufacturing and warehousing applications in which the layout and throughput requirements are not expected to change. Its myriad connections between belts, shafts, and motors make it difficult to "pull up stakes" and move a conveyor. Not only the conveyor itself must be relocated, but also the electrical and compressed air infrastructure supporting it. Because the whole apparatus—the conveyor and its drive system—is bulkier, a large space must be available to receive it. These issues make moving a BDLR conveyor a costly job. Even the lesser task of adding on to an existing system is cumbersome when motor placement, electrical, and air requirements are considered. Modifying a BDLR conveyor system can take weeks.

MDR conveyors ease this burden by eliminating the belts, AC motors, and other hardware that must be relocated along with the BDLR conveyor. But early MDR systems presented some unique challenges of their own when it became necessary to move or enlarge a system, or even to change its FPM rate. In a large system with dozens or hundreds of powered rollers, the speed of each motor must be individually set to match that of all other motors in the system. Using a tachometer to monitor the speed, a mechanic must adjust "speed" controls (which are actually current controls) within each roller driver. Moreover, this speed setting tends to change under loading. A loaded roller (carrying, say, a 100-lb. box) may run slower than the unloaded speed set by the mechanic. This is because the current that determines the speed can change in response to the physical loading.

Fortunately, innovations in MDR control and motor architecture have addressed these issues and added important monitoring capabilities as well.

“Smart” Controllers, Drivers, and Rollers Stay in Touch with PLC

The availability of “smart” MDR and driver technology offers an opportunity to dramatically simplify the installation, maintenance, modification, and operation of conveyor systems.

As explained earlier, the installation of an MDR conveyor is straightforward, and the preventive maintenance requirement for these systems is effectively nil. And via DeviceNet or a basic serial computer interface (depending on the controller/driver arrangement), setting the speed and monitoring roller performance is elegantly simple.

In an earlier section we discussed various Holjeron driver/controller configurations. Using ZL.S-C411-D four-zone controllers with ZoneLink driver modules, it is possible to remotely set the motor speed throughout an entire conveyor system over the DeviceNet interface. Each set of four drivers is linked to a controller by a serial data connection. The controller has a unique DeviceNet address, and each driver is associated with a specific controller port as shown in Figure 16. Consequently, every single motorized roller can receive unique speed-setting data from the PLC.

ZoneLink ZPA modules have a similar capability. These too are serially linked, with a unique relative address associated with each module. Using a common USB serial data port and ZoneLink interface module, speed commands can be sent to any roller or group thereof.

While a detailed programming explanation is beyond the scope of this document, suffice to say that integrators and end-users can now create efficient software templates for centralized speed control, eliminating the tedious tachometer methods of the past. At last, setting and matching zone-to-zone speeds is as effortless in an MDR system as it is in a BDLR conveyor. Roller speed for a given motor speed depends on the reduction ratio of the planetary gear. See Appendix 4 for more data.

The pairing of Holjeron driver modules and motorized rollers offers true speed control. The motor’s actual speed is sampled constantly (20,000 times per second)

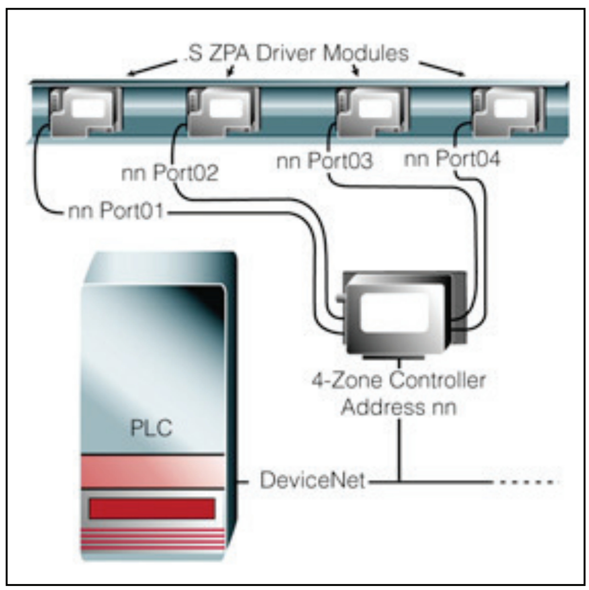


Figure 16 Every driver/roller set has a unique addressable location via DeviceNet and the 4-zone controller module

and corrections are made based on this reading. Contrast this with a fixed current setting that has no way to respond to loading on the roller. While the Holjeron motor's speed is also dependent on current, that value is adjusted in real time based on the observed RPM of the motor. When the motor is under load, more current is made available to sustain the programmed speed. It is a closed-loop PID (Proportional-Integral-Derivative) technique that delivers a steady FPM rate under all normal conditions.

Motor-Driven Roller Helps Computer Giant Reduce Overhead

At a Manufacturing Technologies conference last year, an engineer from a U.S.-based computer/software giant discussed the company's success following the installation of Motor-Driven Roller Conveyors from Holjeron. According to the speaker, the conveyors equipped with MDRs had an initial cost 10% higher than line shaft or live roller belt conveyors. However, due to substantially lower annual labor cost and maintenance fees (a result of fewer overall replacement parts), they were able to get a return on investment in three years.

"If you look at the initial cost, MDR is about 10% more than competing technologies, including the implementation time," he said. "But when you look at the savings in maintenance costs, power consumption, and the flexibility to easily reconfigure the conveyor, we can see a net return on investment in just three years."

According to the speaker's calculations, his company saves $252,000 for 15,000 feet of conveyor in labor costs/year, and $345,000 for the same length in maintenance costs/year when compared with both line shaft and liver roller belt models.

During his presentation, the engineer also discussed the conveyor systems ease of design. At his facility, he said the conveyors make efficient use of space. The motors operate within the frame envelope, allowing tighter conveyor stacking where needed. All power, controls, and compressed air fit within the frame envelope as well. He said the conveyors are ideal for small shop situations, for space reasons, but also because the system runs on lower power consumption (110 VAC to 24 VDC).

"[The conveyor] lends to modular design," he said. "Beds can be modified quickly, and transfers, diverts, and other accessories can be field retrofitted in less time than other types of driven conveyor systems."

Too, because the conveyors only run when required to move material, there is lower overall noise operation. He said that 45 DB and under can be achieved with the precision slave rollers, or rollers that are dependant on product being transported.

For future materials handling needs, the company is looking forward to blending its current system with Computerized Maintenance Management System (CMMS).

"Predictive Failure Tools can blend with SCADA Factory systems and CMMS," he said. "This enables a truly Proactive Maintenance system for conveyor systems."

Spotting Failures Before They Occur

But suppose the conditions aren't normal. Not all faults are hard failures that can be spotted at a glance. Sometimes motors stall, then recover and resume after cooling off for a few moments. Or they simply slow down when they hit current limits too often. Intermittent problems like this are insidious because they can slow traffic, yet are very difficult to detect. The failing roller might cause longer wait times and accumulation queues, slowing the traffic upstream in the conveyor system. The change is hard to spot visually, especially in conveyor sections that are not manned. But the slowdown reveals itself in the monthly productivity reports.

In almost every MDR conveyor system, the motorized rollers have internal thermistors that light up an LED on the driver module when heat builds up inside the roller motor. Of course, this scheme requires constant visual monitoring and has no way to record the frequency with which the offending conditions occur. Did that over-temp condition happen just once, or a fifty times in the last hour? Knowing that information can make the difference between replacing a roller and simply watching it a little more closely.

This is the kind of situation where the smart roller/controller scheme really pays off. The Holjeron ZoneLink™ module records events such as current limit, various warnings, stops (stalls), and more. In total there are 12 different fault and warning indications that are tracked. Again, the data can be easily associated with individual drivers and rollers. The information remains available in the controller module until it is read by software commands from the central PLC. Because the data requirements are user- and application-specific, software implementation of the readback and interpretation commands is the responsibility of the integrator or end-user.

The ZoneLink scheme makes it possible to track system performance in real-time and equally important, it enables a rigorous program of predictive maintenance. Note the difference between the words "preventive" and "predictive." Preventive maintenance (as in a BDLR system) often strives to forestall problems by replacing parts after a nominal service life, even if they are still working perfectly. Predictive maintenance measures the actual behavior of system components and only calls for replacement when there is a measurable change in performance. The savings in parts costs and time can easily offset the up-front costs of planning and programming the system.

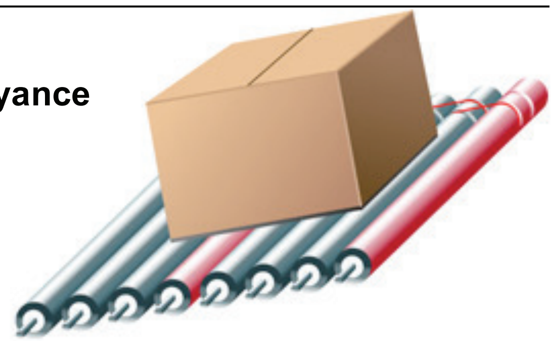
Appendix 1: Specifying Holjeron MDRs

1-1 Torque Calculation

Typical Coefficients of Rolling Friction for 1.9" Roller

	WORK	Steel	Plastic	Wood	Corrugated
TUBE	Steel	0.02	0.04	0.05	0.1
	PVC Coating	0.02	0.04	0.05	0.15
	Kastalon Sleeve	0.02	0.04	0.05	0.15
	Sleeve Urethane	0.03	0.04	0.06	0.15
	Molded Urethane	0.02	0.04	0.05	0.15

Tangential Force Required for Conveyance



(STEP 1) Enter the number of rollers, including the motor-driven Microroller, in the zone.

Number of Rollers in Zone: 10
Incline in Degrees: 0 (deg)

(STEP 2) Enter the angle of the incline up which the item is being conveyed. Use a negative angle on a decline. If there is no incline, enter 0.

W_{lbs}	x	$Efr_{coefficient\ of\ friction}$	=	$F_{tangential\ force}$	=	$Torque_{in/lbs}$
70	x	0.04	=	2.8	=	2.7

(NOTE)
Tangential force x Radius = Torque

Diameter = 1.9
Radius = 0.95

(STEP 3) Enter maximum potential weight of item being conveyed. Include weight of pallet if applicable.

(STEP 4) Enter coefficient of friction based on both materials being used for both roller and item being conveyed.

(STEP 5) Enter the diameter of the roller to be used for conveyance. If lagging is used, include overall diameter.

Guidelines to Be Considered for Determination of Safety Factors

1.5x safety factor to be applied to all minimum tangential force / torque requirements
2.0x safety factor to be applied to all minimum tangential force / torque requirements (IF)
- (IF) speed is critical
- (IF) application may be subject to loading in excess of design parameters
- (IF) only one roller is being used per zone

(NOTE) anticipated torque loss per idler: 2%

Minimum Tangential Force Required For Conveyance	3.1	(lbs)
Minimum Torque Required For Conveyance	2.9	(in/lbs)
Minimum Torque Required with Safety Factor 1.5	4.4	(in/lbs)
Minimum Torque Required with Safety Factor 2.0	5.8	(in/lbs)

1-2 Holjeron MDR Selection Table

					No Load Speed						Rated Speed																							
							18%		6%				18%		6%		Tangential ForceRated						Tangential ForceStarting						TorqueRated		TorqueStarting			
					1.9		2.24		2.38		1.9		2.24		2.38		(N)			(Lbs)			(N)			(Lbs)			(Nm)	(Inch Lbs)	(Nm)	(Inch Lbs)	Amp Draw	
		Gearbox		motor RPM	m/ min	fpm	m/ min	fpm	m/ min	fpm	m/ min	fpm	m/ min	fpm	m/ min	fpm	1.9	2.24	2.38	1.9	2.24	2.38	1.9	2.24	2.38	1.9	2.24	2.38	1.9 2.24 2.38	1.9 2.24 2.38	1.9 2.24 2.38	1.9 2.24 2.38	Rated	Starting
24VDC Brushless - 22W	PMR-AD-4	3 stage	low	600	1	5	2	5	2	6	1	4	1	5	2	5	298	254	239	67	57	54	679	578	545	153	130	123	7.2	64	16.4	145	0.6	5.5
			high	2400	5	18	6	21	7	22	5	16	6	19	6	21																	2.0	
	PMR-AD-5	3 stage	low	600	2	6	2	7	2	8	2	5	2	6	2	7	218	185	175	49	42	39	497	423	399	112	95	90	5.2	46	12.0	106	0.6	5.5
			high	2400	7	24	9	29	9	30	7	22	8	26	9	28																	2.0	
	PMR-AD-7	3 stage	low	600	3	9	3	11	4	12	2	8	3	9	3	10	146	124	117	33	28	26	334	284	268	75	64	60	3.5	31	8.1	72	0.6	5.5
			high	2400	11	36	13	43	14	46	10	33	12	39	13	42																	2.0	
	PMR-AD-10	2 stage	low	600	5	17	6	20	6	21	4	14	5	17	6	18	79	67	63	18	15	14	186	158	149	42	36	33	1.9	17	6.1	54	0.6	5.5
			high	2400	20	66	24	77	25	82	18	60	22	71	23	75																	2.0	
	PMR-AD-15	2 stage	low	600	6	20	7	24	8	25	5	17	6	21	7	22	67	57	53	15	13	12	152	129	122	34	29	27	1.6	14	3.6	32	0.6	5.5
			high	2400	24	80	29	94	30	100	22	73	26	86	28	92																	2.0	
	PMR-AD-20	2 stage	low	600	8	28	10	32	11	35	7	24	9	28	9	30	49	41	39	11	9	9	111	94	89	25	21	20	1.1	10	2.7	24	0.6	5.5
			high	2400	33	109	39	129	42	137	31	100	36	118	38	125																	2.0	
	PMR-AD-30	2 stage	low	600	10	33	12	39	13	42	9	29	10	34	11	37	40	34	32	9	8	7	91	77	73	20	17	16	0.9	8	2.2	19	0.6	5.5
			high	2400	41	134	48	157	51	167	37	122	44	144	46	152																	2.0	
	PMR-AD-40	1 stage	low	600	18	60	22	71	23	76	17	55	20	65	21	69	22	18	17	5	4	4	51	43	40	11	10	9	0.5	4	1.2	11	0.6	5.5
			high	2400	73	240	86	283	92	301	73	238	85	280	91	298																	2.0	
24VDC Brushless - 35W	PMR-AD-20AZAA	2 stage	low	1000	8	28	10	32	11	35	8	26	9	30	10	32	90	76	71	20	17	16	384	327	308	86	74	69	2.1	19	9.3	82	1.8	7.5
			high	3300	27	90	32	106	34	113	27	88	31	103	33	110																	3.0	
	PMR-AD-30AZAA	2 stage	low	1000	10	33	12	39	13	42	10	31	11	37	12	39	74	62	59	17	14	13	315	268	253	71	60	57	1.7	15	7.6	67	18	7.5
			high	3300	34	110	39	130	42	138	33	107	38	126	41	134																	3.0	
	PMR-AD-40AZAA	2 stage	low	1000	14	46	17	54	18	58	13	43	15	50	16	53	54	45	43	12	10	10	230	196	185	52	44	42	1.3	12	5.5	49	1.8	7.5
			high	3300	46	150	54	177	57	188	45	146	52	172	56	183																	3.0	
	PMR-AD-60AZAA	1 stage	low	1000	21	70	25	83	27	88	20	65	23	77	25	82	35	29	28	8	7	6	150	128	121	34	29	27	0.8	7	3.6	32	1.8	7.5
			high	3300	70	231	83	272	88	289	70	229	82	270	88	287																	3.0	
	PMR-AD-80AZAA	1 stage	low	1000	31	100	36	118	38	126	29	94	34	110	36	117	24	20	19	5	4	4	105	89	84	24	20	19	0.5	4	2.5	22	1.8	7.5
			high	3300	101	330	119	390	126	414	100	328	118	387	125	411																	3.0	

1-3 Minimum Roller Length Table

	Minimum roller length		Minimum roller length - standard single groove		Minimum roller length - standard 2 groove		Minimum roller length - brake		Minimum roller length - standard single groove with brake		Minimum roller length - standard 2 groove with brake		Minimum roller length - waterproof		Minimum roller length - standard single groove with water-proof		Minimum roller length - standard 2 groove with waterproof	
Shaft details	mm	inches	mm	inches	mm	inches	mm	inches	mm	inches	mm	inches	mm	inches	mm	inches	mm	inches
Spring Loaded Shaft	292	11.50	297	11.69	329	12.95	346	13.62	329	12.95	361	14.21	311	12.24	313	12.32	345	13.58
Non Spring Loaded Shaft	260	10.24					314	12.36					297	11.69				
Spring Loaded Shaft	317	12.48	323	12.72	355	13.98	371	14.61	377	14.84	409	16.10	336	13.23	339	13.35	371	14.61
Non Spring Loaded Shaft	285	11.22					339	13.35					322	12.68				
Spring Loaded Shaft	302	11.89	308	12.13	340	13.39	357	14.06	363	14.29	395	15.55	328	12.91	331	13.03	363	14.29
Non Spring Loaded Shaft	267	10.51					322	12.68					314	12.36				
Spring Loaded Shaft	327	12.87	333	13.11	365	14.37	382	15.04	388	15.28	420	16.54	346	13.62	349	13.74	381	15.00
Non Spring Loaded Shaft	295	11.61					350	13.78					332	13.07				
Spring Loaded Shaft	320	12.60	326	12.83	358	14.09	375	14.76	380	14.96	412	16.22	346	13.62	349	13.74	381	15.00
Non Spring Loaded Shaft	285	11.22					340	13.39					332	13.07				
Spring Loaded Shaft	347	13.66	353	13.90	385	15.16	402	15.83	407	16.02	439	17.28	366	14.41	369	14.53	401	15.79
Non Spring Loaded Shaft	315	12.40					370	14.57					352	13.86				
Spring Loaded Shaft	317	12.48	323	12.72	355	13.98												
Non Spring Loaded Shaft	285	11.22																
Spring Loaded Shaft	327	12.87	333	13.11	365	14.37												
Non Spring Loaded Shaft	295	11.61																
Spring Loaded Shaft	304	11.97	297	11.69	329	12.95	358	14.09	352	13.86	384	15.12	323	12.72	314	12.36	346	13.62
Non Spring Loaded Shaft	259	10.20					314	12.36					303	11.93				
Spring Loaded Shaft	329	12.95	323	12.72	355	13.98	383	15.08	377	14.84	409	16.10	348	13.70	340	13.39	372	14.65
Non Spring Loaded Shaft	284	11.18					339	13.35					328	12.91				
Spring Loaded Shaft	314	12.36	308	12.13	340	13.39	369	14.53	363	14.29	395	15.55	340	13.39	332	13.07	364	14.33
Non Spring Loaded Shaft	267	10.51					321	12.64					320	12.60				
Spring Loaded Shaft	339	13.35	333	13.11	365	14.37	394	15.51	388	15.28	420	16.54	358	14.09	350	13.78	382	15.04
Non Spring Loaded Shaft	295	11.61					349	13.74					338	13.31				
Spring Loaded Shaft	332	13.07	326	12.83	358	14.09	387	15.24	380	14.96	412	16.22	358	14.09	350	13.78	382	15.04
Non Spring Loaded Shaft	285	11.22					339	13.35					338	13.31				
Spring Loaded Shaft	359	14.13	353	13.90	385	15.16	414	16.30	407	16.02	439	17.28	378	14.88	370	14.57	402	15.83
Non Spring Loaded Shaft	315	12.40					369	14.53					358	14.09				
Spring Loaded Shaft	329	12.95	323	12.72	355	13.98												
Non Spring Loaded Shaft	284	11.18																
Spring Loaded Shaft	339	13.35	333	13.11	365	14.37												
Non Spring Loaded Shaft	295	11.61																

1-4 Maximum Weight per Holjeron MDR by Roller Length

	kg									
Diameter/Length	8"	10"	12"	16"	20"	24"	28"	32"	35"	40"
1.9"	0	75	70	60	50	40	35	30	25	20
2.24"	120	100	100	100	80	80	60	60	50	50
2.38"	190	160	160	160	130	130	100	100	80	80

2.2046

	LBS												
Diameter/Length	8"	10"	12"	16"	20"	24"	28"	32"	35"	40"	45"	50"	55"
1.9"	0	165	154	132	110	88	77	66	55	44	36	29	23
2.24"	265	220	220	220	176	176	132	132	110	110	91	80	70
2.38"	419	353	353	353	287	287	220	220	176	176	149	131	115

	LBS									
Diameter/Length	8" - VO	10" - VO	12" - VO	16" - VO	20" - VO	24" - VO	28" - VO	32" - VO	35" - VO	40" - VO
1.9"	0	109	102	87	73	58	51	44	36	29
2.24"	175	146	146	146	117	117	87	87	73	73
2.38"	277	233	233	233	190	190	146	146	117	117

NOTES:
In applications where the item being conveyed is dropped onto the Holjeron MDR, reduce the static load limits by 50%.

Appendix 2: Powered Roller Belts

Powered roller belts are also called motorized roller belts. They connect a motorized roller to a group of six to ten slave rollers, called a zone. Usually the motorized roller is in the center of the zone, but on inclines it is at the top end.

When selecting a belt, choose the one that will move your maximum box weight (shown below). Also note that four-groove rollers let you double box weights.

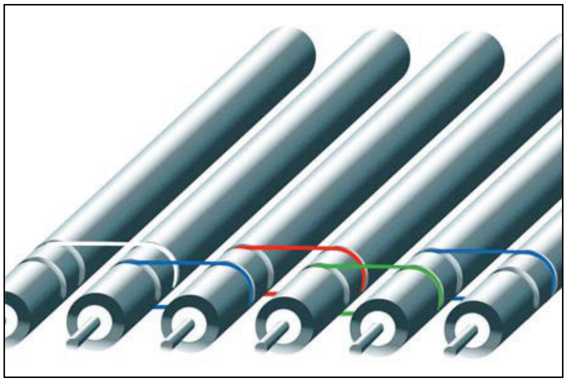


Figure 17 Various Powered Roller Belts

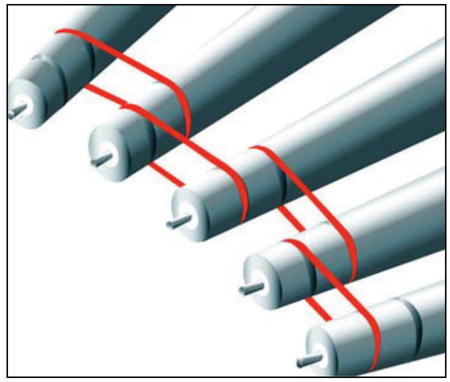


Figure 18 HT RED Belts on Curve

PMR-OR3 (for rollers on 3 centers) or PMR-OR4 (for rollers on 4 centers) - Standard 3/16 belt 83A Color: clear. For boxes up to 50 lbs (6 lbs/roller). Stretch: 14%.

Other belts can be available upon request. Examples:

Table 2 Round Urethane Belt Selection Table

Diameter	Durometer	Load
3/16	83A	6#/roller
3/16	85A	9#/roller
¼	85A	17#/roller

Belt Specifications

Belting Material Standard Thermoplastic Polyurethane (TPU)

Durometer 83A

Characteristics Food grade (FDA), excellent oil and abrasion resistance

Property	Test	Unit	83A
Best application			Low cost
Food grade, FDA approved (** also NSF approved for contact with drinking water)			Yes
Shore Hardness (durometer)	ASTM D 2240	"A" Scale	85 +-3
Ultimate Tensile Strength (force needed to break)	ASTM D 412	PSI**	7,000
Ultimate Elongation (% stretched at break)	ASTM D 412	%	500
Tensile Fatigue Endurance (flex life for sharp 180° bends)	Zwick Flexometer	cycles to failure	>1,000,000
Modulus of elasticity at 10% elongation (force to stretch 1% at 10% stretch)	ASTM D638	PSI/%	30
Tensile Modulus - 100% Elongation (force to stretch 100%)	ASTM D 412	PSI	800
Tensile Modulus - 300% Elongation (force to stretch 300%)	ASTM D 412	PSI	1,800
Tensile set at failure (% stretched after break and rebound)	ASTM D 412	%	25
Tear Strength (lateral force to tear)	ASTM D 624	PLI	425
Compression set at 25% deformation (% squashed)	ASTM D 359-B	%	18
Abrasion Resistance (weight lost when ground)	ASTM C 501 Taber H18	MG/M.	40
Coefficient of Friction on Steel	ASTM D 1894		0.53
Coefficient of Friction on Aluminum	ASTM D 1894		0.61
Coefficient of Friction on Brass	ASTM D 1894		0.70
Melting Point		°F	390 - 410
Vicat Softening Point	ASTM D 1525	°F	196
Continuous Ambient Operating Temperature Limits*	See note below	°F	30 to 130
Continuous Ambient Operating Temperature Limits*	See note below	°C	-1 to 54
"Short time" Ambient Operating Temperature Limits*	See note below	°F	10 to 155

Belt Tolerances

Elastomeric urethane belts are not precision belts. The key tolerance is the Modulus of Elasticity for each resin lot, which can vary by +/-10%. In other words, the belt tension can vary from one order to another by up to +/-10%. Therefore, you should design your application so it will work throughout that range.

Table 3 Urethane Belt Characteristics (Courtesy of Durabelt)

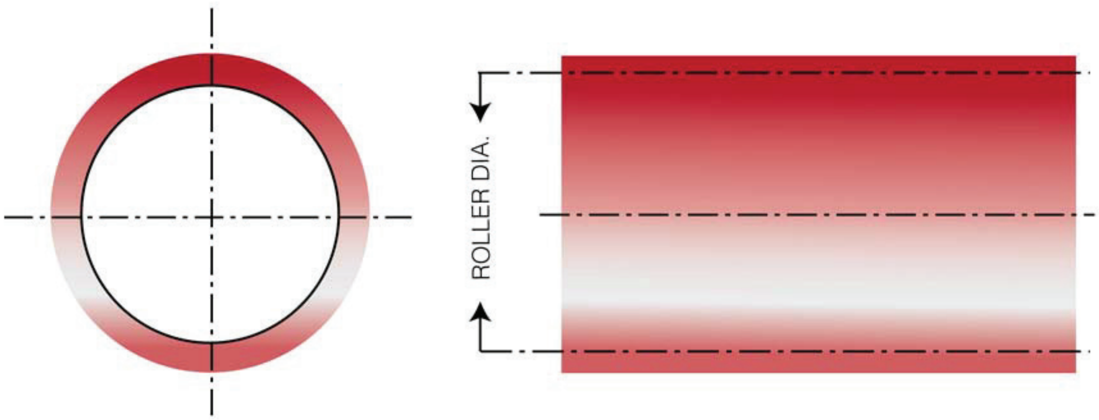
Dimension Name	Standard Tolerances
Modulus of Elasticity	+/-10% Be sure to allow for this tension range in your application's design.
Cross-Section Diameter of round cord	+/- 0.005" (+/-0.13mm) or +/-3%, whichever is greater.
Cut Length (same as pitch circumference)	Standard length tolerance is +/-1/8" (+/-3mm) or +/-1%
Shore A Durometer	+/-3. Since durometer is a surface feature, it often does not correlate well with performance.
Flash created by butt welding	+/- 0.010" (+/-0.26mm) per side
Length of ground area	Not to exceed 1/2", but almost always less than this --Typically 3/8" or 1/4".
Joint Alignment, measured at edges of ground section	Axial tolerance is the same as the absolute range of the cross section diameter tolerances above. Angular is 5° and is also a function of how they are packaged. Sometimes the belts get bent when they are packaged and take a set by the time they have reached the end user, but that bend vanishes immediately after they are installed. Therefore, this in not a tolerance that is normally specified.

Appendix 3: Roller Lagging

Kastalon Urethane

In cases where an item requires special care, the Holjeron MDR can be covered with Kastalon™ brand urethane.

- Will not mark, mar, or scratch finished, sensitive, or coated products and materials.
- Absorb impact and shock.
- Reduce system noise by as much as 10 decibels.



Part Number	Roller O.D.	Wall Thickness	Hardness	Color
K-1.90	1.90"	1/8"	83 Shore A	Safety Orange
K-2.25	2.25"			

PHYSICAL PROPERTIES	ASTM TEST	VALUE
Hardness	D2240	83 Shore A
Tensile strength	D412	5000 psi
100% Modulus	D412	780 psi
300% Modulus	D412	1700 psi
Elongation	D412	500%
Compression set	D395	16%
Abrasion loss	D1044	3 mg
Split tear	D470	460 Ib/in
Dynamic coefficient of friction (against 125 rms steel)	D1894	0.54
Bashore resilience	D2632	36%

PHYSICAL PROPERTIES	ASTM TEST	VALUE
Brittle temperature		-90°F
Glass transition temperature		-44.1°F
Vicat softening		196°F
Reduction in sound as compared to metal roller		7-10 decibels
Load rating		Equal to the load rating of the roller being covered
Specific gravity		1.20 g/cc

FDA and 3A CONFORMANCE

Standard Koat-A-Roll® conforms to FDA 21 CFR 175.105, 177.1680, 177.2600 and meets the 3A Sanitary Standards for Multiple-Use Materials Used as Product Contact Surfaces for Dairy Equipment Number 20-15 testing requirements and are subject to the limitations of these and any other regulations.

ELECTRICAL PROPERTIES	ASTM TEST	CONDITION	VALUE
Dielectric Strength	D179	Short Term	330 volts/mil
Volume Resistivity	D257	-	2.1x1012 ohm-cm
Surface Resistivity	D257	-	3.3x1013 ohms
Dielectric Constant	D150	60 cps	6.34
		103 cps	6.08
		106 cps	5.15
Loss Factor	D150	60 cps	0.154
		103 cps	0.116
		106 cps	0.326
Dissipation Factor	D150	60 cps	0.0242
		103 cps	0.0191
		106 cps	0.0632
Capacitance	D150	60 cps	69.5 Farads
		103 cps	66.7 Farads
		106 cps	56.8 Farads

The information herein is believed to be reliable, but is not to be construed as a warranty or representation for which we assume legal responsibility. Users should undertake sufficient verification and testing to determine the suitability for their own particular purpose of any information or products referred to herein. Courtesy of Kastalon. Used with permission.

Molded Urethane

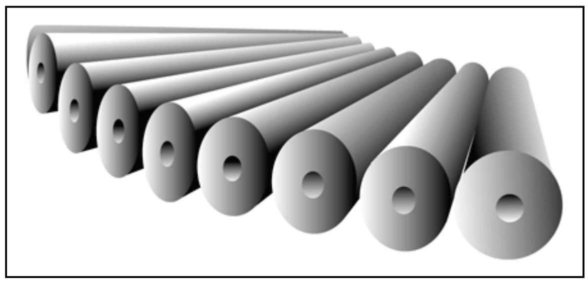
In high torque or high speed applications, the Holjeron MDR can be coated with a molded urethane cover. Molded urethane is particularly adherent to the steel surface of the Holjeron MDR, and may prove to be more durable than a normal urethane sleeve.

Roller laggings range in durometer from bone hard to soft as a rubber band. Lagging can be precision ground with different roller covering finishes to meet your tolerance requirements. Finishes include polished, fine and rough grind, tooled, and antislip.

PVC

For items that are particularly susceptible to static discharge, the Holjeron MDR can be coated with anti-static PVC.

Tapered Sleeve



In order to maintain alignment of load in curves, the outer edge of the curve must be traveling faster than the inner edge. One way to achieve this result is to cover the all the rollers in a curve with a tapered sleeve. Holjeron currently stocks sleeves for 15 , 16 , 17 22 , 24 , and 30 curves; however, sleeves can be customized to fit the curve. The outer diameter of the curve (OD_{curve}) must be rotating at a rate proportional to the ratio of the OD_{curve} to the ID_{curve}. To correctly calculate the taper specifications, use this formula:

$$OD_{TS} = ID_{TS} * \frac{OD_{curve}}{ID_{curve}}$$

Table 4 Holjeron MDR Lagging Selection Table

Lagging	Scuff resis-tance	High speed/torque	Static resis-tance	Curve
Sleeve Urethane	X			
Kastalon	X			
Molded Urethane	X	X		
PVC	X		X	
Tapered Foam Sleeve	X			X

Table 5 Holjeron MDR Lagging Cross-Reference

Lagging	Sleeve Urethane	Kastalon	Molded Urethane	PVC	Tapered Sleeve
1.9 inch	X	X		X	X
2.24 inch		X	X		
2.38 inch			X		

Appendix 4: The .S (“dot-S”) Communication Protocol

Developed by the Holjeron Corporation, the .S communication protocol is an 8-bit serial communications protocol that ensures concise, accurate communication with the driver’s internal microcontroller.

.S simplifies the installation and operation of BLDC conveyor systems, and increases up-time. Instead of requiring local speed adjustments on every single motorized roller, a global speed command over .S can cause all of the rollers on the line to automatically configure for the desired speed. This significantly reduces setup time.

The .S command and control set allows common, low-cost Cat 5 LAN cable to connect controllers and drivers for BLDC rollers. .S enables efficient one-wire communication between intelligent Four-Zone Controllers and .S driver modules (it also provides a means to interface a PC directly to ZPA modules as explained above).

The .S protocol is defined by a binary structure that is compatible with one-wire serial communications. It is based on service request/response message packets, and supports both single-unit and multi-unit service requests. All .S messages contain a minimum of three (3) header bytes, followed by up to thirty-one (31) data bytes. The majority of service requests and responses, however, will contain just a few data bytes.

Appendix 5: A Closer Look at DeviceNet™

According to the ODVA™ (Open DeviceNet™ Vendors Association), more than 40% of industrial automation end-users rely on a networking environment known as DeviceNet. DeviceNet is the means by which the motor controllers are themselves controlled. It is at the heart of the most advanced conveyor components from Holjeron Corp and others.

DeviceNet brings together computers, servers, and software elements connected via industry-standard LAN with the workhorse hardware devices on the manufacturing floor or warehouse.

The DeviceNet protocol is a stable and thoroughly proven open networking protocol based on widely-accepted industry standards including:

- CAN (Controller Area Network) standard, a low-speed serial communication environment whose cost-effectiveness is assured by its universal presence in automobiles;
- CIP™ (Common Industrial Protocol), which allows seamless interaction with other established industry standards such as EtherNet/IP™ and ControlNet™.

The DeviceNet standard is overseen by the ODVA (Open DeviceNet Vendor Association) which manages conformance processes and certifies compliant vendors (more than 700 to date). Rigorous conformance testing policies ensure interoperability among DeviceNet products from vendors at all levels.

DeviceNet networks support up to 64 nodes (where a Four-Zone Controller such as the Holjeron ZL.S C411D represents one node) and offers selectable data rates for communication among the network elements. These rates are inversely proportional to the network length; a 100-meter (328') network will operate at 500 kbps. The network follows a linear trunkline/dropline topology.

DeviceNet offers a simple, standardized means of interconnecting computing, control, and execution elements. With just one Cat-5 cable attached to each local zone controller, a remote PC can control every aspect of conveyor operation and monitoring. DeviceNet is a bi-directional communications medium that integrates into enterprise networks and link conveyor actions to commands from manufacturing or distribution software applications.

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