DRIVEN BY POSSIBILITY™

MORE THAN A MATCH FOR ROLLER CHAIN

SYNCHRONOUS BELT DRIVES

DESIGNED FOR ROLLER CHAIN APPLICATIONS

A NEW BREED OF SYNCHRONOUS BELT DRIVES HELPS DESIGNERS DEVELOP MARKET-LEADING INDUSTRIAL EQUIPMENT.

INTRODUCTION

As technologies mature and modernize, manufacturers expect more from less. More power from a smaller footprint. Greater power from fewer materials. Synchronous belt technology has evolved, matching the performance of roller chain while reducing weight, mess, and maintenance.

The first toothed belt was invented in 1945. It was called a “timing” belt because it synchronized, or timed, the movements of the bobbin and the needle on a sewing machine. Timing belts today perform similar but more demanding tasks, such as synchronizing the crankshaft and camshaft on automobile engines.

The terms “timing belt” and “synchronous belt” are often used interchangeably to describe a class of toothed, positive drive belts. But while the function of a timing belt is primarily synchronization, industrial synchronous belts have evolved into a power transmission system that rivals roller chain.

PERCEPTION VERSUS REALITY

Technology marches on, but in every field, perception lags reality. Many design engineers continue to think that synchronous belts are incapable of performing the work of roller chain drives, especially in low speed, high torque applications.

Why is this so?

For one thing, chain is one of man's oldest forms of power transmission. The first chain drives in recorded history date back to 225 B.C. By the early twentieth century, roller chain had evolved into a sophisticated method of transmitting power.

Roller chain technology has matured. It continues to improve, but incrementally. In contrast, synchronous belt technology has evolved dramatically. Today's synchronous belt bears little resemblance to the first timing belt that was designed for use on a sewing machine in 1945. What about the industrial products that use roller chain? How fast are they evolving?

Most new and redesigned products are brought to market with increasing speed. Customers expect more and have more and better products from which to choose. So the pressure is on manufacturers to continuously improve their products.

As a result, engineers can no longer treat the power transmission drive or the motion control components as an isolated sub-system. Instead, they must think about how the systems contribute to the end product. Can it help reduce cost or extend service life? How easily can it be integrated? How will it improve product performance? What effect will it have on end-user satisfaction?

In this context, how do synchronous belt drives stack up against roller chain drives in industrial power transmission applications?

TAKING MEASURE OF ROLLER CHAIN PERFORMANCE

The popularity of roller chain drives stems from a number of factors. As a power transmission system, chain can transmit high torque loads in a compact package. Chain can be spliced to nearly any length. And standard roller chain is relatively inexpensive and readily available.

Chain is well-suited for hostile environments. It can withstand temperatures well above 180°F (82.2°C); it tolerates wet, oily, dusty, dirty and corrosive atmospheres, albeit at the sacrifice of longer life.

Roller chain drives can also tolerate fluctuations in center distance caused by a non-rigid or compliant drive mounting.

But a number of characteristics make chain drives less than ideal for many power transmission applications. The most significant factors include chain stretch or elongation, the need for lubrication, and noise.

Stretching, or elongation, results from pin and bushing wear at the articulated joints of the chain. Chain elongation results in the need to take up slack or retension the chain at regular intervals.

Lubrication is essential to the proper functioning of a chain drive. Without proper lubrication, chains and sprockets wear out quickly, forcing replacement. By chain industry estimates, improperly lubricated chain drives wear approximately 300 times faster than properly lubricated ones. And chain manufacturers acknowledge that up to 90-95% of all installed chain drives are not properly lubricated, or not lubricated at all.

At a time when maintenance personnel are being pushed to their limits, lubricating roller chain is an unwelcome chore. To compensate, equipment designers may include an oil bath or oil spray system, or they may specify lube-free chains on their drives, adding to the cost of the system.

In some applications, the lubricant itself poses a problem. Equipment used in the food processing industry, for example, must meet stringent food-grade standards. Leaked lubricant can cause slips or environmental hazards.

ROLLER CHAIN SIZING SIMPLIFIED

In the U.S., roller chains must meet ANSI standard B29.1. Among other things, B29.1 standardizes the sizing of chains and sprockets.

According to the standard, there are 14 sizes of roller chains, numbered 25, 35, 41, 40, 50, 60, 80, 100, 120, 140, 160, 180, 200 and 240. These numbers refer to the chain "pitch," or the distance between individual links.

The first one or two digits refer to the chain pitch in eighths of an inch. Thus, #80 chain is 8/8, or one inch; #160 chain is 16/8, or two inches, and so on. The majority of power transmission roller chain sold in the U.S. ranges between pitch sizes #35 to #100.

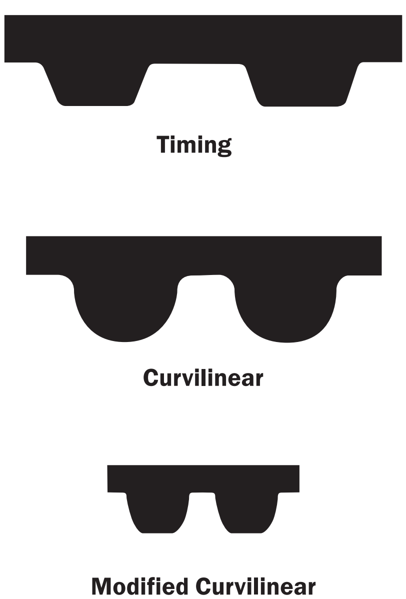
Stainless steel roller chain may be required for applications such as food processing or maritime equipment, again, adding to cost. Silent chain may be needed for certain applications. Noise is another factor to consider with chain. Noise is produced by the metal-to-metal contact inherent in chain drives. Also, vibration between the roller and the bushing, and by the sprocket itself, generates noise.

Also, there is the issue of cost. A standard roller chain drive typically has a lower acquisition cost than a comparably-rated synchronous belt drive. But a standard roller chain may not be suited for the application.

All these specialized types of roller chain can bring the initial cost of chain drives to a par with a synchronous belt drive, and fail to address the long-term cost implications of ongoing maintenance and replacement life.

In spite of these disadvantages, engineers continue to specify roller chain drives for high torque applications, thinking that synchronous belt drives are not a suitable alternative. But are they correct?

Figure 1



THE EVOLUTION OF SYNCHRONOUS POWER

Much like chain, synchronous belts transmit power through positive engagement between belt teeth and sprocket grooves. As seen in Figure 1, there are three general families of synchronous belt tooth designs:

- **Timing**
- **Curvilinear**
- **Modified Curvilinear**

The trapezoidal tooth shape is characteristic of timing belts. This design dates back to 1945 and the invention of the first toothed belt. Timing belts are still used for applications where accurate synchronization or registration is a must. Because the teeth are small and shallow, timing belt drive systems have relatively low horsepower ratings.

The curvilinear belt tooth form (such as Gates HTD tooth profile) is a more advanced design with higher performance capabilities than trapezoidal-toothed timing belts. The increased tooth depth distributes stress more evenly as it enters and leaves the sprocket.

The modified curvilinear design (such as Gates GT® tooth profile) is a refinement of the curvilinear tooth. Both belt and sprocket grooves were improved to allow better entry and exit from the sprocket. This design substantially increased the meshing ability and performance of synchronous belts.

In addition to improvements in belt tooth and sprocket design, synchronous belts have evolved in the use of body and tensile cord materials.

Originally, rubber timing belts were reinforced with steel to ensure stable belt length and prevent elongation. Later, rubber belts were reinforced with fiberglass. Fiberglass-reinforced belts (such as Gates PowerGrip® belts) are still commonly used today.

To meet more demanding load applications, belts were developed with polyurethane bodies and aramid (Kevlar®) fiber tensile cords. These belts could compete with standard roller chain in a wide range of power transmission applications.

The latest evolution came when Gates introduced its Poly Chain® GT® Carbon™ belt, with carbon fiber tensile cords (Figure 2). When used in a dynamic application such as the tensile member of a synchronous belt, carbon fiber delivers a number of performance attributes never before achieved.

Figure 2

A 20mm wide Gates 14M Poly Chain® GT® Carbon™ belt (right) can do the same job as a 157mm wide Gates PowerGrip® timing belt (left). Also, the Poly Chain GT Carbon belt drive weighs 73.4 (33.3kg) less than the PowerGrip drive, a 70% reduction.

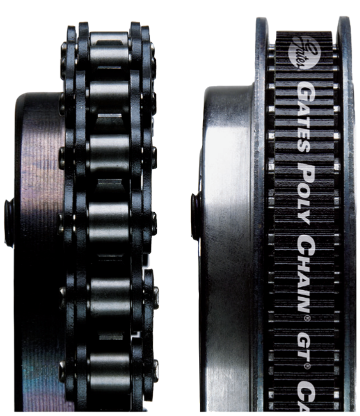
These performance attributes include:

- **Higher power density for more compact drive designs (as shown in Figure 2)**
- **Higher flex fatigue resistance**
- **Higher modulus (pitch stays constant regardless of load)**
- **Higher strength to weight ratio**
- **Greater environmental resistance (no degradation from water, oil, most contaminants)**

Incorporating carbon fiber tensile cords into the design of a synchronous belt tested the limits of synchronous belt technology. Gates scientists and engineers in the Advanced Materials Development Group spent years developing a patented technique for fusing carbon tensile cord fiber into the polyurethane body to produce a synchronous belt with the strength and durability of steel roller chain.

Figure 3

Gates Poly Chain® GT® Carbon™ belt drive can match the load capacity of a roller chain drive width-for-width in almost any application.



MATCHING ROLLER CHAIN PERFORMANCE WIDTH-FOR-WIDTH

Design engineers grapple with three major concerns at the thought of replacing roller chain with synchronous belts in their drive system designs. One concern is the belt's load carrying capacity. A second is the size of the drive package. And the third is cost.

Formerly, in order to achieve the desired load carrying capacity, designers would have had to increase the size of the drive package to accommodate the greater width required by the belt drive – often an impractical solution.

Now, however, the use of carbon fiber tensile cords has dramatically increased the load carrying capacity of synchronous belts to the point where they can replace roller chain width-for-width in sizes #35 to #180 and higher. See Figure 3.

Chart 1 below compares the load carrying capability of roller chain (top row) to carbon synchronous belts (left column) in incremental widths for the most widely used chain sizes. To ensure a fair comparison, the load values behind the chart were derived by comparing both chain and belt drives of comparable diameters at 10, 100 and 500 rpm.

POLY CHAIN® GT® CARBON™ BELT /ROLLER CHAIN COVERAGE CHART

		ROLLER CHAIN COVERAGE																
CHAIN		ISO	06C1	08A-1	10A-1	08A-2	12A-1	08A-3	10A-2	10A-3	12A-2	16A-1	12A-3	20A-1	16A-2	24A-1	20A-2	28A-1
		BS	06B-1	08B-1	10B-1	08B-2	12B-2	08B-3	10B-2	10B-3	12B-3	16B-1	12B-3	20B-1	16B-2	24B-1	20B-2	28B-1
		ANSI	#35	#40	#50	2/#40	#60	3/#40	2/#50	2/#60	#80	3/#50	#100	3/#60	2/#80	#120	2/#100	#140
WIDTH (MM)			7.75	9.65	11.68	31.5	26.4	45.7	39.4	57.4	49.3	33.5	72.1	40.9	62.7	50.8	76.7	54.4
Poly Chain	8M-12																	
	8M-21																	
	8M-38																	
	8M-62																	
	14M-20																	
	14M-37																	
	14M-68																	
	14M-90																	
	14M-125																	

Chart 1

Note:
Chain ratings per American Chain Association.
Chain width dimensions represent chain pin width.
Not to be used for drive design purposes.

The top entry in the left column of Chart 1 (8M-12) represents an 8mm (tooth pitch) carbon synchronous belt that measures 12mm in width. The three grey boxes to the right of this entry indicate that this 12mm-wide belt can meet or exceed the load carrying capability of three sizes of chain, ranging in width from 12.7mm (#35) to 21.1mm (#50).

To the far right of the chart, you can see that a 14mm (tooth pitch) belt that measures 68mm in width can match two strands of #100 roller chain measuring 76.7mm in width.

In the center of the chart, roller chain sizes 3/#40 to 2/#80 could be matched with either an 8mm or a 14mm belt. Which belt to use would depend on the application. For example, the diameter constraints of the drive package might dictate using a narrower belt versus a wider 8mm belt. In either case, a belt is available to match the capacity of the chain.

Drives with either limited center distance adjustment or non-adjustable centers pose another problem for engineers thinking about replacing a roller chain drive with a synchronous belt drive. In these situations, chain drives had an advantage because chain length can be adjusted simply by adding or removing links. In contrast, synchronous belts are made in discrete lengths, and the exact belt length to match the center distance is rarely available.

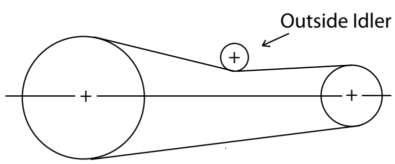


Figure 4

The use of backside, or outside, idlers gives designers flexibility in fitting a synchronous belt drive into a compact drive package with fixed or limited center distance adjustment.

Now there are heavy-duty backside idlers that can be installed as part of a synchronous belt drive system, allowing the drive to fit into drive packages that were formerly reserved for chain. See Figure 4. Using flat, adjustable outside idlers lets designers design drives that allow belt pre-tensioning and take-up in cramped quarters.

Engineers must also grapple with the issue of cost. A synchronous belt drive comes with a higher acquisition cost than a comparable standard roller chain drive. However, the designer must also consider the lifetime cost of the drive system. Longer belt and sprocket life, combined with eliminating the need for lubrication and retensioning, can make a synchronous belt drive less costly for the customer over the long haul.

SYNCHRONOUS BELT ADVANTAGES

What is the value of replacing a roller chain drive with a synchronous belt drive of equivalent or narrower width? For one thing, narrower drives are easier to align. They are also less sensitive to misalignment, because they don't generate the tracking forces of a wider belt.

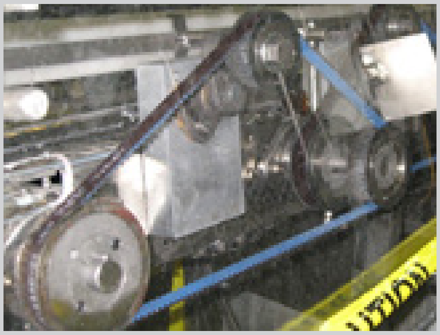
ROLLER CHAIN TO SYNCHRONOUS BELT CONVERSION SAVES BOTTLING PLANT $330K PER YEAR

A conveyor system in this bottling plant was designed with seven #60 chain drives. Linked in a series, the chain drives conveyed bottles to a labeling machine at the rate of 10,000 cases per hour.

As it wore, each chain drive stretched or elongated at a different rate. Consequently, the conveying line began to run unevenly. Bottles piled up and broke. So the line had to be shut down periodically to retension each of the seven chain drives. This entire process took three hours, and completely halted production.

In addition, one hour of preventive maintenance time per shift was devoted to lubricating and inspecting the chain drives.

By replacing the chain drives with synchronous belt drives, the plant eliminated the one-hour-per-shift maintenance time. Production increased by 30,000 cases per day. The line ran smoothly, so fewer bottles were lost. It also ran continuously, since there was no longer a need to halt production to retension the drive. Total savings was calculated to be $330k per year on just one conveying system.



Also, a narrow belt can be placed closer to the outboard bearing on the shaft. The less the distance between the outboard bearing and the belt center of load, the less the bearing load. A narrow synchronous belt provides the least center of load distance of any drive system. The result is less strain, and wear, on the bearings and shafts.

In addition, synchronous belt drives offer the designer a number of advantages inherent to belts as compared to roller chain.

A synchronous belt drive system requires no lubrication – a key advantage over the most problematic aspect of a roller chain drive. In addition, once the belt drive is installed and properly tensioned, it never needs retensioning. Roller chain, no matter how well maintained and lubricated, eventually elongates, requiring periodic take-up and retensioning. A synchronous belt drive system is essentially maintenance-free.

Synchronous belts are capable of operating at higher speeds than chain. The maximum operating speed of a carbon synchronous belt drive using cast iron sprockets is 6,500 ft/min (33 m/sec). With made-to-order sprockets, speeds up to 10-12,000 ft/min (50.8 – 61.4 m/sec) can be achieved. Speed ratios as high as 10:1 can be reached with stock components.

One can also expect a synchronous belt drive to last considerably longer than a chain drive. Compared to a standard roller chain drive, a carbon synchronous belt will last up to 3x longer than chain, and the drive sprockets up to 10x longer.

Minimal maintenance and longer life make synchronous belt drives competitive in cost to roller chain drives over the life of the drive. Roller chain remains popular due to its low acquisition cost. But roller chain drives have hidden costs, including lubrication, frequent maintenance, and faster wear.

Customers who purchase equipment that has been equipped with roller chain drives may benefit initially from the lower cost of the power transmission sub-system, but they pay more down the road in maintenance and replacement costs.

CONCLUSION

Drive system engineers now have the option of developing more market-competitive and innovative equipment by replacing roller chain drives with synchronous belt drives. The new breed of carbon synchronous belt drive systems can match the load carrying capability of standard roller chain width-for-width in a pitch range of #35 to #180 and higher.

IN ADDITION, SYNCHRONOUS BELT DRIVES OFFER THE DESIGN ENGINEER A NUMBER OF ADVANTAGES, INCLUDING:

- **Designing more compact, lighter weight drive systems**
- **Designing longer-lived drive systems**
- **Designing maintenance-free drive systems**
- **Wide range of belt lengths and sprocket diameters to choose from**
- **Easy integration into current system design**
- **Suited for a wide range of industrial applications**
- **Heavy-duty backside idlers to eliminate center-distance limitations**

Gates Product Application Engineers are always available to help you design the right synchronous belt drive system for your equipment or application. Contact them by phone at +61 3 9797 9666, or email gatestech@gates.com.

Also visit www.gates.com/ptsavings and www.gates.com/ptdesign for tools and resources to help you with roller chain conversions, including Gates Design Flex® Pro™ and Design Flex® Web™ drive design software.

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