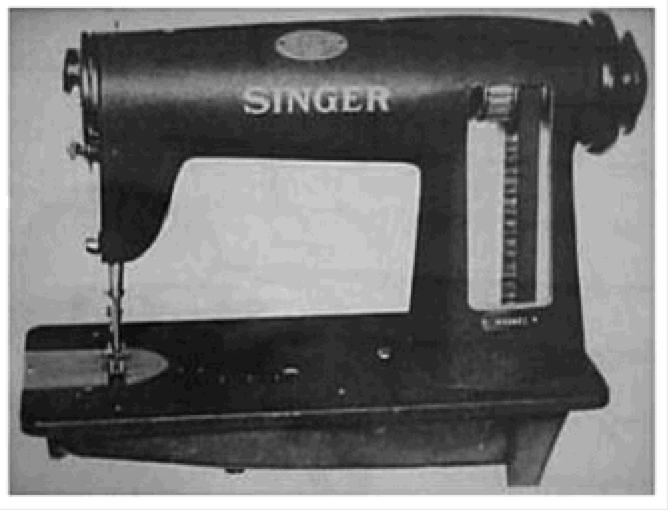
Introduction to Power Transmission with Synchronous Belts

Or

The Scholarship Belt

A Brief History of Synchronous Belts

[HT]^3



- The first use of the synchronous belt was in 1945 in the Singer A33 sewing machine
  - Singer wanted a quieter alternative to the metal clip belts in use at the time
  - Uniroyal had just patented a chloroprene rubber based belt with trapezoidal teeth

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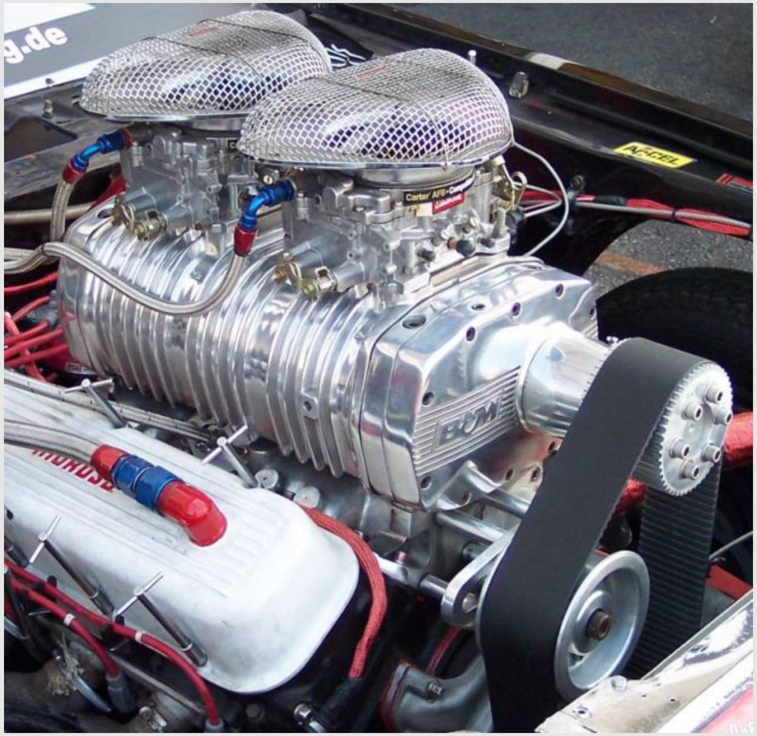
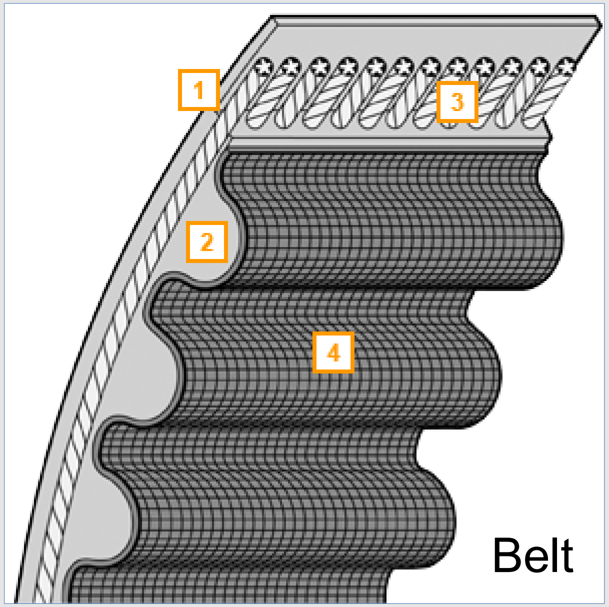


- In the following years, synchronous belts became an alternative to the roller chain used in engines for camshaft timing
- High torque drive (HTD) belts arrived in 1970 featuring a rounded tooth shape with a broader base to allow transmission of high torque
- Modern synchronous, or timing, belts are capable of transmitting power levels similar to roller chain in the same or, sometimes, less volume
- Uniroyal sold its power transmission operations to the Gates Corporation in 1986

Anatomy of a Synchronous Belt



Belt

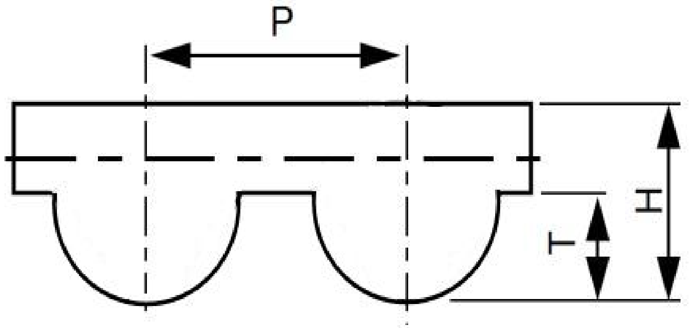

Toothed pulley

1. Rubber or polyurethane body. The rubber or polyurethane protect the tensile fibers from exposure to oil, grease, moisture, and other harmful environmental factors

2. Tensile cord: Provides tensile strength to carry elongation, shock, and surge loads. Belts are available with tensile cords made from polyester, aramid, fiberglass or carbon fiber.

3. Tooth: Engages sprocket grooves. Made of high modulus rubber or polyurethane.

4. Facing: Typically a nylon fabric that serves as the wear surface and strengthens the belt



Pitch (P)
Tooth Depth (T)
Belt Height (H)

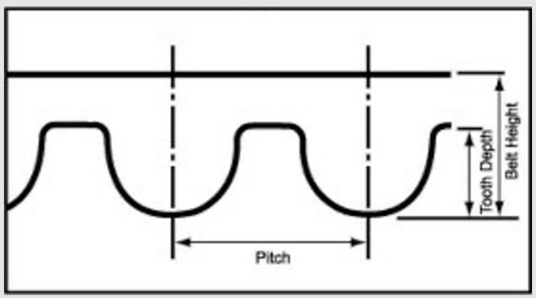
Synchronous Belt Standards

- Two standards organizations have produced standards for synchronous belts
  - Rubber Manufacturers Association (RMA): Specifications for Drives Using Synchronous Belts
  - International Organization for Standardization (ISO): Synchronous Belt Drives
- Many manufacturers publish individual standards. For example, Gates manufactures the HTD line of belts and licenses their production to other manufacturers.
- In general, selecting belts and pulleys for a synchronous belt drive system from the same manufacturer will prevent compatibility issues

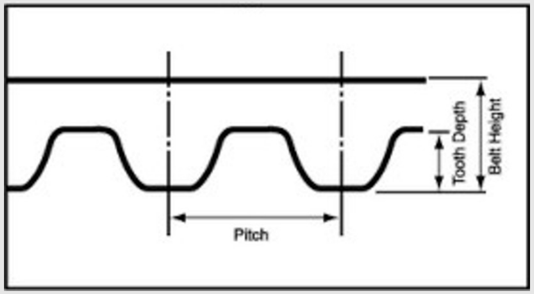
Tooth Profile Examples

- HTD: high torque drive
  - Common curvilinear tooth profile licensed by Gates Corporation and produced by multiple manufacturers
  - VEXPro sells self branded HTD timing belts in 9 and 15 mm widths with a 5 mm pitch
  - AndyMark sells Gates HTD timing belts with a 15 mm width and a 5 mm pitch
  - Good power transmission capabilities; not optimized for timing
- STD: super torque drive
  - Modified trapezoid tooth profile
  - Continental ContiTech manufactures this profile as Roulunds Rubber

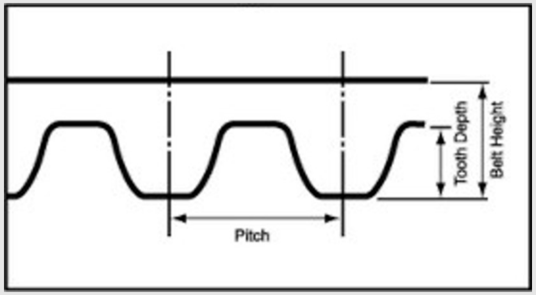
HTD



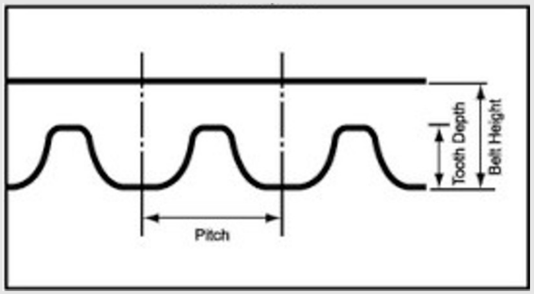
STD



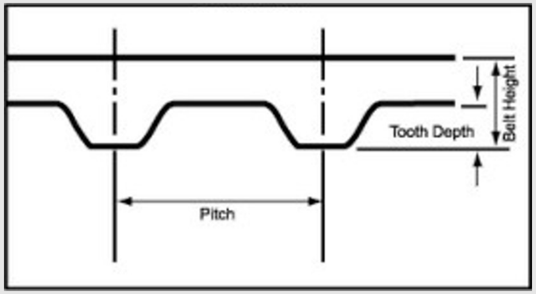
CTD



PowerGrip GT2



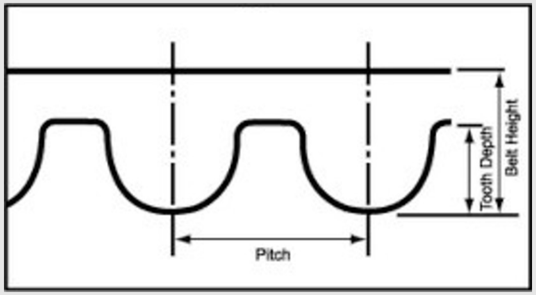
Trapezoidal



Tooth Profile Examples, continued

- CTD: Conti torque drive
  - Modified trapezoid tooth profile
  - Proprietary to Continental ContiTech
- PowerGrip GT2
  - Modified curvilinear tooth profile
  - Proprietary to Gates Corporation
  - Uses carbon fiber for tensile cord
  - Provides power to volume ratio comparable to or better than roller chain

HTD



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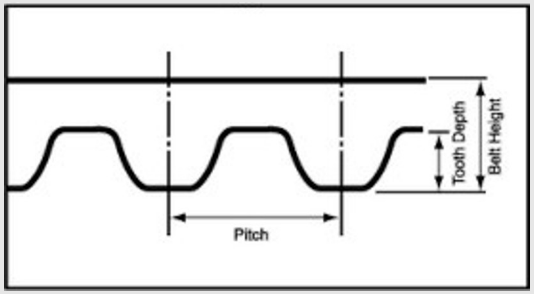
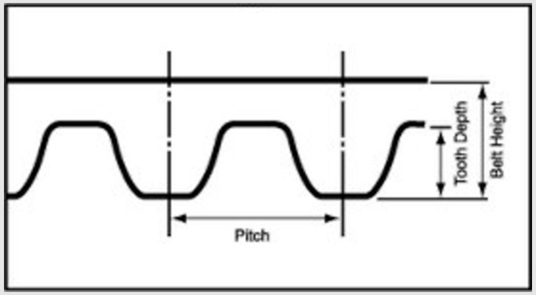
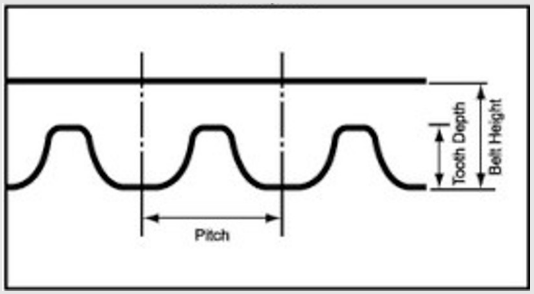


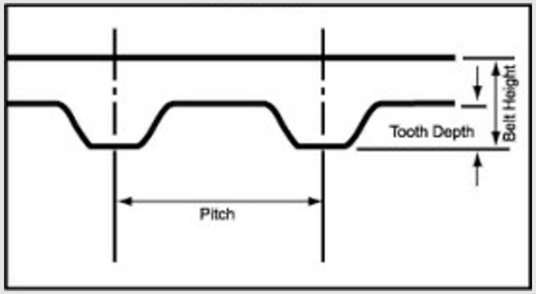
CTD



PowerGrip GT2



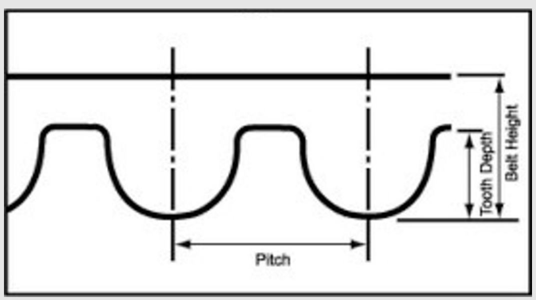
Trapezoidal



Tooth Profile Examples, continued

- Trapezoidal
  - Standard tooth profile produced by multiple manufacturers
  - Traces lineage back to original synchronous belt design
  - Good for timing applications; not optimized for power transmission
  - RMA set standards for six (6) pitches: MXL, XL, L, H, XH, XXH

HTD



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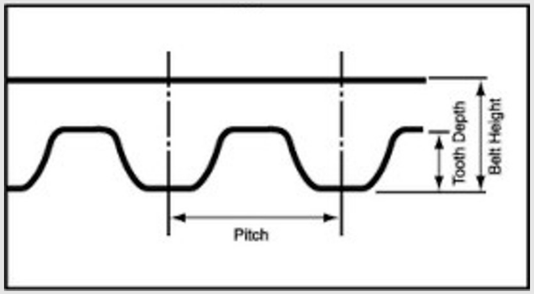
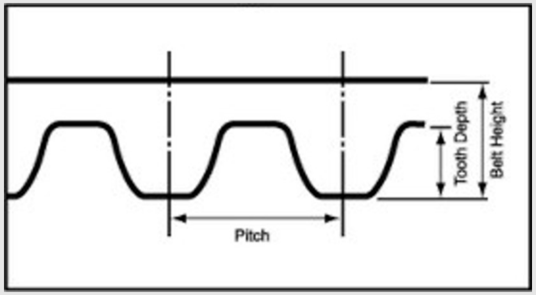
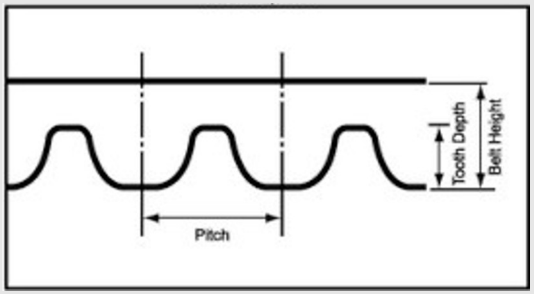


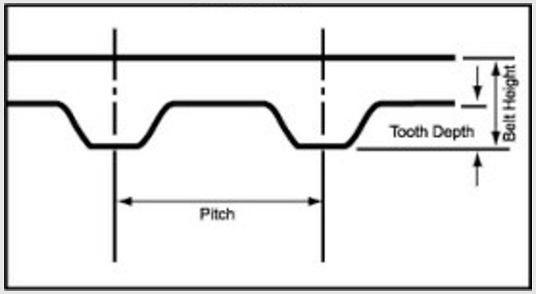
CTD



PowerGrip GT2



Trapezoidal



Pulley Fabrication Techniques and Materials

- Machined
  - Excellent dimensional accuracy
  - Economic for low to moderate production quantities
  - Steel offers excellent wear resistance
  - Aluminum has good wear resistance, but should be hard anodized when used for power transmission
- Powdered metal and die casting
  - Good dimensional accuracy
  - Economic for moderate to large production quantities
  - Sintered iron offers excellent wear resistance
  - Sintered aluminum offers good wear resistance, light weight, and corrosion resistance
  - Die cast zinc has good wear resistance
- Plastic molding
  - Good dimensional accuracy
  - Economic for high production quantities
  - Best suited for light to moderate toque loads
  - Increased belt wear can result from abrasive fiber ends on the finished pulley surface

Synchronous Belt vs. Roller Chain

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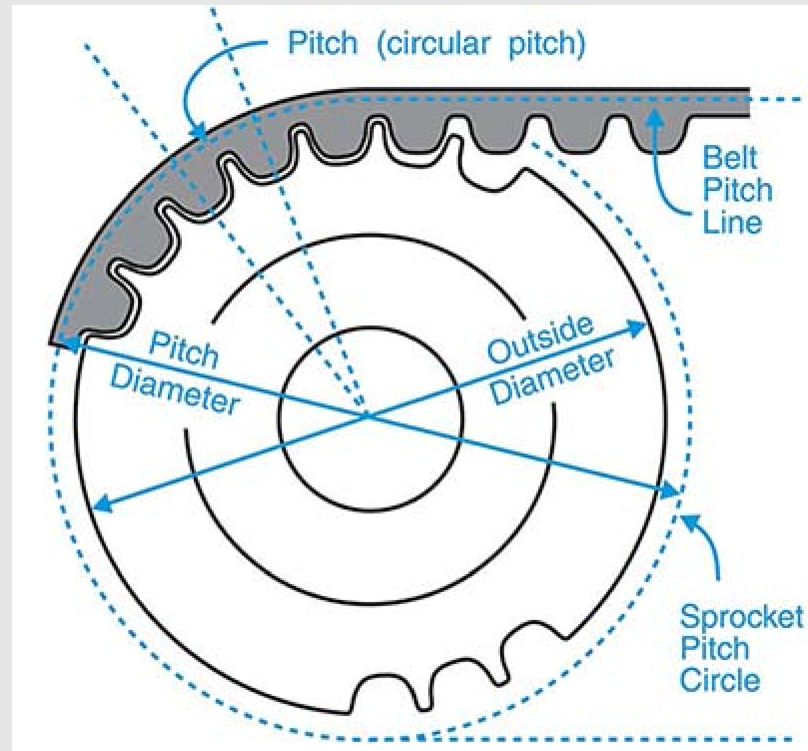
Consideration	Belt	Chain
Design flexibility		
Center to center distance flexibility		**win**
Readily available speed ratios		**win**
Power transmission		
Maximum torque/power	**tie**	**tie**
Maximum and sustained efficiency	**win**	
Speed capability		
Maximum speed	**tie**	**tie**
Speed fluctuation	**win**	
Maintenance		
Tension maintenance	**win**	
Lubrication	**win**	
Alignment	**win**	
Environmental tolerance		
Grease and oil		**win**
Rust	**win**	
Chemicals and contaminants	**win**	
Noise and vibration	**win**	
Cost		**win**

Pulley and Belt Geometry

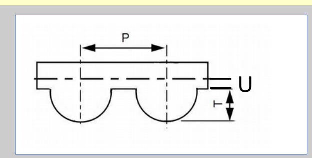
- The pitch diameter of the synchronous pulley is larger than the pulley outside diameter (OD)



$$pitch\,diameter\,(pd) = \frac{P * N}{\pi}$$

where P = pitch
N = number of pulley teeth

- While the belt is in contact with the pulley, the reinforcing cord centerline will coincide with the pitch diameter
- At the same time, the outside diameter of the pulley will be in contact with the bottom of the belt tooth
- The distance, U, between the reinforcing centerline and the bottom of the belt tooth determines the OD of the pulley

Distance from Pitch Line to Belt Tooth Bottom “U”	Common Description	Pulley OD OD = pd - 2U
0.0150 inches	3 mm HTD	
0.0225 inches	5 mm HTD	
0.0270 inches	8 mm HTD	

Belt Side Force

- Synchronous belts will always track to one side
- Contributing factors from the drive
  - Misalignment: belts will normally track “downhill” to a state of lower tension or shorter center distance
  - Adjusting tension may alter or modify lateral travel
  - Vertical drives have a greater tendency to move laterally due to gravity
  - Belts that are wider than the pulley OD will have a strong tendency to travel laterally
  - Increasing the length to width ratio of the belt reduces the tendency to travel laterally
  - Short belts tend to exhibit higher tracking forces than longer belts
- Contributing factors from the belt
  - Twisted individual fibers comprise the belts tensile cords
  - In turn, the tensile cords run around the belt in a helical spiral
  - Even though most belts intermix the twist and spiral, belts still tend to travel laterally consistent with the right hand rule when spinning

Installation Considerations: Design

- Belts should be rated at only 1/15th of their respective ultimate strength
- For HTD belts, surface speed shall not exceed 6,500 feet per minute (33 meters/sec)
- Pulley diameter should never be smaller than the width of the belt
- To deliver rated power, a belt must have six (6) or more teeth in mesh with the grooves of the smaller pulley
- If the belt tensile cord and belt material have high tensile strength and minimal elongation, the belt will not effectively absorb shock loads. In designs with high shock load, consider belt materials and smallest pulley size for load alleviation.
- Belts drives are 95 to 99% efficient
- Surface speeds of less than 50 ft/min (0.25 m/s) are considered low speed
- Surface speeds of more than 1,300 ft/min (6.6 m/s) are considered high speed

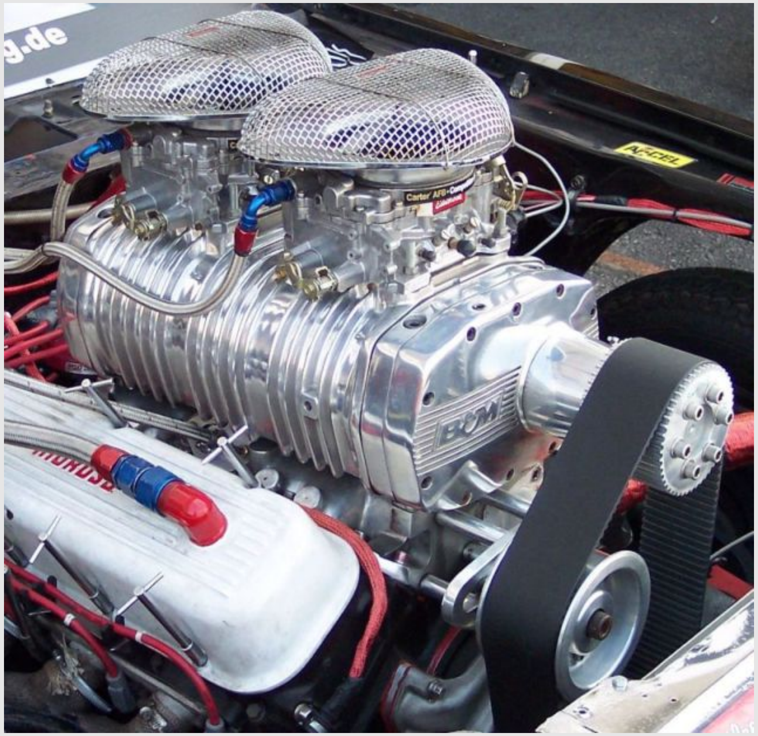
HTD Belt Minimum Pulley Size and Maximum RPM

Pitch		RPM	Suggested Minimum*		
			# of Grooves	Pitch Diameter	
inch	mm	maximum		inch	mm
0.118	3	3500	20	0.752	19.10
		1750	18	0.677	17.20
		1160	17	0.639	16.23
0.197	5	3500	30	1.880	47.75
		1750	26	1.629	41.38
		1160	22	1.379	35.03
0.315	8	3500	32	3.208	81.48
		1750	28	2.807	71.30
		1160	24	2.406	61.11

* Smaller pulleys than shown under "Suggested Minimum" may be used if a corresponding reduction in belt life is satisfactory.

Installation Considerations: Pulley Flanging

- On simple two pulley drives, one pulley should be flanged on both sides or both pulleys should be flanged on opposite sides
- For multiple pulley or serpentine drives, every other pulley should be flanged on both sides or every pulley should be flanged on alternating sides around the system
- On vertical shaft drives, at least one pulley should be flanged on both sides and the remaining pulleys should be flanged on at least the bottom side
- Belt drives with long spans, generally spans 12 or more times the diameter of the smaller pulley, should use pulleys flanged on both sides
- Large pulleys tend to require less lateral restraint than small pulleys and can often perform reliably without flanges
- Idlers are typically not necessary in belt drive systems, but when used, generally do not need flanges



Installation Considerations: Operating Environment

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- Dust: Not usually a problem for synchronous belt drives, but will accelerate pulley and belt abrasion. Damp or sticky particulate matter deposited and packed into pulley grooves will increase belt tension.
- Debris: Generally not a good idea
- Water: Light and occasional contact with water should not seriously affect synchronous belts. Prolonged contact significantly reduces tensile strength in fiberglass belts and causes length variation in aramid belts. Water also causes rubber components to swell and internal belt adhesion systems to fail.
- Oil: Light contact with oils on an occasional basis will not usually damage synchronous belts. Prolonged contact significantly reduces service life. Lubricants cause rubber compounds to swell, breakdown internal adhesion systems, and reduce belt tensile strength.
- Ozone: Detrimental to the compounds used in rubber synchronous belts. In the presence of ozone, chemical breakdown eventually occurs causing the belt to become hard and brittle and begin cracking.
- Radiation: Exposure to gamma radiation can degrade rubber and urethane belts
- Static electricity: Synchronous belts generate static electricity and should not be placed in very close proximity to electrostatic discharge (ESD) sensitive components

Belt Tensioning

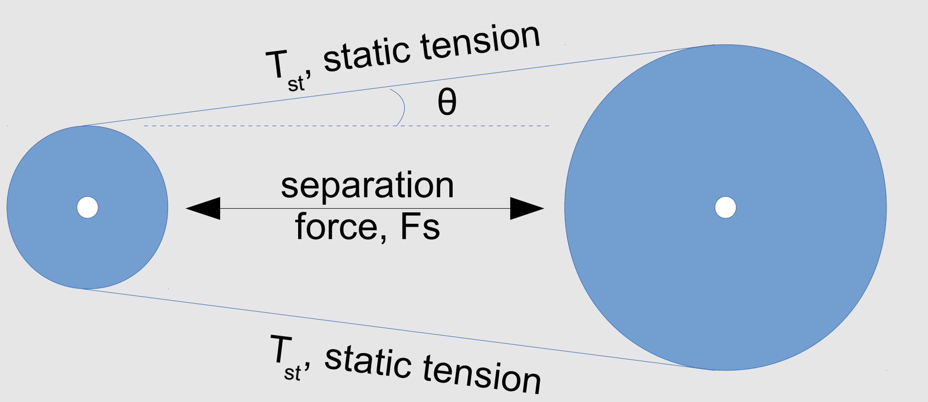
- Synchronous belt drives need less tension than comparable V-belt drives, but proper tension is still important
- Belt installation tension is needed to maintain proper fit with pulleys under load and prevent belt ratcheting under peak loads
- Static tension per span for drives with service factor greater than 1.3:

$$T_{st} = \frac{0.812 * DQ}{d} + m * S^2$$

where:
- T_{st} = static tension in each span (lb)
- DQ = driver design torque (in-lb)
- d = driver pitch diameter (in)
- S = belt speed/1000 (ft/min)
- m = mass factor, see table

HTD Belt Mass Factor and Minimum Span Tension				
Pitch		Belt Width	m	Minimum T_{st} per span
inch	mm	mm		lb
0.118	3	6	0.068	2.5
		9	0.102	4.3
		15	0.170	7.8
0.197	5	9	0.163	6.3
		15	0.272	12.0
		25	0.453	21.3

$$F_s = 2T_{st} \cdot \cos(\theta)$$



Synchronous Belt Drive Alignment Guidelines

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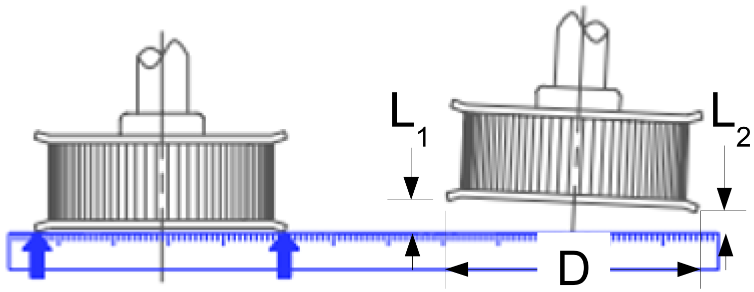
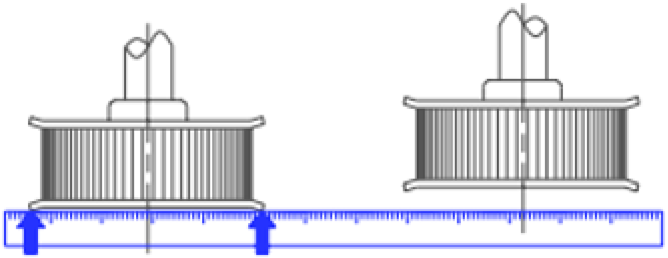
- Misalignment is one of the most common causes of premature belt failure
- In synchronous belts, angular misalignment causes high tracking forces, uneven tooth and land wear, edge wear, and potential tensile failure due to uneven cord loading
- Within reason, parallel misalignment is not an issue for synchronous belts
  - As long as the width between opposite flanges is less than the belt width, the belt will align itself
  - Synchronous belts normally operate with the belt lightly contacting at least one of the pulley flanges
- In general, the total misalignment for a synchronous belt should not exceed 0.25 degrees or 1/16 inch per foot traveled

$$Misalignment = \arctan\left(\frac{L_1 - L_2}{D}\right)$$



Angular Misalignment


Parallel Misalignment

Measurement of Belt Length

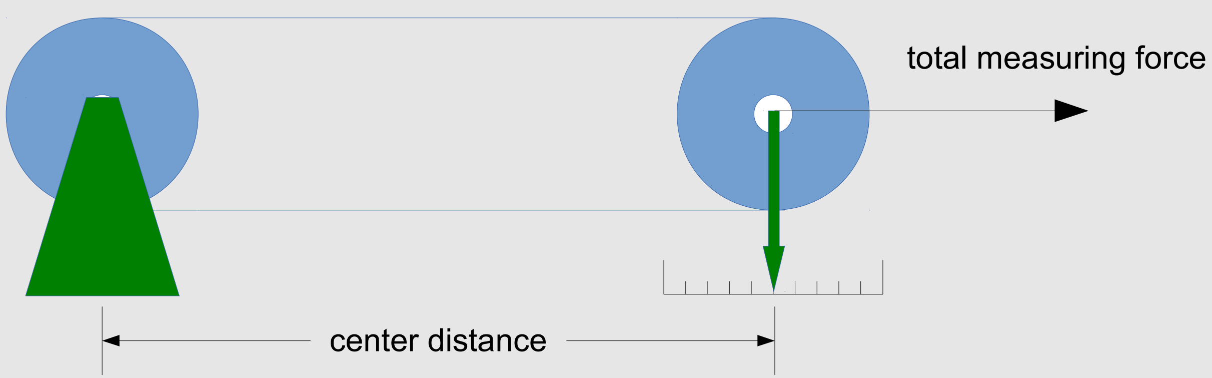
- Determine the pitch length of a synchronous belt with a measuring fixture comprising two pulleys of equal diameter, applying tension, and measuring the center distance between the two pulleys
- Hold one of the pulleys in a fixed position while pulling the other along a graduated scale to apply a measuring tension per the following table

Total Measuring Tension			
Belt Width		Measuring Force	
inch	mm	lbf	N
0.25	6.4	8	36
0.31	7.9	10	44
0.37	9.5	12	53
0.50	12.7	24	105
0.75	19.1	40	180
1.00	25.4	55	245

$$Belt\ pitch\ length = 2C + N_{pulley} * Pitch$$

$$C = \frac{Pitch * (N_{belt} - N_{pulley})}{2}$$

where C is center distance in the same units as pitch



Drive Ratio Calculation

- For a given belt size, drive ratio or speed ratio is determined by the number of teeth on the larger and smaller pulleys
- N1 is the number of teeth on the larger pulley
- N2 is the number of teeth on the smaller pulley
- The drive ratio is

$$drive\,ratio = \frac{N1}{N2} \text{ or } \frac{N2}{N1}$$

- Approximate minimum center distance for this drive ratio depends on belt pitch thus

$$C_{min} = \frac{N1 + N2}{2\pi} * (belt\ pitch)$$

- Gates Corporation publishes tables for drive ratio pulley selection

N1/N2	N2/N1	N1	N2	C min
1.067	0.938	16	15	4.934
		32	30	9.868

Center Distance Calculation

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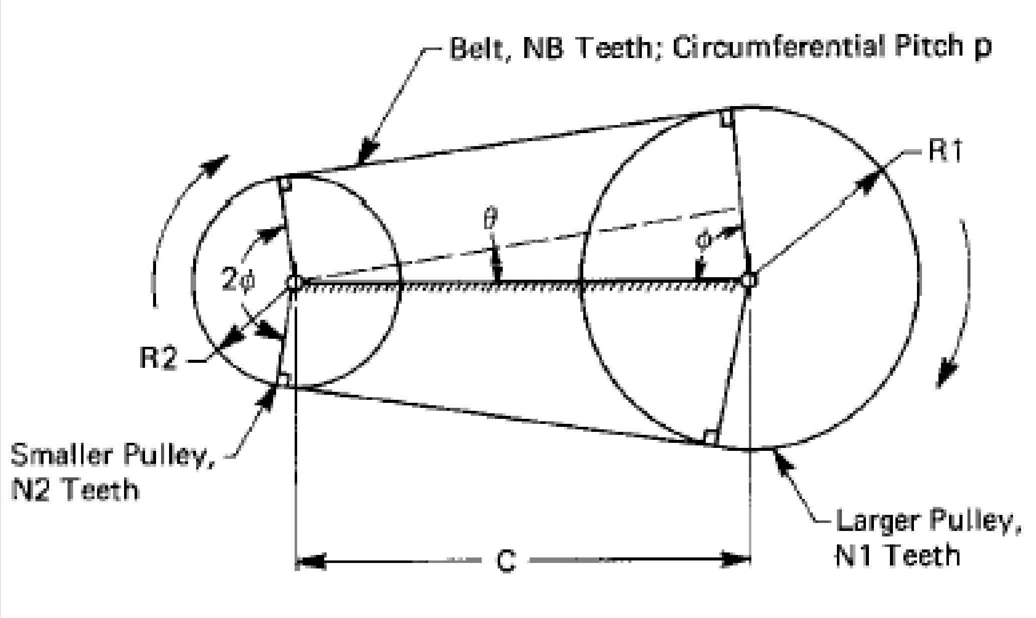
C	center distance (units)
L	belt length (p*NB) (units)
p	pitch of belt (units)
NB	number of teeth on belt (L/p)
N1	number of teeth on larger pulley
N2	number of teeth on smaller pulley
φ	half angle of wrap on smaller pulley (radians)
θ	π/2 – φ; angle between straight belt and line of centers (radians)
R1	pitch radius of larger pulley
R2	pitch radius of smaller pulley



The basic equation for determination of center distance is

$$2C*\sin(\phi)=L-\pi*(R1+R2)-(\pi-2\phi)*(R1-R2)$$

where

$$2C*\cos(\phi)=R1-R2$$

Exact Center Distance Calculation

Unequal pulleys

$$C = \frac{p * [(NB - N1) + k * (N1 - N2)]}{2}$$

where

$$k = \frac{1}{\pi} * [\tan(\frac{\pi}{4} - \frac{\phi}{2}) + \phi]$$

and φ (radians) is determined from

$$\frac{\tan(\phi) - \phi}{\pi} = \frac{NB - N1}{N1 - N2}$$

Calculate center distance as follows:

1. Select values of N1, N2, and NB
2. Compute (NB – N1)/(N1 - N2)
3. Solve for φ numerically
4. Compute k
5. Compute C

An exact center distance calculator is available at www.sdp-si.com

Equal pulleys

$$C = \frac{p * (NB - N1)}{2}$$

Number of Teeth in Mesh

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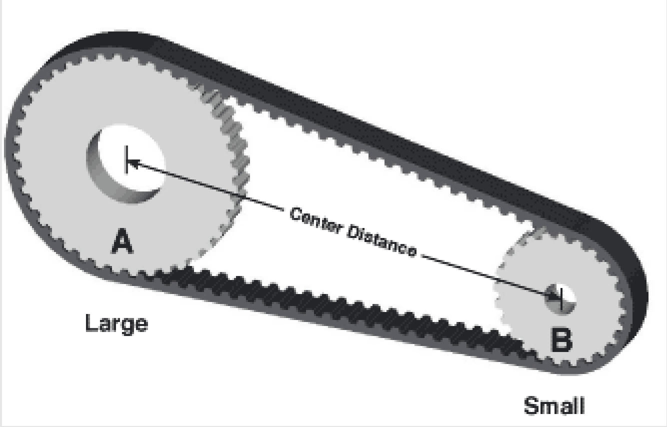
- As mentioned previously, a synchronous belt must have six (6) or more teeth in mesh with the grooves of the smaller pulley to deliver rated power
- The number of teeth in mesh (TIM) is

$$TIM = \frac{\phi * N2}{\pi}$$

- N2, the smaller pulley, will have fewer engaged teeth than the larger pulley



Synchronous Belt Drive Selection Procedure: Step 1

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Step 1: Determine the design load

- Base the drive design on the smaller pulley, which will be subjected to higher speed
- Use a service factor of 1.5 to 2.0 when designing small pitch synchronous drives
  - Higher service factors apply for applications with high peak, high operating speeds, unusually sever operating conditions, etc.
  - We'll use 1.75
- Use the driver stall torque
- For this example, we will use a motor providing 21.5 in-lb torque at stall with 5,310 rpm maximum

$$T_{peak} = T_{stall} * 1.75$$

$$T_{peak} = 21.5 * 1.75$$

$$T_{peak} = 37.6 \text{ in-lb}$$

CIM			
Condition	Torque, in-lb	Speed, rpm	Power, hp
Free load	0.0	5,310	0.000
Normal load	4.0	4,320	0.275
At max efficiency	2.8	4,614	0.206
At max power	10.7	2,655	0.452
At stall	21.5	0	0

Synchronous Belt Drive Selection Procedure: Step 2

Step 2: Select belt type and pitch, then confirm belt pitch

- Synchronous belt type selection depends on design application
  - Trapezoidal tooth profiles provide less backlash, but transmit less power
  - HTD belts provide good power transmission, but have more backlash
  - Proprietary belts like the Gates GT3 provide the lowest volume solution with good backlash performance, but cost more
- Since 5 mm pitch HTD belts are readily available to us, we will proceed with this belt type
- A 5 mm HTD belt works with a 37.6 in-lb peak torque and maximum speed of 5,310 rpm

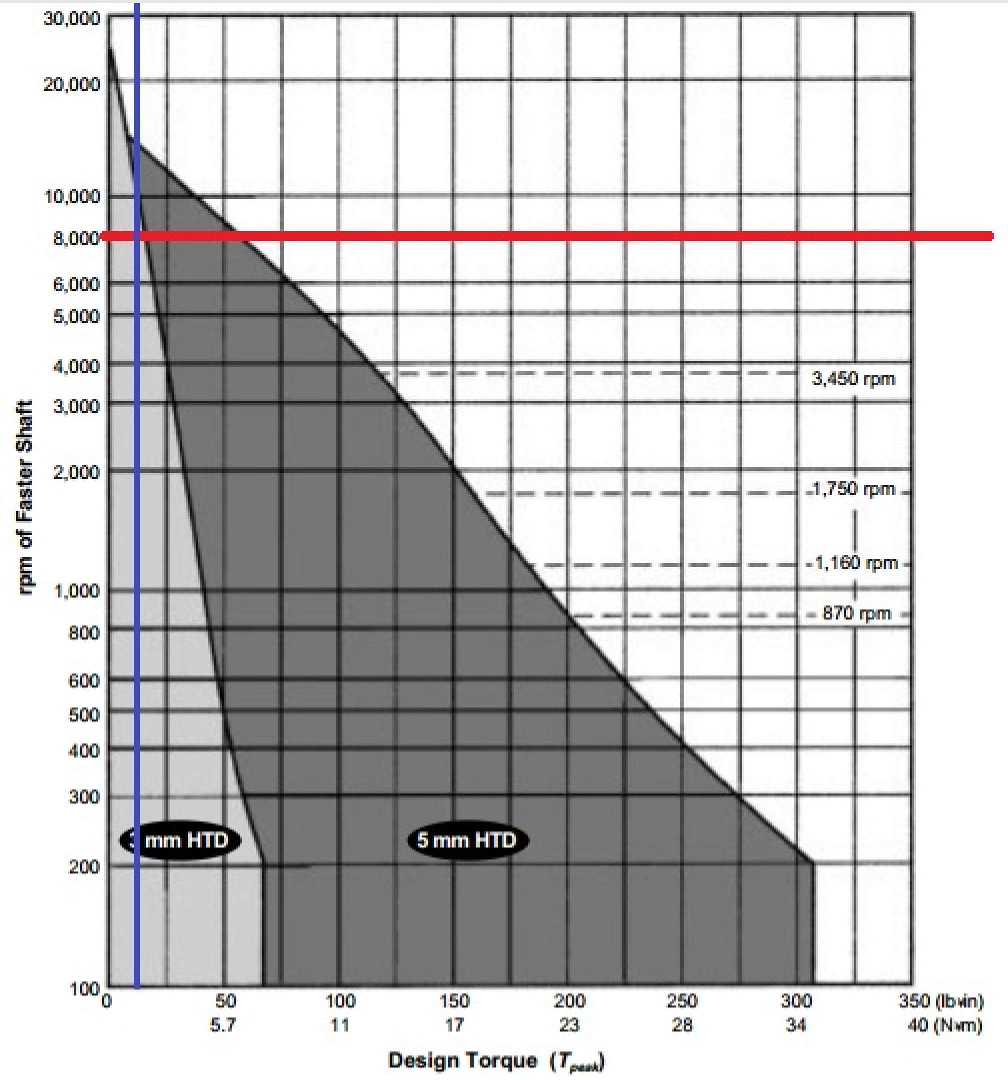

Fig. 42 HTD Belt Selection Guide

Synchronous Belt Drive Selection Procedure: Steps 3 to 5

Step 3: Select small and large pulleys based on the desired drive ratio

- Use the calculation procedure shown earlier for drive ratio
- Select available stock sizes for greatest economy
- We'll use 0.938 for this example to yield a 30 tooth small pulley (1.880 in PD) and a 32 tooth large pulley (2.005 in PD)

Step 4: Check that belt speed is less than 6,500 fpm (33.02 fps)

$$V\left(fpm\right) = 0.262 * pulley\,PD\,(\text{in}) * pulley\,rpm$$

$$V\left(fpm\right) = 0.262 * 1.880\,(\text{in}) * 5{,}310\,rpm$$

$$V = 2{,}615\,fpm$$

Step 5: Determine belt length

- The application drives the desired center distance of the pulleys
- Selecting a readily available belt length will reduce cost and schedule constraints
- Use the known pulley diameters, center distance calculation, and belt length calculation shown earlier to select an available belt length (www.sdp-si.com is convenient here)

Synchronous Belt Drive Selection Procedure: Step 6

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Step 6: Determine the belt width

- From the table on the following page, the uncorrected torque rating for a 5 mm pitch HTD belt that is 9 mm wide, operating on a 30 tooth pulley at 5,000 rpm is 20.4 in-lb
- Since we must size for 37.6 in-lb torque, use a correction factor of 1.89 for a 15 mm wide belt
- Let's assume we want a center distance of approximately 10 inches. Our center distance calculations indicate that a 131 tooth belt meets our need for a center distance of 9.823 inches. Apply a length correction factor of 1.00 for a 131 tooth belt.
- Apply the correction factors

$$T_{corrected} = 20.4 * 1.89 * 1.00 \ \text{in-lb}$$

$$T_{corrected} = 20.4 * 1.89 * 1.00 \ \text{in-lb}$$

$$T_{corrected} = 38.6 \ \text{in-lb}$$

- An HTD belt with 5 mm pitch, 15 mm wide, and 131 teeth meets our design conditions
- AndyMark sells that belt

Gates HTD Belt Rated Torque Table

[HT]^3

5 mm Pitch PowerGrip HTD Belts

Belt width (mm)	9	15	25
Width multiplier	1.00	1.89	3.38

Rated torque (in-lb) for small pulleys – 9 mm belt width

	Groove Count	14	16	18	20	22	24	26	28	32	36	40	44	48	56	64	72
Pitch Diameter	mm	22.28	25.46	28.65	31.83	35.01	38.20	41.38	44.56	50.93	57.30	63.66	70.03	76.39	89.13	101.86	114.59
	inch	0.877	1.003	1.128	1.253	1.379	1.504	1.629	1.754	2.005	2.256	2.506	2.757	3.008	3.509	4.010	4.511
rpm of fastest shaft	**10**	19.0	22.3	25.7	29.3	33.0	36.9	40.9	45.1	53.8	63.1	73.0	83.5	94.5	113.3	129.5	145.7
	20	19.0	22.3	25.7	29.3	33.0	36.9	40.9	45.1	53.8	63.1	73.0	83.5	94.5	113.3	129.5	145.7
	40	19.0	22.3	25.7	29.3	33.0	36.9	40.9	45.1	53.8	63.1	73.0	83.5	94.5	113.3	129.5	145.7
	60	19.0	22.3	25.7	29.3	33.0	36.9	40.9	45.1	53.8	63.1	73.0	83.5	94.5	113.3	129.5	145.7
	100	19.0	22.3	25.7	29.3	33.0	36.9	40.9	45.1	53.8	63.1	73.0	83.5	94.5	113.3	129.5	145.7
	200	19.0	22.3	25.7	29.3	33.0	36.9	40.9	45.1	53.8	63.1	73.0	83.5	94.5	113.3	129.5	145.7
	300	17.3	20.2	23.3	26.5	29.9	33.3	36.9	40.6	48.3	56.5	65.2	74.4	84.0	100.4	114.8	129.1
	400	16.2	18.9	21.8	24.7	27.8	31.0	34.3	37.7	44.8	52.3	60.2	68.5	77.2	92.2	105.3	118.5
	500	15.3	17.9	20.6	23.4	26.3	29.3	32.4	35.6	42.2	49.2	56.5	64.3	72.3	86.2	98.5	110.8
	600	14.7	17.2	19.7	22.4	25.1	28.0	30.9	33.9	40.2	46.8	53.7	61.0	68.5	81.7	93.3	104.9
	700	14.2	16.5	19.0	21.6	24.2	26.9	29.7	32.6	38.6	44.9	51.5	58.3	65.5	78.0	89.1	100.1
	800	13.7	16.0	18.4	20.9	23.4	26.0	28.7	31.5	37.2	43.3	49.6	56.1	63.0	74.9	85.5	96.2
	870	13.5	15.7	18.0	20.4	22.9	25.5	28.1	30.8	36.4	42.3	48.4	54.8	61.4	73.0	83.4	93.7
	1000	13.0	15.2	17.4	19.8	22.1	24.6	27.1	29.7	35.1	40.7	46.5	52.6	58.9	70.0	79.9	89.8
	1160	12.6	14.7	16.8	19.1	21.3	23.7	26.1	28.6	33.7	39.1	44.6	50.4	56.4	66.9	76.3	85.7
	1400	12.0	14.0	16.1	18.2	20.4	22.6	24.9	27.2	32.0	37.1	42.3	47.7	53.2	63.1	71.9	80.7
	1450	11.9	13.9	15.9	18.0	20.2	22.4	24.6	27.0	31.7	36.7	41.9	47.2	52.7	62.4	71.1	79.8
	1600	11.7	13.6	15.6	17.6	19.7	21.8	24.0	26.3	30.9	35.7	40.7	45.8	51.1	60.4	68.9	77.2
	1750	11.4	13.3	15.2	17.2	19.2	21.3	23.5	25.6	30.1	34.8	39.6	44.6	49.7	58.7	66.8	74.9
	1800	11.3	13.2	15.1	17.1	19.1	21.2	23.3	25.5	29.9	34.5	39.3	44.2	49.2	58.2	66.2	74.1
	2000	11.1	12.9	14.7	16.6	18.6	20.6	22.7	24.7	29.0	33.5	38.1	42.8	47.6	56.2	63.9	71.4
	2500	10.5	12.2	13.9	15.7	17.6	19.4	21.3	23.3	27.3	31.4	35.6	39.9	44.2	51.9	58.8	65.5
	3000	10.0	11.7	13.3	15.0	16.7	18.5	20.3	22.1	25.8	29.7	33.5	37.5	41.5	48.5	54.6	60.5
	3600	9.6	11.1	12.7	14.3	15.9	17.6	19.3	21.0	24.4	27.9	31.5	35.1	38.6	44.8	50.1	55.0
	5000	8.8	10.2	11.6	13.1	14.5	15.9	17.4	18.9	21.8	24.7	27.6	30.4	33.1	37.4	40.6	43.0
	8000	7.8	8.9	10.1	11.2	12.3	13.4	14.4	15.4	17.3	19.0	20.4	21.5	22.3	*	*	*
	10000	7.2	8.2	9.2	10.1	11.0	11.9	12.7	13.4	14.5	15.3	*	*	*	*	*	*

For Belt Length							
	From	length (mm)	**350**	**440**	**555**	**845**	**1095**
		# of teeth	**70**	**88**	**111**	**169**	**219**
	To	length (mm)	**435**	**550**	**840**	**1090**	**1100 & up**
		# of teeth	**87**	**110**	**168**	**218**	**220 & up**
	Length correction factor		0.80	0.90	1.00	1.10	1.20

Torque values within this table should be multiplied by the factor for belt width and the factor for belt length to determine the corrected rated torque capacity.

Shaded area indicates drive conditions w here reduced service life can be expected.

Synchronous Belt Drive Selection Procedure: Step 7

[HT][3]

Step 7: Check the number of teeth in mesh

- Calculate the arc of contact

$$arc\ of\ contact = 2 * \arccos\left(\frac{PD - pd}{2C}\right)$$

$$arc\ of\ contact = 2 * \arccos\left(\frac{2.0051 - 1.8798}{2 * 9.8423}\right)$$

$$arc\ of\ contact = 179.27\ deg$$

- Calculate the number of teeth in mesh

$$\text{teeth in mesh} = \frac{arc\ of\ contact * n}{360}$$

$$\text{teeth in mesh} = \frac{179.27 * 30}{360}$$

$$\text{teeth in mesh} = 14$$ (rounded down)

C	center distance (units)
PD	Large pulley pitch diameter (units)
pd	Small pulley pitch diameter (units)
n	Number of teeth on the small pulley

Synchronous Belt Drive Selection Procedure: Wrap

Step 8: Calculate the belt installation tension

Step 9: Procure the components

Step 10: Install

Gates FRC Support

4014 [HT]³

- In 2015, Gates offered FRC teams the chance to custom order up to five (5) belts and/or pulleys free of charge
  - Belts are only available in 5 mm pitch and 15 mm widths
  - Pulleys are aluminum and match the belts
  - Gates allocates a quantity of 500 of each belt or pulley for FIRST use
  - First come first served. Once out of a particular belt or pulley, no more of that belt or pulley are available free.
  - Orders ship in about three (3) days after processing
- Gates also provides some online calculators here http://ww2.gates.com/FIRST/resources.html

The Scholarship

[HT]3

- Gates FIRST Robotics Scholarship (2015)
  - One (1) scholarship awarded
  - Four (4) year scholarship
  - $4,000 per year
- Requirements
  - Be a senior in high school during the competition year
  - Have participated on an FRC team during the competition year
  - Provide evidence that your FRC team used a belt on your competition robot
  - Enroll in a four (4) year college with a declared engineering major
- 2015 application package required
  - A completed Gates FIRST Scholarship Online Application
  - A one page or shorter answer to the Gates 2015 Challenge Question, uploaded as a Word doc, PDF or image file. The 2015 Challenge Question will be posted on this website (www.gates.com/FIRST) after the 2015 FRC Kickoff.
  - A one page or shorter letter of recommendation from an adult mentor/coach on your FIRST team, confirming the use of a belt drive on the competition robot and your participation in the 2015 FRC season, uploaded as a Word doc, PDF or image file.

Questions

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References

1) The World of Timing Belts, Gates Corporation

2) Center distance calculator
http://www.sdp-si.com