DESIGNING DRIVES FOR A COMPETITIVE EDGE

How Field Retrofits Can Point the Way to Drive Designs That Better Satisfy Customers

Introduction

Electromechanical engineers who design power transmission or motion control systems for industrial equipment face an ongoing challenge. For their equipment designs to remain competitive in the marketplace, they must adopt new technologies. But while there are many options for transforming one form of mechanical power into another, why change a drive design that's working?

Standard engineering practice for the equipment you design may call for a roller chain or gearhead. Replicating these solutions feels safe. On the other hand, design changes pose risk and expense. So where do you find solutions that minimize risk and cost while offering a marketable advantage? The answer lies in drive conversions already made by industrial customers who are using your equipment or machinery. Field redesigns can point the way to next-generation machines.

This paper will examine two field retrofits that led to better performing, more competitive drive designs. But first we'll review some basics.

Drive Design Considerations

Market (Application) Criteria

Designing a drive system to deliver rotary and/or linear motion begins with some basic objectives, such as the following:

- Cost (initial price, replacement cost, total cost of ownership)
- Performance (speed, torque, power, acceleration)
- Efficiency (mechanical and electrical)
- Size, weight and space limitations
- Geometry (center distance, layout)
- Precision and accuracy
- Noise and vibration
- Environment (temperature, contaminants, etc.)
- Reliability and service life
- Customer satisfaction

Manufacturing Criteria

Consideration must also be given to the economics of manufacturing the drive sub-system. Some factors include:

- Cost and accessibility of components
- Ease of manufacture
- Assembly time
- Production line output
- Rework
- Warranty

Popular Drive Design Options

Several technologies are available to the designer of power transmission and motion control drive systems. Common ones include:

- Roller chain
- Gears and gearboxes
- Belts

We'll briefly review the pros and cons of each of these systems, and present examples of roller chain and gear drive conversions that led to improved designs.

Roller Chain

Roller chain technology is one of the oldest forms of power transmission in existence. Comprised of a series of connected metal links that engage sprocket teeth, roller chain is available in a wide variety of styles and materials to meet cost, operational and horsepower transmission requirements.

Roller chain is a popular design option due to its ability to transmit high power/torque at low speed, at relatively low initial cost, using readily available components. It's also fairly forgiving when misapplied.

Advantages of roller chain include:

- 91% - 94% efficient
- Simple, readily available
- Versatile (length, attachments, splicing)
- Serpentine capability
- Synchronization ability
- Low cost of acquisition

A key disadvantage is that roller chain drives are noisy and need high maintenance. Regular lubrication is essential to ensure reasonable chain and sprocket life. Even with proper lubrication, pins and bushings wear and cause the chain to stretch or elongate over time. Periodic retensioning is then needed, which results in downtime and lost productivity.

Gears

Gears are toothed machine parts, such as a wheels or cylinders, which mesh with other toothed parts to transmit motion or to change speed or direction. They are made from many different types of materials (plastic to hardened steel), and are classified according to their application. Gear types commonly used in power transmission and positioning applications include the following:

- Spur gears (straight teeth that are parallel to the axis of rotation and can transmit power between parallel shafts)
- Helical gears (spiral teeth that can transmit power between parallel as well as right-angled axes)
- Bevel gears
- Planetary gears
- Cycloidal gears
- Spline or harmonic gears
- Worm gears
- Rack and pinion gears (convert rotary motion into linear motion)

Gear reducers (also called speed reducers, gearboxes, gearheads) are gear sets that convert input from a motor or other power source into lower RPM and correspondingly higher torque.

Gears are available in a wide range of sizes and power capabilities, a wide speed operating range and are compact. Like roller chains, they also require lubrication and tend to be noisy. Depending on the gear type, efficiencies range widely (from 60% for worm gears to 97% for cycloidal gears), which means loss of torque on large motors.

Trapezoidal, Gilmer

Curvilinear

Modified Curvilinear

Belts

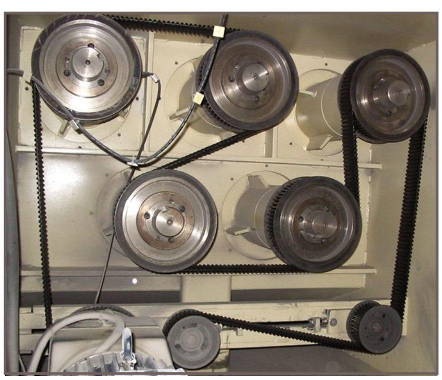
Belts are designed to transmit power via pulleys, sheaves or sprockets. V-belts have a V-shaped cross section that wedges into a corresponding V-shaped groove in the sheave or pulley.

Synchronous belts are toothed belts. Power is transmitted by the belt teeth engaging the teeth in a pulley or sprocket, not by wedging friction, as in V-belts. Synchronous belts work on the tooth-grip principle. Belt teeth mesh with sprocket teeth to provide positive power transmission on high-torque applications at high and low speeds. Synchronous belts are identified by their pitch length, profile type (trapezoidal, curvilinear, modified curvilinear), tooth pitch (distance between adjacent teeth) and top width.

In addition to transmitting power, synchronous belts can also provide positioning accuracy for motion control applications. Depending on pitch and tooth type, backlash ranges from .002" to 0.15". High modulus tensile cords minimize dynamic elongation, allowing for greater precision.

Because they don't slip, synchronous belts offer a near constant 98% efficiency over their useful life. They require no lubrication, eliminating the need for maintenance and avoiding contamination problems caused by lubricants. Minimal elongation eliminates the need for retensioning.

Advantages of a synchronous belt include the following:



- Wide range of power capability
- High power density
- Wide speed operating range
- 98% efficient
- No lubrication required
- Clean running and quiet
- Maintenance free (no retensioning)
- Positioning accuracy
- Low acquisition cost
- Low cost of ownership
- Widely available

A synchronous belt drive system typically has a slightly higher component cost than those of a comparable standard roller chain drive, but less than a comparable gear or ball screw drive. On a total cost of ownership basis, synchronous belt drives cost less than roller chains, gear drives or ball screws, all of which have higher ongoing maintenance requirements.

Synchronous belt drives are sensitive to improper alignment and should not be used on systems where misalignment is inherent to the drive operation.

Market Impact of Inappropriate or Outdated Designs

A poorly performing drive is costly to the user and could spell disaster for the original equipment manufacturer. The equipment may operate inefficiently, consuming too much energy and raising energy costs. It may slow the production cycle, or cause damage to other components in the system. Poorly designed drives will increase the user's maintenance expense budget.

How can you tell when a drive is just "wrong" for the equipment? Some signs of a poorly performing drive include:

- Frequent replacement
- Premature failure
- Higher than usual maintenance
- Noise
- High temperature
- Vibration

The drive may have been improperly sized for the application. Or the application may have changed over time, placing requirements such as higher speed or throughput on the equipment not intended in the original design. Whatever the cause, the cure is to reassess the drive and application.

When converting to a different type of drive design, consider not only the end-user's equipment acquisition cost, but also the total cost of ownership and customer satisfaction. A drive system that minimizes maintenance and replacement of components can not only save money in the long run, but also increase uptime and productivity.

The following case studies demonstrate how better designs emerged from field retrofits.

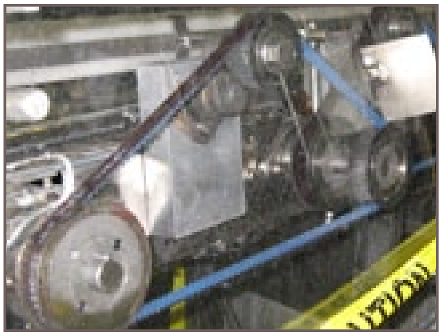
Market Solutions That Led to Better OE Designs

Roller Chain to Synchronous Belt

A bottling facility was troubled by glass bottles breaking at the end of a series of conveyor lines driven by #60 roller chain, which fed bottles into a labeling unit. Differing rates of chain wear, stretch and elongation on the multi-stage drives caused variations in speed so that one end of the conveying line would begin running faster than the other. As a result, bottles were slammed against each other, breaking and immediately halting production.

Multi-stage roller chain drives on a conveyor wore unevenly, creating synchronization problems

When this happened the entire operation had to be shut down to retension the chain drives, which took two hours of maintenance time and stopped all production downstream. Dumpsters of broken bottles were cleaned up and sent to a recycling facility. Additionally, each shift was spending two hours of preventive maintenance time in an attempt to keep the roller chain drives running properly. Regardless, the roller chain had to be entirely replaced every three months.



Retrofitting with synchronous belt drives made line speed consistent and eliminated maintenance downtime

This ongoing problem was solved by improving the original design through conversion to synchronous belt drives, using Gates Poly Chain® GT® Carbon® belt drive systems. The high power rating of these carbon fiber-reinforced belts allowed width-for-width replacement.

Because a synchronous belt doesn't stretch over time as does roller chain, the conveying speed remained consistent across all the lines, preventing the bottles from piling up and breaking. Throughput increased by 20 percent. Fewer bottles breaking reduced the need and cost of recycling. Synchronous belts don't need lubrication, which eliminated the two hours per shift of preventive maintenance time, freeing maintenance personnel to handle other tasks and eliminating the risk of contamination from the lubricant. And without metal-to-metal contact, the synchronous belts are less subject to wear. Life expectancy for the synchronous belts is two years, compared with three months for the roller chain.

The annual cost savings resulting from this chain to belt conversion was calculated at $330,000 per year, not including the recovery of lost production time and reduced recycling costs. Payback on this one conversion was less than one year.

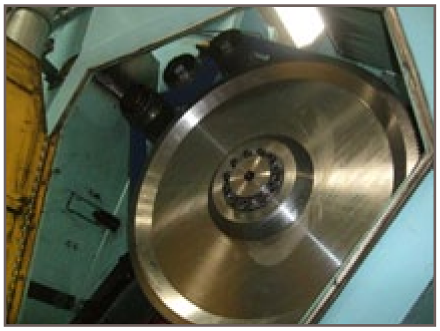
Gears to Synchronous Belt

Bull gears on a stamping press needed replacing every three months due to wear

Gear-driven 30-ton stamping presses operate 24/7 in a manufacturing plant. The continuous hammering action wore down and narrowed the gear teeth on the 24" bull gears, creating slack in the system, throwing off the timing of the stroke, and gradually reducing product output. When the speed variation of the motor reached ± 35 rpm, the plant engineer knew that the gears were so thoroughly worn it was time to replace them, typically every 3-4 months.

Each stamping press has an electric motor with a set of gears on either side, an $18,000 replacement cost. It took 48 hours to shut down the machine, replace the gears, and put the stamping press back into operation. That's two days of lost productivity per machine.

The plant engineer was looking for a better solution, such as hardening the gears to make them last longer. But a better solution was a synchronous belt drive. The drive had to be compact and strong and space was limited. The solution was a Gates Poly Chain® GT® Carbon® belt drive system, at about 1/3 the cost of the replacement gears, and an anticipated installation time of half a day.



A synchronous belt drive fit into the same limited space, needs no lubrication, and has a two year lifespan

After the conversion the belt drive operated more smoothly and efficiently than the gear drive it replaced. Backlash was eliminated. There was no split-second delay in the hammer stroke with the belt drive. The speed variation in the motor was only ± 0.5 rpm. This greater efficiency translated into a gain of three strokes and 15 products per minute. By the end of one week the belt-driven stamping press was producing an extra pallet of products compared with the gear-driven machine. The drive has been in operation for over 10 months with no technical problems.

As a result of this conversion, the user is asking the stamping press manufacturer for additional machines to be redesigned with belt drives. The redesign is taking $48,000 out of the cost of each machine.

Conclusion

Field experience is the true test of a drive system. When high maintenance or frequent replacement of drive components becomes the norm, it's time to reassess the drive design. As the examples above demonstrate, synchronous belt drives present a viable alternative to roller chains or gears in many industrial applications. Replacing these older drive technologies with a synchronous belt system offers one way for your equipment or machinery to gain a competitive edge in the market.

Additional Resources

Engineering design assistance with belt drive systems is available from Gates Corporation. Contact a Gates Product Application Engineer, (303) 744-5800, email ptpasupport@gates.com, or visit www.gates.com.