**Introduction**

Synchronous belts have taken a quantum leap forward since their invention in the 1940s. They now rival roller chain, gears, and other forms of power transmission in almost any application.

In the past 60 years, Gates has pushed the limits of synchronous belt technology. Research into new compounds, additives, blending processes, jackets, tensile cord materials, and tooth profiles yields further advances every day.

Combined with a standard of manufacturing excellence that rivals any in the world, Gates synchronous belt technology results in a product line without equal.

Following is a guide to Gates line of synchronous belts that will enhance your understanding of the product line and what stands behind it.

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Belt Anatomy 101

A standard Gates synchronous belt is comprised of the following components:

A. Rubber or polyurethane body. The body encases the tensile cords and protects them from oil, grease, moisture, and other adverse environmental conditions.

B. Tensile Cord. Tensile cords provide muscle for the belt, resisting elongation, shock and surge loads. Gates produces tensile cords from fiberglass, aramid, and carbon fibers.

C. Teeth. Belt teeth engage corresponding grooves on the sprocket. Made of high modulus rubber or polyurethane, the teeth are precisely formed and spaced.

D. Facing. Teeth are faced with a nylon fabric that serves as the wearing surface barrier as well as adds significant strength to the belt.

Unlike V-belts, which transmit power through wedging friction between belt and pulley, synchronous belts transmit power through positive engagement between belt teeth and sprocket grooves. This method of power transmission provides synchronization between driveR and driveN shafts, resulting in a high level of drive efficiency. Properly aligned and tensioned, a synchronous belt drive will operate at 98+% efficiency for the duration of its life.

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.
When compared to V-belt drives, synchronous belt drives have much higher horsepower ratings, size for size.

Synchronous belts are well suited for applications with the following demands:

› Synchronizing power transmission between shafts
› High mechanical drive efficiency
› Compact drive layout
› Low maintenance
› Energy savings
› No tolerance for contamination [lubrication]
› Slow and high speed, high torque drives

**Tooth Profiles**

Tooth profile refers to the shape of the belt teeth. There are three common synchronous belt tooth profiles manufactured by Gates:

› Trapezoidal (Timing)
› Curvilinear (HTD)
› Modified Curvilinear [GT®]

**Trapezoidal Tooth Profile**

Dating back to the 1940s, the first synchronous belts were designed with trapezoidal shaped teeth.

The term “timing belt” is often applied to this tooth profile because it is used primarily for synchronizing, or timing, the movement between two shafts. Timing belts have lower horsepower ratings than comparable curvilinear or modified curvilinear belts.

Following are industry standard cross-sections describing trapezoidal toothed belts. The letters indicate belt pitch, measured in inches:

<table>
<thead>
<tr>
<th>Designation</th>
<th>Description</th>
<th>Belt Pitch</th>
</tr>
</thead>
<tbody>
<tr>
<td>MXL</td>
<td>Mini Extra Light</td>
<td>0.080”</td>
</tr>
<tr>
<td>XL</td>
<td>Extra Light</td>
<td>0.20”</td>
</tr>
<tr>
<td>L</td>
<td>Light</td>
<td>0.375” [3/8”]</td>
</tr>
<tr>
<td>H</td>
<td>Heavy</td>
<td>0.50” [1/2”]</td>
</tr>
<tr>
<td>XH</td>
<td>Extra Heavy</td>
<td>0.785” [7/8”]</td>
</tr>
<tr>
<td>XXH</td>
<td>Double Extra Heavy</td>
<td>1.25” [1-1/4”]</td>
</tr>
</tbody>
</table>
HTD Curvilinear Tooth Profile
The curvilinear tooth profile was introduced by Gates in 1971. Unlike the rectangular-shaped trapezoidal tooth profile, Gates HTD® (High Torque Drive) profile had deeper, rounded teeth. This design distributed stress more evenly from the base to the top of the tooth, resulting in the ability of the belt to transmit higher torque with less ratcheting, or tooth jump.

For belts with curvilinear tooth profiles, tooth pitch is measured in millimeters. They are available from a wide variety of manufacturers in the following industry-standard pitches:

<table>
<thead>
<tr>
<th>Designation</th>
<th>Belt Pitch (mm)</th>
</tr>
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<tbody>
<tr>
<td>3M</td>
<td>3mm</td>
</tr>
<tr>
<td>5M</td>
<td>5mm</td>
</tr>
<tr>
<td>8M</td>
<td>8mm</td>
</tr>
<tr>
<td>14M</td>
<td>14mm</td>
</tr>
<tr>
<td>20M</td>
<td>20mm</td>
</tr>
</tbody>
</table>

GT Modified Curvilinear Tooth Profile
The modified curvilinear belt tooth profile is a refinement of the curvilinear form. The term “modified curvilinear” describes a number of belts with different tooth forms that followed after Gates HTD. Gates modified curvilinear design was patented in 1985 and called GT® (Gates Tooth).

As part of the GT system, Gates redesigned both belt tooth and sprocket grooves for smoother belt tooth entry and exit properties, and improved belt tooth flank support in the sprocket grooves. This redesigned belt tooth profile increased belt drive performance, allowing higher load capacity, improved drive registration accuracy, quieter operation, and longer life.

Modified curvilinear belts are available in the following sizes:

<table>
<thead>
<tr>
<th>Designation</th>
<th>Belt Pitch (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2MR</td>
<td>2mm</td>
</tr>
<tr>
<td>3MR</td>
<td>3mm</td>
</tr>
<tr>
<td>5MR</td>
<td>5mm</td>
</tr>
<tr>
<td>8M</td>
<td>8mm</td>
</tr>
<tr>
<td>14M</td>
<td>14mm</td>
</tr>
</tbody>
</table>
The Gates GT belt tooth and sprocket groove patent expired in 2005, allowing other manufacturers to develop look-alike belts and sprockets. While these products might appear dimensionally equivalent to Gates GT belts and sprockets, they lack equivalent performance.

Gates and other synchronous belt manufacturers have various modified curvilinear profiles. Gates belts are constantly being re-engineered for higher performance, and Gates retains patents on tensile cord and jacket technologies, as well as other belt components, that make them unique.

Teeth on Both Sides
Double-sided, or serpentine, timing belts have identical teeth on both sides of the belt. They are used in applications where synchronization is needed from both sides of the belt.

Some synchronous belts with teeth on both sides have reduced power capacity on the back side. Gates PowerGrip® have the same load carrying capabilities on both sides. It is available in GT, HTD and Timing profiles.

Identification of Synchronous Belts
Synchronous belts are specified using three different dimensions:
  › Belt pitch, or cross-section is the distance from the center of one tooth to the next
  › Pitch length is the circumference of the belt, determined by multiplying the belt pitch by the number of teeth in the belt
  › Top width is the distance across the top of the belt

Gates line of synchronous belts offers drive engineers the option of designing compact, lighter drives over a wide load/speed range, with minimal maintenance requirements and increased wear resistance for longer life.
**Body Compounds and Jacketing Material**

In Gates synchronous belts, the body, tensile cord, and cover are chemically bonded to form an integral unit that combines strength and flexibility for high performance and long life.

**Rubber Synchronous Belts**

Gates PowerGrip line of rubber synchronous belt tooth profiles (PowerGrip® GT®2, HTD®, Timing) are made with a premium chloroprene elastomer. The neoprene material forms the teeth and backing of the belt, encasing and protecting the tensile cord. Belt teeth are faced with a nylon fabric that reduces friction, and provides resistance to wear and abrasion.

Chloroprene is an oil-resistant synthetic rubber originally developed as a substitute for natural rubber. Gates compounds chloroprene to give it the characteristics needed to perform in power transmission applications, including:

- Physical toughness
- Resistance to oils and many chemicals
- Flexing and twisting ability
- Ability to operate through a wide temperature range
- Resistance to sun, ozone and weather

Gates also offers belt materials and constructions to meet the needs of specific applications, such as oil resistance, static resistance, static and non-marking characteristics.

**Polyurethane Synchronous Belts**

Gates Poly Chain® synchronous belts are made with a polyurethane elastomer that forms the teeth and backing. The teeth are faced with wear-resistant nylon fabric.

Polyurethane combines some of the best properties of rubber, plastic and metal, including resistance to oils and chemicals, abrasion, moisture, weather, and adverse environments. Gates compounds polyurethane to provide Poly Chain belts with the following characteristics:

- High load carrying capacity
- Excellent abrasion and wear resistance
- Resistance to a wide range of chemicals
- Improved temperature operating range
- Ability to withstand shock loads or surges
**Synchronous Belt Tensile Cord**

The tensile cord is the muscle of a synchronous belt, bearing most of the load for transmitting power. Steel, fiberglass and aramid fibers are the most common materials making up the tensile cord in synchronous belts. Gates pioneered the use of carbon fibers to make the tensile cord in its Poly Chain® GT® Carbon™ synchronous belts.

Each of these materials has advantages and disadvantages. As noted in the accompanying graph of Commercial Fiber Materials, carbon fiber has the highest strength and modulus [resistance to elongation] among commercial fiber materials. It is also light in weight.

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**Commercial Fiber Materials**

Gates proprietary twisting and treating process produces a carbon fiber tensile cord that instills Gates Poly Chain GT Carbon belts with the following characteristics and advantages:

- High power density for more compact drive designs
- High flex fatigue resistance
- High modulus [pitch stays constant regardless of load]
- High strength-to-weight ratio
- Superior environmental resistance [no degradation from water, oil, most contaminants]
Steel, fiberglass, and aramid fibers also possess relatively high strength, high modulus characteristics. fiberglass is used as a tensile cord material in Gates PowerGrip line of synchronous belts [Timing, HTD, and GT2]. Compared with steel, fiberglass is lighter, more flexible, and cost competitive.

Aramid fibers [introduced by DuPont in 1973 under the brand name Kevlar®], are strong, shock load-resistant fibers used as tensile cord material in special construction belts.

Alignment and Tensioning

Alignment

Misalignment between belt and sprockets can wear out belts quickly, leading to premature belt failure as well as increased drive noise. Misalignment can be angular or parallel.

There are several methods used to check alignment:
- Straight edge
- String
- Laser alignment tool

The total allowable misalignment [angular and parallel] in a synchronous belt drive system should not exceed 1⁄4° or 1⁄16-inch per foot of belt span.

Design Software for Roller Chain Replacement

Using Gates Design Flex® Pro™ software, one can design a Poly Chain GT Carbon synchronous belt drive to replace an equivalent standard roller chain drive width-for-width in sizes #35 to #180 and higher.

Existing roller chain drive parameters needed include the following:
1. Roller chain size [pitch and number of strands]
2. Number of teeth on all chain sprockets
3. Load [hp of torque] at individual driven shafts
4. Speed [rpm] of drive input shaft
5. Center distance between shafts [2-point drives] or X-Y coordinate dimensions [multiple shaft drives]
6. Method of applying tension
Tensioning
Under-tensioned belts increase belt and sprocket wear and can cause the belt to ratchet (jump teeth) under heavy start-up or shock loads.

Proper tension depends on the drive load requirements, operating speeds, sprocket diameters, center distance, and the belt type. Tension specifications should be calculated for the belt drive system.

In a properly tensioned drive, belt teeth are fully seated in the sprocket at all entry and exit points while in operation and fully loaded.

There are two common methods of measuring belt tension:
- Force/deflection method
- Span vibration method, such as using Gates Sonic Tension Meter

The force/deflection method relies on measuring deflection force with a pencil gauge or spring scale. The span vibration method is performed using a sonic tension meter.

Sprockets and MTO [Made-To-Order] Metals
Sprockets are a highly engineered component of synchronous belt drive designs. It takes both belt and sprockets working together in harmony to deliver a high performance belt drive system.

Gates sprockets are designed for precise compatibility with Gates synchronous belt tooth profiles. Sprocket grooves are accurately machined to ensure smooth belt tooth meshing and even load distribution.

Considering that sprockets may operate at rim speeds up to 6,500 feet, or more, per minute and transmit loads as high as 1,200 horsepower, sprocket design and analysis must be comprehensive. Gates hardware designs consider many features such as:
Synchronous belt drives don’t operate in a vacuum. They are connected to other power transmission components, typically the output shaft of a motor or gear reducer. The force exerted by the belt drive is a component in overhung load.

Manufacturers of rotating equipment allow for certain levels of overhung load, which can usually be determined from their catalogs. Exceeding overhung load limits leads to trouble. It’s one of the major (and often overlooked) causes of shaft and bearing wear and failure. In contrast, keeping overhung load within design limits extends equipment service life.

It’s important to calculate the overhung load value when designing or altering the design of a belt drive to ensure that shaft and bearings are not overloaded. Key design factors influencing overhung load in a belt drive system include:

- Sprocket diameter
- Belt width
- Sprocket position on the shaft

In greatly simplified terms, one can reduce overhung load by using narrower belts and larger diameter sprockets mounted as close as possible to the outermost bearing on the shaft.

In addition to standard sprockets, Gates offers Made-To-Order (MTO) custom prototypes and production sprockets to meet specialized application needs. Sprockets can be ordered to match all Gates synchronous profiles and pitches. They can be engineered from a variety of materials, including aluminum, steel, stainless steel, ductile iron, cast iron, and plastics. They can also be finished with custom platings and coatings, and designed with a variety of shaft attachment methods.
**Conclusion**

Gates synchronous belt drive systems are highly engineered products manufactured with exacting precision. From design to manufacturing, Gates continues to lead the way in the application of synchronous belt technology.

Other belts may have a similar outward appearance, but beneath the cover of a Gates belt resides 60 years of innovation, testing, validation and performance in the field. Nothing matches a Gates synchronous belt.

**Additional Resources**

For more information on the application of Gates synchronous belts, visit [www.gates.com/drivedesign](http://www.gates.com/drivedesign)

Learn how design engineers are using Gates synchronous belts at [www.gates.com/ptdesign](http://www.gates.com/ptdesign)

To better understand how improper alignment and tensioning causes belt failure, visit [www.gates.com/ptsavings](http://www.gates.com/ptsavings)

Contact Gates Made-To-Order Metal Specialists at 800-709-6001 or visit [www.gates.com/mtometals](http://www.gates.com/mtometals)

Or contact a Gates engineer at [ptpasupport@gates.com](mailto:ptpasupport@gates.com) or by calling 303-744-5800.