



A Practical Guide to Pulley Alignment

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INTRODUCTION

The purpose of producing this handbook is to provide basic information and guidelines for the implementation of good pulley alignment for standard belt-driven systems.

Laser alignment is an essential component of a viable maintenance strategy for machines. In isolation each strategy can help to reduce unexpected machine failure but taken together they form the hub of a proactive maintenance strategy that will not only identify incipient problems but allows extending machine operating life considerably.

In this handbook we have used one or two examples of the available methods for measuring the required parameters. We do not suggest that the methods illustrated are the only ones available.

We hope that this information is presented in a clear readable form and that it will provide for the reader new to the subject a platform to successfully apply profitable maintenance practice in their plant.

We are indebted to our colleagues in Pruftechnik AG (Germany) and our associates at Ludeca Inc. (USA) for permission to reproduce some of the graphics used in this handbook. Additionally, we have drawn on information previously published in Pruftechnik equipment handbooks for information on alignment standards, and graphical and mathematical methods. For this information we are grateful.

Pulley Alignment

The use of flexible belt drives represents a significant percentage of all industrial power transmission applications, particularly when the speed of the driver and driven shafts are different or where shafts have to be widely separated. There are obviously a number of design factors that preclude the use of flexible belts, but where appropriate such drives offer an efficient and economic design solution with some useful advantages over other means of power transmission including:

- Very high efficiency
- Overall economy
- Cleanliness
- No need for lubrication
- Low maintenance costs
- Damping of shock loads
- Ability to be used for variable speed power transmission
- Ability to accommodate widely spaced shafts

The power that is transmitted by a belt during operation works on the rim of a pulley. Therefore, the belt on a pulley drive system must be tight enough to prevent slippage during operation. The forces that work during operation are not uniform around the entire belt length; there is always a tight side tension and a slack side tension. The difference between these tensions is often called by belt manufacturers the effective or net pull. This effective pull is applied at the rim of the pulley and is the force that produces work.

The design of pulley systems and the selection of correct belt design and application are by no means simple. The number and variety of available belt types is a testament to this. V-belts, flat belts, wedge belts, synchronous belts and others all have their specific design and application criteria, and within each design section there are numerous different configurations, cross sections and operating criteria. It is not the purpose of this section to consider either belt design or selection criteria in detail; it is however useful to note the following basic design criteria:

- The maximum center to center distance of pulleys should be around 15 times that of the pitch of the smallest pulley, and should not exceed 20 times the pitch of this pulley. Greater distances than this require tight control of belt tension because a small amount of stretch will cause a large drop in belt tension, creating slippage and reducing power transmission efficiency.

During operation a flexible belt experiences three types of forces as it rotates around a pulley:

- Working tension (tight side - slack side)
- Bending
- Centrifugal force

Belts are designed to withstand these working operation states (provided that pre-selection of the belt meets the operating criteria.) The design life of the belt will be achieved and usually exceeded provided that no forces other than the above act upon the belt during its operating life. Forces generated by such conditions as misalignment

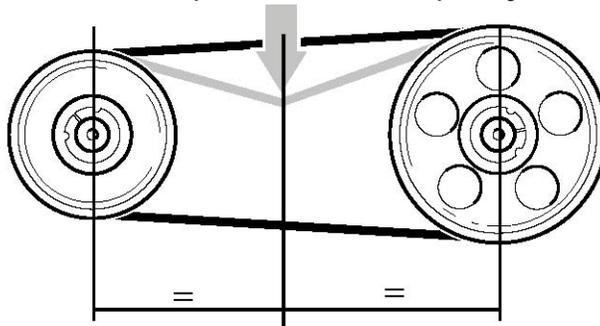
and loose or over tight belts are killers of flexible belt drives. Useful operating life can be reduced by as much 80% by poor pulley alignment. In addition to belt wear, the pulleys, bearings and seals can all be damaged by inattention to basic installation requirements.

Belt Tension

The required tension for new and used belts is virtually always specified by the belt manufacturers and these specifications should always be followed meticulously. If there is no specification, then the following guide to belt tension may be applied:

Tension load = the distance in inches between the axes of the driver and driven shafts $\times 0.1$ inch (1.0mm)

Max deflection = 0.010" per inch of total pulley center distance.



After tensioning and alignment start the machines, and after a running period of 48 hours the tension on the new belts should be re-checked and if necessary re-tightened to correct any mid span deflection that exceeds the tension specification. It is advisable to use a custom designed belt tension testing device for accurate and repeatable measurement of belt tension. Periodic checking of each belt drive will quickly identify any drives that need tightening (or loosening) before incipient damage to the belts and other components cause premature failure.

If you are not sure of the belt span length you may also use the center-to-center distance of the pulleys, which will be similar. Tension the belts until the force required for this deflection equals the belt manufacturer's maximum recommended force values for the specific belts you are using. Also make certain this force does not exceed the machinery's design loads. The force values for all belts should fall within 10% of each other. Using a matched set of belts and having a good alignment are essential in achieving this goal.

The final step is to run the machines for about two hours to allow the belts to stretch and seat themselves properly in the grooves. The belts must then be re-tensioned to the recommended values. Now run the machines at least 72 hours, but not more than 10 days, and re-tension once again, this time to the manufacturer's recommended force values for used belts.

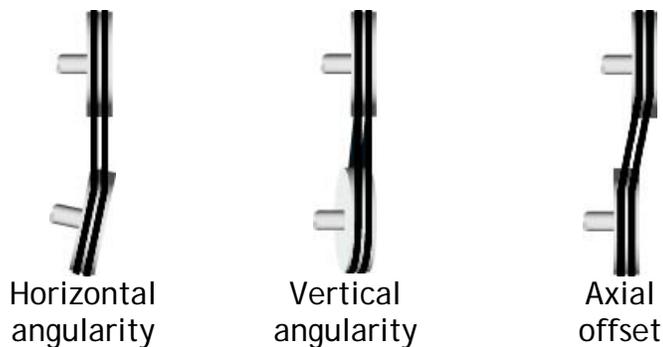
Pulley Alignment

By far the most common and damaging installation error that occurs on belt drives is that of misalignment of the driving and driven pulleys. This is not usually due to carelessness on the part of the installer; it is more often due to a lack of suitable tools with which to carry out the required alignment. For many years at best a tight wire or straight edge were the only available tools with which to do the job.

Both methods rely entirely on the installer's eyesight to ensure that the alignment is correct. Neither method has any measurements documented, both rely upon the installer adjusting the driven pulley until the faces or grooves of the driven pulley touch the surface of the straight edge or tight wire. The driven pulley is then rotated half a turn and then rechecked and adjusted. The measurement is then repeated until the pulleys appear to be in line. No angularity or inaccurate mounting of the reference line is measurable. The system is purely an estimate of the alignment of the two pulleys.

Types of pulley misalignment

There are three basic parameters that describe pulley misalignment. These are horizontal angularity, vertical angularity and axial offset. These conditions usually occur in any or all combinations of alignment condition.



Pulley Run Out

In addition to correct alignment of the pulleys, the run-out errors of the pulley should also be measured and corrected. The two types of run-out - rim (radial) and face (axial) should be corrected until they meet tolerance before final alignment of the pulleys takes place. If this is not corrected the effect could be that the belts slacken off at one position and then snap into tension at the opposite position.

This continuous snapping action if not corrected quickly wears out belts and bearings. The tolerance for radial or rim run-out on high speed pulleys (1500 rpm and higher) should not exceed 0.005 inches (0.12mm) total indicator reading (T.I.R.) on average, and may be increased up to 0.01 inches (0.24mm) on slower pulley drives. The tolerance for axial or face run-out should not exceed 0.0005 inches per inch (0.05mm per 100mm) of pulley diameter for high-speed pulleys, and may be increased up to 0.001 inches per inch (0.1mm per 100mm) of pulley diameter for slower pulley drives.

Check that the offset from the pulley mounting face to the groove is the same for both pulleys.

The pulley or machine manufacturers' tighter tolerance recommendations should be followed where possible. Start by checking for radial run-out if unsatisfactory, check for shaft run-out. If excessive run-out is present on the shaft it may be bent and must be replaced before radial run-out on the pulley is checked again. If no shaft run-out is detected, replace the pulley instead. If the pulley is mounted on a tapered shaft bushing, inspect and clean the bushing both inside and out to ensure proper seating. Now check for face (axial) run-out and, if necessary, correct it by repositioning the pulley on its shaft. When run-out is in tolerance, proceed to install new belts.

Drive Belt Fitting

Clean pulleys of all foreign matter with a stiff brush and not a wire brush as this can damage the surface of the groove walls. Use the "go-no-go" profile gauges that can be obtained from the belt manufacturer to ensure the pulley condition is acceptable for the fitting of new belts. Replace any pulleys with worn, chipped or cracked groove surfaces.

Install new belts on the pulleys so that the slack sides of all belts are on the same side at either top or bottom of the drive. **DO NOT UNDER ANY CIRCUMSTANCES** install belts by prying them onto pulleys by any forcible method; belts should be fitted by hand pressure only. De-tension the motor to allow this fitting to be effected without undue pressure. In the case of multiple belt drives, when replacing belts, even where only one belt appears worn, all belts should be replaced together. Only belts from the same manufacturer should be combined together, preferably a factory matched set. After replacing belts it is worth examining the replaced belts for noticeable defects such as cracking or glazing. The condition of the belt is a good indication of the type of installation problems. Uneven wear or cracking on belt sides are a good indication of misalignment; glazing on the contact surface of the belts, indicates slipping and therefore, poor belt tension.

Checking Soft Foot

Having mounted the belts and positioned the driver and driven units in their approximately correct position, a check on the soft foot condition of the moveable machine (usually the driver) is useful. Undetected soft foot can lead to distortion of the machine frame when bolted down, causing damage to bearings, seals and higher than acceptable vibration on machine bearings. To check for soft foot, use feeler gauges under each machine foot in turn (or a dial indicator mounted on a magnetic base). Loosen each foot in turn, measure any rise in the loosened foot and record it. Tighten the foot down and proceed to the next foot. Having established the type of soft foot (if any), shim as necessary and re-check each foot. As a guide, no reading of soft foot should be larger than 0.002 inches (0.05 mm).

Pulley Alignment

Having completed the soft foot check the drive is ready for alignment, whatever system is employed for this be it tight wire, straight edge or laser system the alignment should be as accurate as possible. The nominal recommended tolerance for belt drives is 0.5 degrees. Most major belt and pulley manufacturers specify this value. Better tolerances can be achieved if the alignment procedure is carefully followed. The table below converts the tolerance from degrees into offsets in mm per 100 mm and in thousandths of an inch per inch.

Angle of misalignment	Offset mm /100 mm	Offset in inches / inch
0.1°	0.18	0.00175
0.2°	0.35	0.00349
0.3°	0.52	0.00524
0.4°	0.70	0.00698
0.5°	0.87	0.00873
0.6°	1.05	0.01047
0.7°	1.22	0.01222
0.8°	1.40	0.01396
0.9°	1.57	0.01571
1.0°	1.74	0.01745

Note - values between 0.1° and 0.5° fall within recommended tolerance.

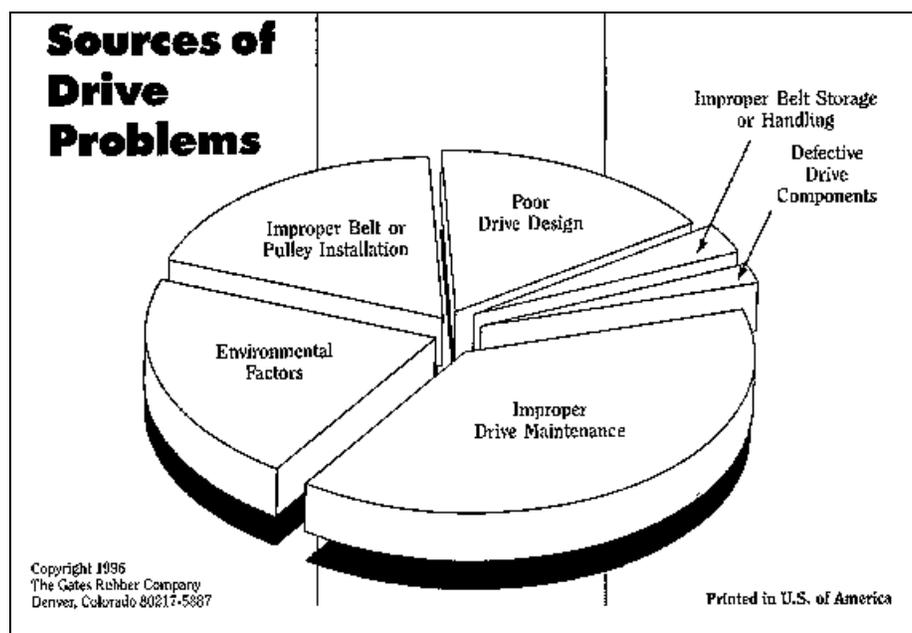
Sheave Maintenance

Good sheave alignment will increase efficiency by reducing premature wear or failure of belts, pulleys and bearings. This can be accomplished by several different alignment methods, such as the labor intensive string and straightedge method (most common), or by laser. The latter, in the form of the [DOTLINE LASER® Pulley Alignment Tool](#), is new to the sheave alignment field, but has proven itself in greatly reducing downtime and the manpower needed to do the alignment, while simultaneously achieving far greater accuracy. This results in great labor savings and increased production uptime.

A V-Belt drive is a very efficient method of power transmission (from 90 to 98%) and has traditionally been thought of as very forgiving; however, proper alignment and belt tension are extremely important and can make a huge difference in MTBR (Mean Time Between Repair). Good drive maintenance involves a number of steps, roughly half of which involve aligning the drive. These are, in order: Removing old belts, inspecting all components for wear and damage, checking for bent shafts and correcting sheave runout, installing new belts, performing the alignment, and tensioning the belts.

Your foremost concern should always be safety. *Never* allow loose neckties or long hair anywhere near belt-driven machinery, and make *certain* all equipment is locked out and tagged out.

Prior to beginning a sheave alignment, it is a good idea to try to determine (if possible) the cause of your belt or sheave failure, and correct it to prevent unnecessary reoccurrence. The cause of failure could be associated with poor drive maintenance (improper belt tension, poor sheave alignment), environmental factors (sunlight, harsh temperature fluctuations), improper installation (wrong belts/sheaves, belts pried on by force), or operating factors (overload, shockload).



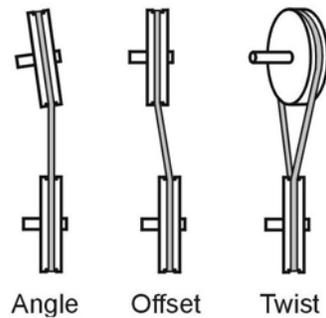
When embarking on belt drive maintenance, one important step, often forgotten, is to perform a close inspection of the belts and of each sheave and its grooves. This inspection should include looking (and feeling) for cracks, chips, or excessive groove wear, and checking for proper contact between the belts and the sheaves. Problems of this nature *must* be corrected before proceeding with anything else, to prevent premature or catastrophic failure.

Replacing belts only requires moving one sheave toward the opposing sheave, to slacken the belts. Replace a belt with a new belt of the correct length, material, and pitch angle. Never force a belt onto a sheave as this will damage the tensile member of the belt, or damage the sheave itself. If aligning a multiple-belt drive, replace all of the belts together, not singly, since new and used belts that are otherwise identical have greatly different operating and tensile characteristics. Only combine belts from the same manufacturer, and preferably use a factory-matched set. Inspect the removed belt for any noticeable defect (cracking, gouges or crumbling) and signs of slippage (glazing). Notice *where* the belt is worn. This may be a good indication of what type of misalignment or other problem might be in play. It is appropriate to change a belt anytime undue wear is detected. When replacing a belt, make sure you replace it with one that has been properly stored. Belts should be stored in a cool, dry place with no exposure to direct sunlight or heater drafts. Do *not* hang belts from a single peg; this may damage the tensile member and distort the belt over time. Preferably hang them from two pegs, or better yet pile them on shelves. Coil long belts, and don't make the piles too big or heavy, to avoid distorting the bottommost belts.

The next step of the process is to measure sheave run-out. There are two types of run-out: rim (radial) and face (axial), both of which must meet tolerance prior to actually performing final alignment corrections.

The tolerance for radial or rim runout on high speed sheaves (1800 R.P.M. and higher) should not exceed 5 mils total indicated reading (T.I.R.) on average, and may be increased to up to 10 mils on slower sheaves. The tolerance for axial or face runout should not exceed 0.5 mils per inch of sheave diameter (T.I.R.) for high speed sheaves, and may be increased to up to 1 mil per inch for slow sheaves. Always follow the sheave or machine manufacturer's tighter tolerance recommendations, if given. Start by checking for radial runout. If unsatisfactory, check for shaft runout. If excessive runout is also present on the shaft, it may be bent. If so, you must replace the shaft and check radial runout on the sheave again. If no runout on the shaft is detected, replace the sheave instead. If the sheave is mounted on a tapered shaft bushing, remember to inspect and clean the bushing both inside and out to ensure proper seating. Next check for face (axial) runout (wobble) and if necessary correct it by repositioning the sheave on its shaft. Once runouts are in tolerance, proceed to install new belts.

Place the new belts into the sheave grooves, reposition the sheaves to rough alignment, and check that the belts are properly seated within their grooves.



Now for the alignment: Misalignment consists of three types: Vertical angularity (twist), horizontal angularity, and axial offset, all of which can coexist in any combination.

There are several sheave alignment methods, the most common of which is the straightedge and string method, wherein these must touch each sheave at two diametrically opposite positions simultaneously (totaling four contact points). The sheaves should be rotated half a turn and checked again. Since a string can bend around corners, you cannot easily differentiate between offset and horizontal angle when only three-point contact is made; nor will a straightedge or a string detect twist angle under certain conditions. This method is also very labor and time intensive.

A fan-type laser such as that produced by the DOTLINE LASER Pulley Alignment Tool overcomes all of these problems. The DOTLINE LASER mounts magnetically to the face of sheaves as small as 2.5" diameter and projects a laser fan line onto three targets magnetically attached on the other pulley(s). All you need to do is ensure that the laser line lines up with the unit's targets. Using additional targets, other pulleys in the drive (such as inside or outside idlers) can all be aligned simultaneously. [Watch demo video.](#)

Always correct vertical or twist angle first by shimming the driver, then correct horizontal angularity by moving the driver with lateral jackscrews, and lastly correct offset by moving the driver with axial jackscrews, or by repositioning one of the pulleys on its shaft. (Be careful not to cock the pulley in so doing!) Since performing one alignment correction almost invariably affects the other alignment conditions, this process may have to be repeated several times. This is where a fan-line laser like the [DOTLINE LASER](#), [SHEAVEMASTER®](#) or [GREENLINE™](#) really pays off, since it allows you to monitor all three alignment conditions simultaneously, as well as greatly increasing the accuracy of the alignment. This makes the job far easier and faster.

The last step, after the sheaves have been aligned, is the proper tensioning of the belts. Incorrect tension (as well as misalignment) will adversely affect the life of the belts and the efficiency of the drive as a whole. Using a spring scale, press down on the belt in the approximate center of its span (on the tight side), to deflect the belt 1/64" per inch of span length and observe the force required to do so. If you are not sure of the belt span length you may also use the center-to-center distance of the pulleys, which will be similar. Tension the belts until the force required for this deflection equals the belt manufacturer's maximum recommended force values for the specific belts you are using. Also make certain this force does not exceed the

machinery's design loads. The force values for all belts should fall within 10% of each other. Using a matched set of belts and having a good alignment are essential in achieving this goal. It is tricky to move the driver to slacken or tighten the belts without changing the alignment! Here again the DOTLINE LASER Pulley Alignment Tool is invaluable, since all three of the alignment parameters can be monitored simultaneously for all sheaves while adjusting the tension.

The final step is to run the machines for about two hours to allow the belts to stretch and seat themselves properly in the grooves. The belts must then be retensioned to the recommended values. Now run the machines at least 72 hours but not more than 10 days and retension once again, this time to the manufacturer's recommended force values for used belts. ☐

[Pie chart courtesy of The Gates Rubber Company, *Belt Preventive Maintenance Manual*, Denver, 1996]

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