CONVEYOR PULLEY SELECTION GUIDE

11/2014

TABLE OF CONTENTS

INTRODUCTION

Conveyor pulleys play an essential role in the performance and reliability of belt conveyor systems worldwide. It is because of this essential role that pulley selection becomes a critical process in keeping equipment up and running. If selection is conducted in haste, a conveyor pulley may be inadequately sized and selected, leading to premature pulley failure and costly downtime.

This document is a step-by-step guide through the process of pulley selection. This selection guide is designed to assist in identifying and determining system loads so that pulley selection addresses the important variables in an application and is conducted as efficiently as possible.

TOPICS COVERED IN THIS DOCUMENT INCLUDE

DETERMINATION OF SYSTEM LOADS

Catenary Load
Take-Up Tension
Product Load and Loading Method
Pulley Weight
Pulley Position

PULLEY SIZING

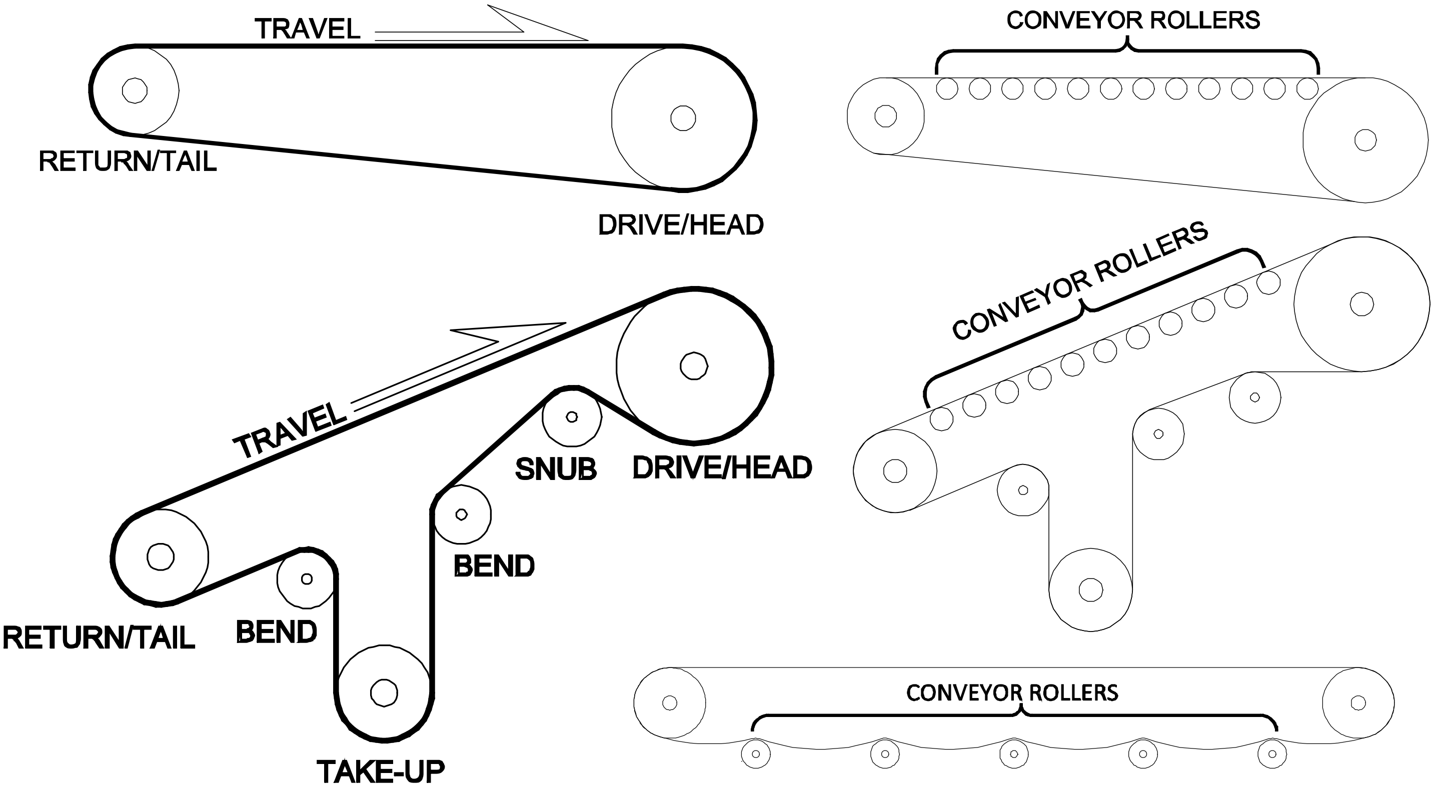
Selecting a Pulley Face Length
Selecting Pulley Diameter and Shaft Diameter
Wall & End Disk Selection

PULLEY CONSTRUCTION

Hub Styles
Axle Details
Common Configurations
Common Profiles
Contact Surfaces (Lagging, Knurling)
Material Selection
Performance Requirements (Runout versus Concentricity)

CONVEYOR PULLEY BASICS

Conveyor pulleys are designed for use on belt conveyor systems as a means to drive, redirect, provide tension to, or help track the conveyor belt. Conveyor pulleys are not designed for the same application intent as conveyor rollers. Conveyor rollers are designed to be used in the bed of a conveyor as a support for the conveyed product and often under the conveyor bed in the return section to support the return side of the conveyor belt.



Drive/Head Pulley – A conveyor pulley used for the purpose of driving a conveyor belt. Typically mounted in external bearings and driven by an external drive source.

Idler Pulley – Any pulley used in a non-drive position that is intended to rotate freely and be driven by the belt.

Return/Tail Pulley – A conveyor pulley used for the purpose of redirecting a conveyor belt back to the drive pulley. Tail pulleys can utilize internal bearings or can be mounted in external bearings and are typically located at the end of the conveyor bed. Tail pulleys commonly serve the purpose of a Take-Up pulley on conveyors of shorter lengths.

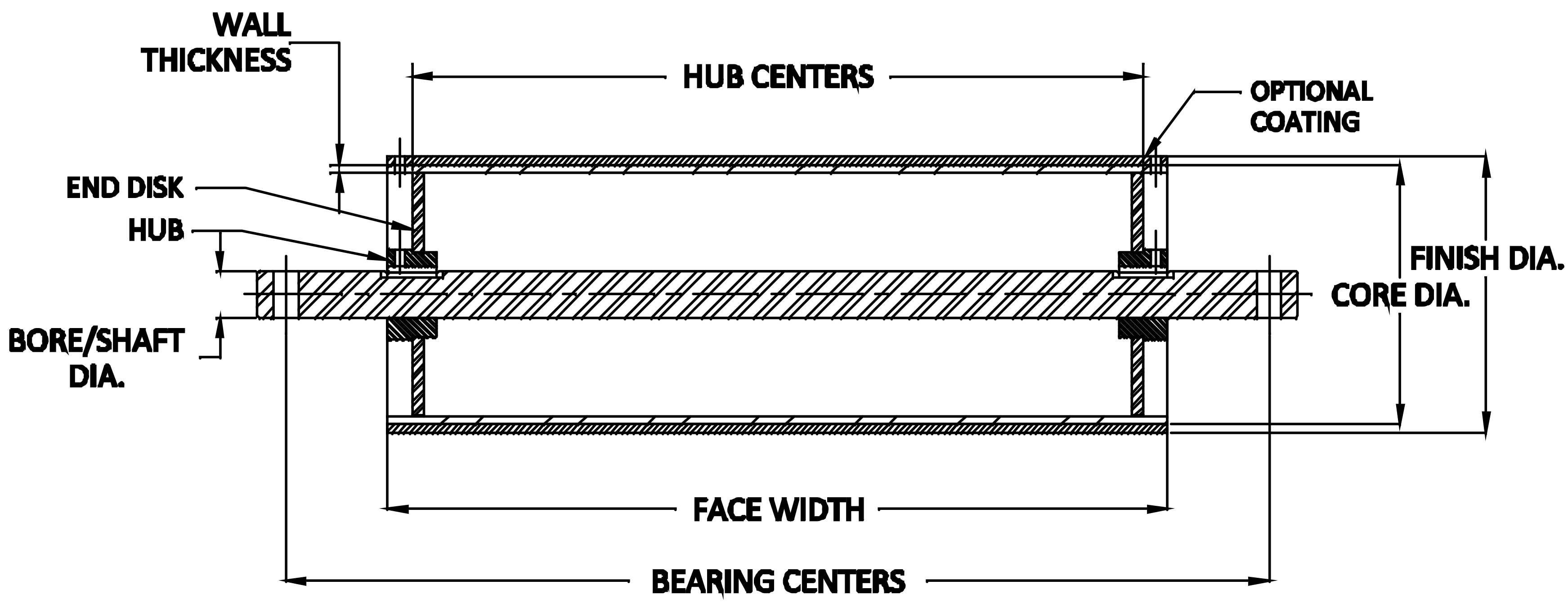
Snub Pulley – A conveyor pulley used to increase belt wrap around a drive pulley, typically for the purpose of improving traction.

Take-Up Pulley – A conveyor pulley used to remove slack and provide tension to a conveyor belt. Take-Up pulleys are more common to conveyors of longer lengths.

Bend Pulley – A conveyor pulley used to redirect the belt and provide belt tension where bends occur in the conveyor system.

Conveyor Roller – A product used either in the bed of a conveyor as a support for the conveyed product or in the return section under the conveyor bed as a support for the conveyor belt

CONVEYOR PULLEY TERMINOLOGY



Pulley/Core Diameter – The outside diameter of the cylindrical body of a conveyor pulley, without coating.
Finish Diameter – The outside diameter of a coated pulley (core diameter + 2 times the coating/wrap thickness).
Face Width – The length of a pulley's cylindrical body. This area is intended to act as the contact surface for the conveyor belt.
Wall/Rim Thickness– The initial thickness of the tube, pipe, or formed plate that makes up the cylindrical body of the pulley.
End Disks – The plates welded on the ends of a pulley which act as the medium between the hub and rim.
Crown/Profile– A change in the shape of the pulley face designed for the purpose of enhancing belt tracking.
Shaft/Axle – The mounting mechanism for the pulley assembly**.**
Hub – The point of connection between the shaft and end disk or pulley wall.
Bore Diameter – The inner diameter of a pulley at the point where the shaft is inserted
Bearing Centers – The distance between the center lines of each bearing race in which a pulley is mounted.
Hub Centers – The distance between the center line of each hub contact surface.
Safety Factor – The capacity of a system or component to perform beyond its expected load

PROPER SELECTION OF A CONVEYOR PULLEY

When selecting a pulley for a belt conveyor application, specifications will be determined by addressing the following steps:

STEP 1 The Face Length of the Conveyor Pulley

STEP 2 The Anticipated Belt Tension of the Conveyor System

STEP 3 The Outer Diameter & Shaft Diameter of the Conveyor Pulley

STEP 4 The Style of Hub Connection

STEP 5 The Pulley Configuration

STEP 6 The Profile of the Pulley Face

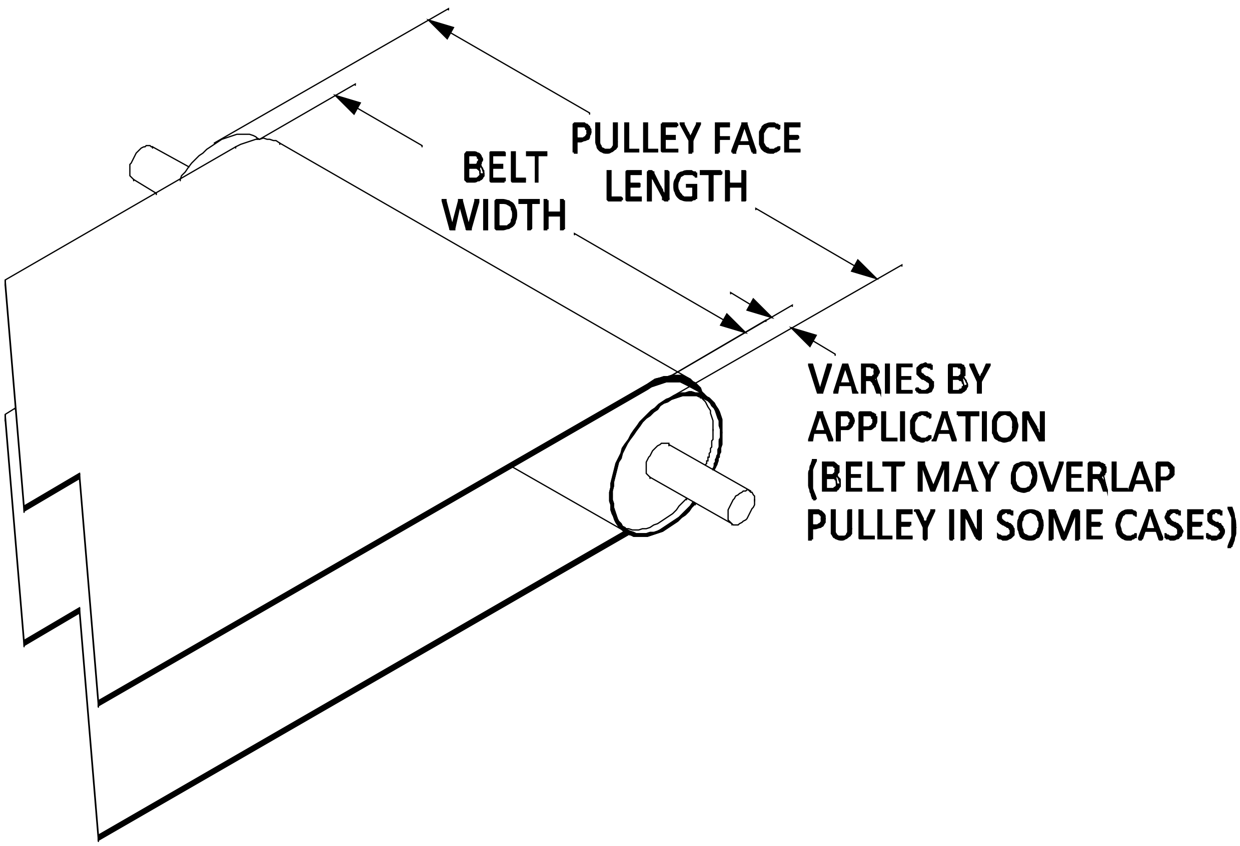
STEP 7 The Appropriate Component Materials

STEP 8 The Type of Contact Surface Required

STEP 9 Other Important Specifications

STEP #1: Determine the Face Length of the Conveyor Pulley

The face length of a conveyor pulley is a derivative of the conveyor belt width. In bulk handling applications, an adequate pulley face length is one that is 2" or 3" greater overall or 1" to 1.5" greater on each end than the overall width of the conveyor belt. Unit handling applications may warrant deviation from these guidelines.

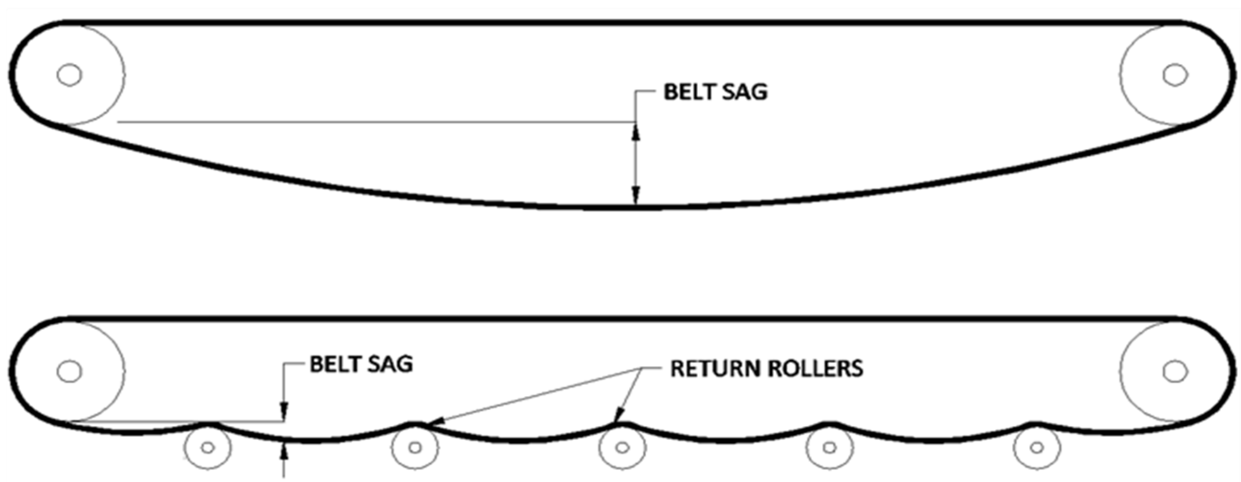


STEP #2: Determine the Anticipated Belt Tension of the Conveyor System

Belt tension measures the degree to which the conveyor belt is stretched or held taut and is typically measured in pounds per inch width (PIW). Conveyor pulleys and shafts of a larger diameter are better equipped to handle elevated levels of belt tension. Belt tension is applied to the conveyor system by the following sources:

Conveyed Load: The weight of the product that is being conveyed produces a resisting force which will fight against the forward motion of the conveyor belt, therefore providing additional belt tension to the conveyor system. The amount of tension produced by the conveyed product is dependent on the amount, size, and type of the product being conveyed, as well as how the belt is supported on the loaded side, considering the variance in coefficient of friction between slider and roller bed conveyor systems.

Catenary Load: The mechanism designed to support the weight of the conveyor belt in the return section of a conveyor will impact the amount of tension experienced by the pulleys. This type of belt tension is produced by catenary load which is a byproduct of the level of catenary sag existing in a conveyor belt. If the conveyor belt is under-supported on its return side, the weight of the belt in that section is supported by the pulleys as a catenary load, and greater belt tension is needed to prevent excessive sagging. Belt return support rollers should be spaced so that the belt does not sag excessively between each roller. The schematics below illustrate the concept of catenary load:



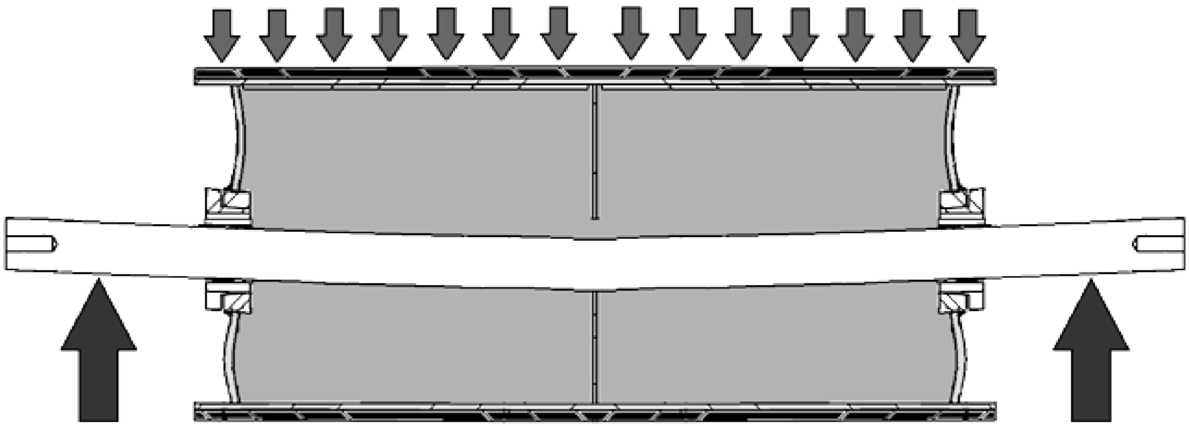
The Take-Up Mechanism: The amount of belt tension on a conveyor system may require belt slack adjustment during installation procedures, during normal operation for belt tracking purposes, or for disassembly purposes during maintenance procedures. The term Take-Up refers to a variety of devices that are used to provide adjustment in the amount of belt tension on a conveyor system. Since many of these devices require manual calibration, adjustment of belt tension with a take-up mechanism requires training and an understanding of how belt tension affects conveyor load. If not adjusted accurately, the take-up device can easily supply excessive belt tension which results in unanticipated loads on the conveyor components, particularly the pulleys and the belt.

STEP #3: Determine the Outer Diameter and Shaft Diameter of the Conveyor Pulley

In order to properly size both the outer diameter of a pulley and select an appropriate shaft diameter, it is important to first understand the pivotal role that selection plays in avoiding the most common cause of premature failure, shaft deflection.

Shaft Deflection

The single largest contributor to premature failure of conveyor pulleys is end disk fatigue caused by excessive shaft deflection. Shaft deflection is the bending or flexing of a shaft caused by the sum of the loads on the pulley. The sources of these loads include belt tension, product load and the weight of the pulley itself. Excessive shaft deflection occurs as a result of an undersized shaft. The drawing below illustrates the concept of shaft deflection:



Excessive shaft deflection occurring as a result of an undersized shaft (exaggerated for effect).

Excessive shaft deflection occurs when shaft diameter is improperly sized for the demands of an application. Although it may appear as a potential solution, selecting a shaft material with greater strength characteristics will have virtually no effect on its stiffness as it pertains to shaft deflection. The Modulus of Elasticity, which is a physical property of a substance which describes its tendency to deform elastically when a force is applied to it, remains virtually the same across all grades of steel, and because of this, the only proper way to increase the stiffness of a steel conveyor pulley shaft is to increase its diameter.

Premature failure of a conveyor pulley is not likely to occur from an oversized shaft, but an undersized shaft can produce harmful and destructive results. The Conveyor Equipment Manufacturers Association (CEMA) recommends that shafts be designed with a maximum bending stress of 8000 psi or a maximum free shaft deflection slope at the hub of 0.0023 inches per inch.

Outer Diameter and Shaft Diameter Selection

Selection of an outer diameter requires comprehension and consideration of several variables found within the given conveyor system. Pulley diameters and shaft diameters should be selected using tools such as ANSI/CEMA B105.1-2003 (SEE APPENDIX A). The following application variables need to be considered in the selection of both the pulley outer diameter and the shaft diameter:

Belt Requirements

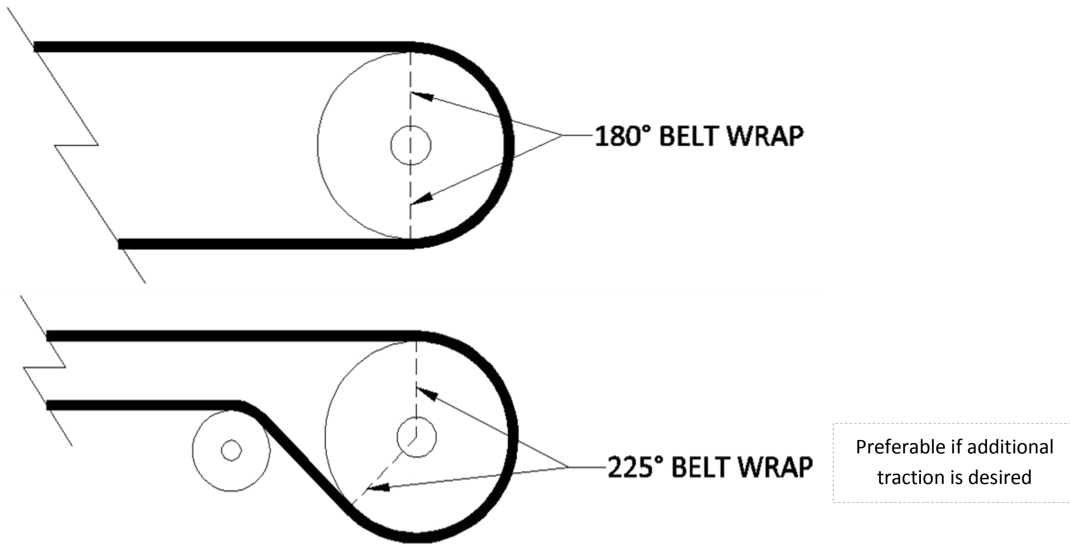
Most conveyor belt manufacturers recommended the minimum pulley diameter specification for conveyor belting based on the individual belt characteristics such as the belt material, construction and profiles.

STEP #3: Determine the Outer Diameter and Shaft Diameter of the Conveyor Pulley (cont)

Belt Wrap Requirements

The amount of traction between a drive pulley and a belt can be increased by increasing the arc of contact between the two surfaces. The arc of contact, or belt wrap is the angular distance a pulley travels while in contact with the belt, and is measured in degrees. Increasing the area of contact between two surfaces does not increase the coefficient of friction between the two surfaces. As explained by the Euler-Eytelwein Formula, increasing the arc of contact will increase the amount of frictional force between a belt or rope and a round object such as a pulley.

The figure below illustrates the concept of arc of contact, or belt wrap:



Pulley Position

The purpose and position of a pulley in the conveyor (i.e. Drive, tail, bend, or take-up) impacts how much load the individual pulley will experience while in operation. In general, pulleys in the position of driving the conveyor belt will experience greater loads than pulleys in other positions. This is largely due to the increased level of work and tension required of the drive pulley as well as the potential for additional loads produced from the setup of the drive device.

Duty Cycle

Selection of a proper shaft diameter will take into account the expected service life of the pulley at the anticipated speeds and capacities. In general, if a longer duty cycle is preferred, shaft diameter should be purposefully oversized.

Keyways

Any slot or groove machined into the outer diameter of the shaft can create stress concentration points on the shaft. These stress concentrations require consideration of selecting a shaft of larger diameter.

Pulley Weight

The total weight of the pulley assembly to be supported by the shaft will impact shaft sizing. Selection of a pulley with robust construction and heavier weight should be accounted for when selecting shaft diameter.

STEP #3: Determine the Outer Diameter and Shaft Diameter of the Conveyor Pulley (cont)

Bearing Centers & Hub Centers

The distance between the center of each bearing support and the center of each hub connection will impact the degree to which the shaft deflects and should be accounted for when selecting a shaft diameter. Having a greater distance between the hub centers and the bearing centers will require a larger diameter shaft to accommodate the same load. Consider the following examples:

16” X 44” drum pulley with XT25 hubs & bushings x 1-15/16” bore
With Bearing Centers located at 48”: axle capacity is 1229 lbs
With Bearing Centers located at 52”: axle capacity is 802 lbs
In order to accommodate a load comparable to that of a bearing center dimension of 48”, the axle with bearing centers at 52” must be sized to a minimum 2-3/16” diameter.

16” X 44” drum pulley with 1-15/16” axle and bearing centers at 48”
With Hub Centers located at 40-7/8” (XT25 hubs): axle capacity is 1229 lbs
With Hub Centers located at 39-15/16” (XT35 hubs): axle capacity is 1119 lbs
In order to accommodate a load comparable to that of a hub center dimension of 40-7/8”, the axle with hub centers at 39-15/16” must be sized to a minimum 2” diameter.

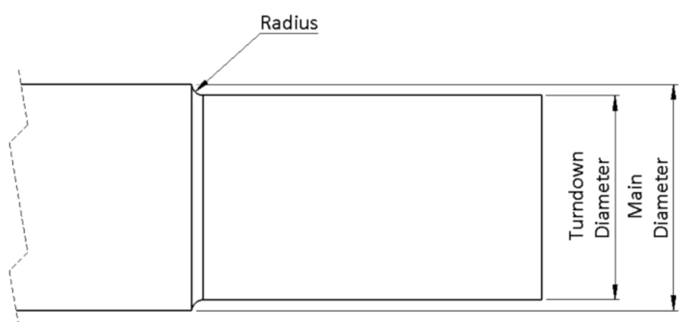
Turndowns

When the physical constraints of a conveyor system will not allow you to properly size your shaft diameter, shaft turndowns may be utilized to increase the load capacity of a pulley. A turndown is where a larger shaft is turned down to a smaller diameter at the ends, while retaining the larger diameter through the pulley. Consider the following example:

16” X 44” drum pulley with 1-15/16” diameter external mounted bearings at 48” bearing centers
With XT25 hubs & bushings for 1-15/16” diameter thru axle, axle capacity is 1229 lbs

With XT25 hubs & bushings for 2-3/16” diameter axle with 1-15/16” diameter turndowns each end, axle capacity is 1998 lbs (a 63% increase over the 1-15/16” thru axle design)

The sudden change in geometry between a shaft major diameter and a turndown is an area of stress concentration. A radius should be incorporated to reduce the stress concentration at this point.



Product Load and Loading Method

In addition to providing some degree of belt tension to the conveyor system, the load of the conveyed product can also contribute to the load being directly applied to the conveyor pulley. This becomes a more significant factor when the product is being loaded on the conveyor in an area near the pulleys. The greater the amount of load applied to the pulley, the greater the shaft diameter required to properly support the load.

STEP #4: Determine the Style of Hub Connection

The hub is the mechanism by which the conveyor pulley is affixed to the shaft. There are many types of hub connections, all of which offer individual advantages and disadvantages. The following variables should be considered when selecting a hub connection type for a conveyor pulley:

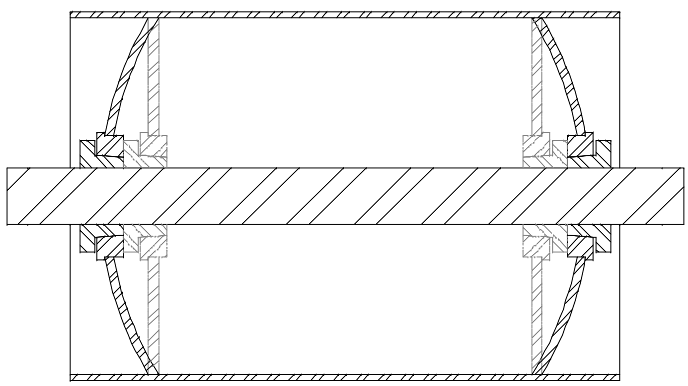
Pulley Position – The location/purpose of the pulley in the conveyor system may impact which hub types will be best suited for the pulley. Some may allow several hub options while others may require a specific hub style.

System Load – Some hub types will be better suited for heavier load environments due to their robust design.

Cost – The type of hub selected may drastically impact the overall cost of the conveyor pulley assembly.

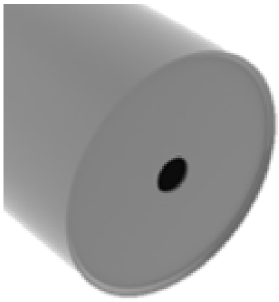
Maintenance – The design of the hub will either allow for replaceable components or require the entire conveyor pulley be replaced after operation in an application. If the intent is to maintain the conveyor pulley by replacing individual components, choose a hub type that offers this feature.

Pre-Stress - The act of installing a compression style hub in a two hub application leads to pre-stressing of end disks. As the bolts are tightened, the bushing is drawn into the hub causing it to compress onto the shaft. At a certain point the shaft will no longer be able to move within the bushing. Further tightening of the bolts will draw the hub outward instead of drawing the bushing inward (assuming the bushing on the opposite side has already been fastened in place). This will cause the end disks to bow outward or pre-stress on the shaft and end disks. The shallower the hub taper, the greater the amount of pre-stressing. Ideally, this pre-stress would be primarily absorbed by the end disks, as depicted in the illustration below. However, if the end disk is built to be more rigid than the shaft, the pre-stressing will not be absorbed by the shaft in place of the end disk, causing the shaft to deflect.



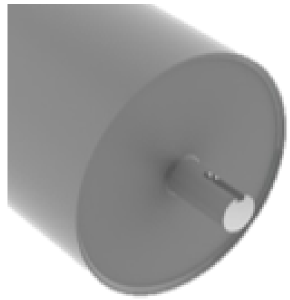
End Disk Pre-Stress (Exaggerated)

PLAIN BORE (WELDED SHAFT) (TYPE 1/TYPE A)



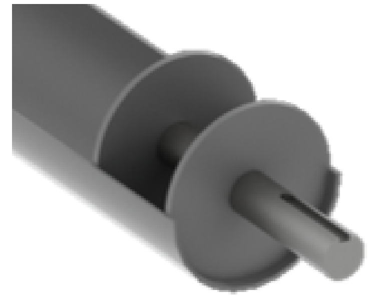
End disks are bored to allow for a customer welded through shaft.

WELDED THROUGH SHAFT (TYPE 1/TYPE A)



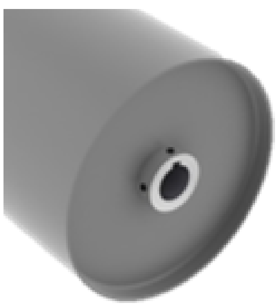
A singular shaft extends through the entire pulley and is welded at both end disks.

WELDED STUB SHAFT



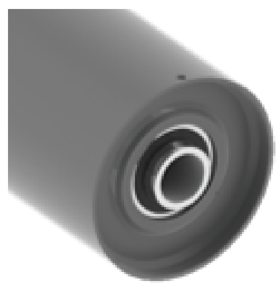
An assembly consisting of a short length of shaft and two disks is welded into each end of the pulley.

KEYED HUBS & SET SCREWS (TYPE 2/TYPE B/TYPE D)



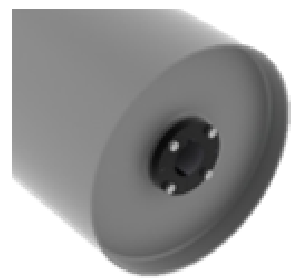
Removable shaft extends thru the pulley, is held in place with set screws and driven by a keyway.

ER STYLE INTERNAL BEARINGS (TYPE 3/TYPE C)



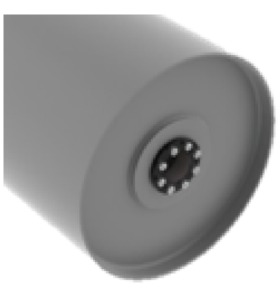
End disks are fitted with bearing units to allow rotation of the pulley around the shaft.

WELDED COMPRESSION STYLE HUBS & BUSHINGS (TYPE 4)



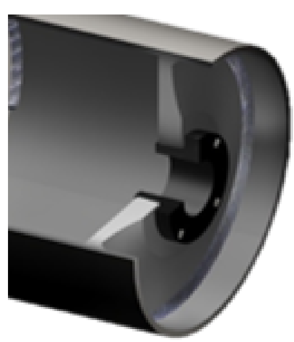
A compression style hub is welded to the end disk and a through shaft is affixed by use of a tapered bushing. XT®, QD® and Taper-Lock® styles are readily available.

KEYLESS LOCKING DEVICES (TYPE 5)



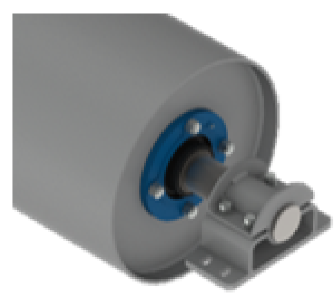
Hubs are welded and machined to accept a mechanical shrink fit style hub and through shaft. Several manufacturers & brands are available.

CONTOURED INTEGRAL END DISKS & BUSHINGS



A compression hub is machined directly into a profiled end disk in place of a welded style hub.

DEAD SHAFT ASSEMBLY



End disks are fitted with piloted flange bearings and the shaft is held by fixed mounting blocks designed to easily replace external pillow block bearings.

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STYLE OF HUB CONNECTION

Style of Hub Connection	PROS	CONS
Fixed Bore End Plates	• Least expensive option of all hub styles • Easy to install	• Generally only recommended for light duty applications • Shaft is not easily replaceable
Fixed Stub Shafts	• Ideal design for small diameters pulleys (≤12”) with long face widths (≥72”) • High fatigue safety factor/minimal shaft deflection • Easy to install	• Typically, parts are not replaceable • Expensive when compared to most other hub connection styles
Removable Stub Shafts	• Ideal design for small diameters pulleys (≤12”) with long face widths (≥72”) • High fatigue safety factor/minimal shaft deflection • Replaceable shaft enables economical maintenance solution over replacing entire pulley assembly	• Expensive when compared to most other hub connection styles
Keyed Hub with Set Screw	• Least expensive option next to fixed bore plates • Replaceable shaft	• Generally only recommended for light duty applications • Pulley may walk on the shaft when overloaded • Fretting may occur when overloaded
ER Style Internal Bearings	• Shaft and bearings are replaceable • Ideal for tight spaces with minimal room for external bearings	• Not ideal when using as a drive pulley • Not suitable for heavy duty applications
Weld-On Hubs & Compression Bushings	• Shaft and bushings are replaceable • Less expensive than keyless locking devices • Higher fatigue safety factor than fixed bore and keyed hubs	• Can cause pre-stressing of end disks during installation • More expensive than fixed bore, keyed hubs, and internal bearings
Keyless Locking Devices	• No end disk pre-stress • Locking device and shaft are replaceable • Eliminates the need for keyways and the stress concentrations associated with keyways	• Typically the most expensive hub option • Can lead to a more complex installation process
Flat End Disk with Integral Hub	• Eliminates stress concentrations caused by sudden changes in geometry in welded hubs • Eliminates the most common failure point (heat affected zone at hub to disk weld)	• Generally, more costly than weld on hubs, especially in smaller diameters (<14”)
Contoured End Disk with Integral Hub	• Same as flat disk w/integral hub plus…… • Contoured design provides a more even distribution of stress across the disk (more material in higher stress areas & vice versa)	• Generally, more costly than weld on hubs, especially in smaller diameters (<14”)
Dead Shaft Assembly	• Shaft and bearings are replaceable • Eliminates risk of end disk fatigue failure • Greater shaft capacity than live shaft designs enabling possibility of reduced cost and space requirement	• Not ideal when using as a drive pulley • Generally, more costly than live shaft styles • Does not allow for easy conversion to varying shaft diameters.

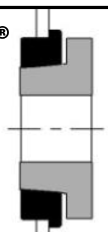
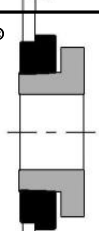
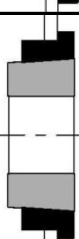
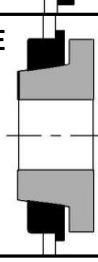
Compression Hub & Bushing Systems

XT® Hubs & Bushings were specifically designed for use in conveyor pulleys with two hub connection points. The steep taper angle of XT® hubs (2” per foot) minimizes end disk pre-stressing that can occur during the installation of the bushings. This design feature reduces the likelihood of pulley failure as a result of end disk fatigue. The reduced clamping pressure caused by the steep taper angle is compensated by use of four adequately sized bolts used to install the bushing in an XT® hub.

QD® Hubs & Bushings were originally designed for use in power transmission products generally utilizing one hub connection point such as sprockets and sheaves. The shallow taper angle of QD® hubs (3/4” per foot) is ideal for torque transmission, but can pre-stress the end disk when bushings are installed; increasing the probability of end disk fatigue in products designed with two hub connection points. The uneven bolt spacing on QD® hubs can also lead to non-uniform draw up, which increases the risk of bolt breakage, bushing breakage, or bending shafts upon installation.

Taper-Lock® Hubs & Bushings were designed for use in power transmission products utilizing one hub connection point such as sprockets and sheaves. Taper-Lock systems have a moderate taper angle (1-11/16” per foot) which minimizes end disk deflection in products with two hub connection points. Taper-Lock systems are also sought for aesthetic reasons due to the clean look of their flush bushing arrangement. However, of all hub & bushing systems, Taper-Lock® has the weakest ability to grip the mating shaft. Additionally, Taper-Lock® systems used in two hub configurations increase the likelihood of shaft misalignment and measurable maximum circular runout.

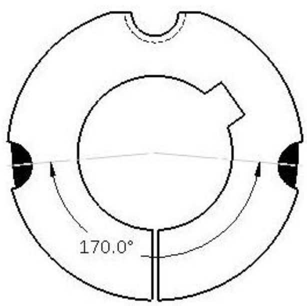
HE Hubs & Bushings were designed for use in conveyor pulleys with two hub connection points. The exaggerated steep taper angle of HE hubs (3” per foot) minimizes end disk pre-stress that can occur during the installation of the bushings. This design feature reduces the likelihood of pulley failure as a result of end disk fatigue. However, the exaggerated steep taper angle of the bushing is at the edge of being self-locking, and significant force is required of the bolts in order to properly seat the bushing in the hub which increases the risk of bolt breakage.

XT® 	**THE DESIGN**: Designed as a self locking hub utilizing 2” of taper per foot. **BACKGROUND**: The XT® system was specifically designed for use in conveyor pulleys with two hub connection points. **ADVANTAGES**: Steep taper minimizes end disk pre-stress to reduce end disk fatigue failure. **DISADVANTAGES**: Not necessarily the optimum choice for single hub arrangements. 2” per foot taper is at the edge of being self-locking.
QD® 	**THE DESIGN**: Designed as a self locking hub utilizing ¾” of taper per foot. **BACKGROUND:** The QD® system was specifically designed for use in power transmission products with one hub connection point (sprockets, sheaves, etc.). **ADVANTAGES**: Gradual taper lends itself well to one hub configurations. **DISADVANTAGES:** Prone to pre-stress of the end disk increasing the risk of end disk fatigue.
Taper-Lock® 	**THE DESIGN**: Designed with 1-11/16” Taper per foot. **BACKGROUND:** The Taper-Lock® system was specifically designed for use in power transmission products with one hub connection point (sprockets, sheaves, etc.). **ADVANTAGES**: Non-flanged bushing mounts flush with face of hub component. **DISADVANTAGES**: Weakest ability to grip mating shaft. Prone to back-out of bushing bolts. Increases the likelihood of pre-stress, shaft misalignment and greater measured runout.
HE 	**THE DESIGN**: Designed at the edge of a self locking taper, utilizing 3” of taper per foot. **BACKGROUND**: Designed for use in conveyor pulleys with two hub connection points. **ADVANTAGES**: Reduces likelihood of pulley failure as a result of end disk fatigue. Steep taper minimizes end disk pre-stress. **DISADVANTAGES**: Has low safety factor. Prone to breakage of bushing bolts, due to the steep taper being at the edge of a self-locking capability.

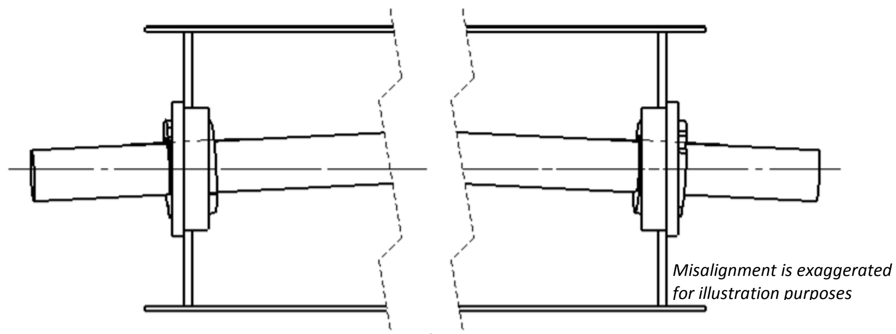
XT® is a registered trademark of VanGorp Corp.–QD® is a registered trademark of Emerson Electric Corp –Taper-Lock® is a registered trademark of Reliance Electric

Shaft Alignment When Using Compression Style Hubs

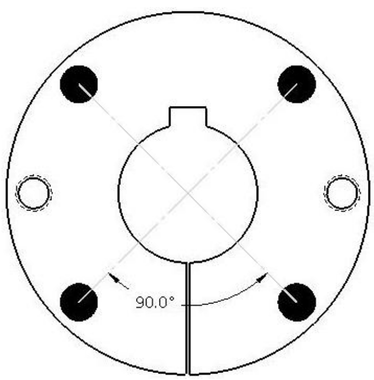
When installing bushings and a shaft into a pulley with compression style hubs, the desired result is to locate the bushing face such that it is fixed on a plane parallel to the hub face. Since three points define a plane, having three or more retaining bolts in the hub/bushing assembly is ideal for maintaining this alignment. Compression style systems which utilize a minimum of three equal spaced bolts (XT® for example, uses a minimum of 4) will generally keep the bushings in acceptable alignment with the mating hubs by allowing even pressure to be applied all the way around the circumference of the bushing. The parallel alignment of the hub and bushing faces will keep the shaft extension perpendicular to the hub face and help to maintain its concentricity with the pulley. Maintaining shaft alignment when using hub and bushing systems with only two retaining bolts (such as Taper-Lock® sizes K12 – K30) can prove to be difficult. The two bolts utilized in these designs are located 170° apart (as opposed to 180°) which causes additional pre-stress on the shaft by creating a moment arm around the centerline of the shaft. The moment arm makes the shaft more likely to bend toward the 170° side of the angle which is already weakened by the split in the bushing being located on this side. These reasons are why XT® hubs & bushings are preferred and Taper-Lock® style hubs & bushings are not recommended for use in two hub pulley configurations.



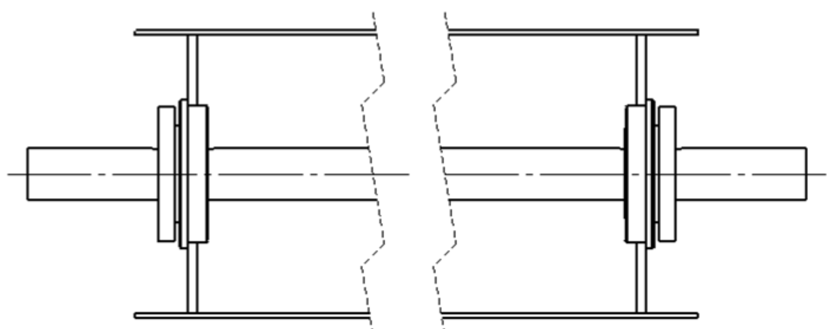
Typical Taper-Lock® Bushing



Typical Taper-Lock® Pulley Assembly



Typical XT® Bushing



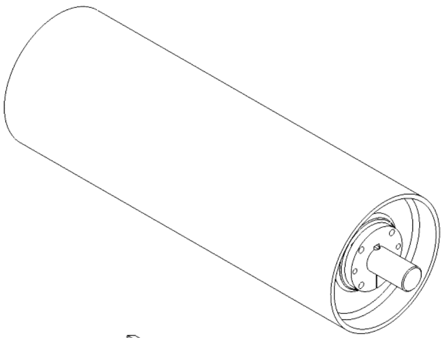
Typical XT® Pulley Assembly

Shaft Alignment & Maximum Circular Runout

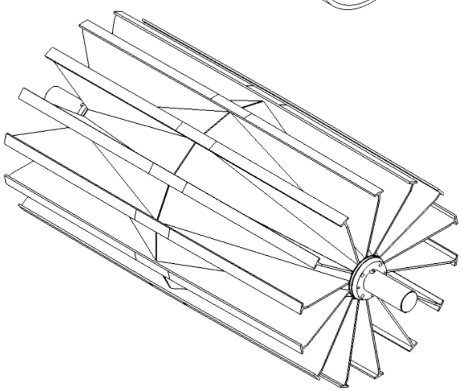
Shaft alignment affects how much runout can be measured on a conveyor pulley assembly (for additional information on measuring runout, see STEP#9). Selection of a hub style should take into account how likely it will be to maintain shaft alignment upon installation of the bushings. Since maintaining shaft alignment with Taper-Lock® systems is difficult, the runout measured on the final pulley assembly is typically greater. Considering this, a pulley manufactured with XT® hubs & bushings will have a more desirable maximum circular runout than a similar pulley manufactured with Taper-Lock® hubs & bushings.

STEP #5: Determine the Pulley Configuration

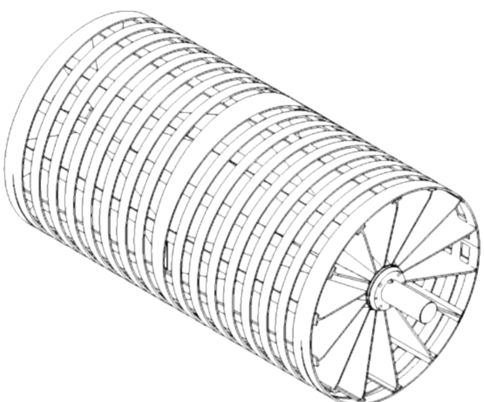
The configuration of a conveyor pulley will impact its ability to effectively operate in a given environment. Pulley configuration should be selected based on application load requirements, environmental requirements, the intent of the pulley in the conveyor system (head/drive, tail, bend, etc.) as well as the type, amount, and characteristics of material being conveyed.



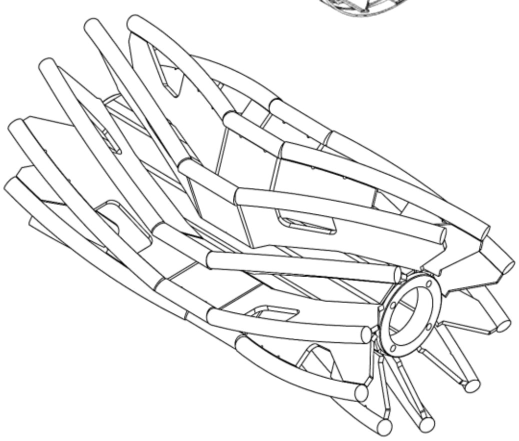
Drum Style Pulleys- contact surface is constructed from a cylindrical shell, tube or pipe allowing for continuous full contact with the conveyor belt. Drum style pulleys are commonly found in all positions on a conveyor system where the conveyed material is contained or where the risk of material buildup between the pulley contact surface and the belt is not a primary concern. Of pulley styles, drum style pulleys achieve the most conveyor belt contact and because of this, drum style pulleys are the preferred configuration choice of pulleys in drive positions.



Wing Style Pulleys – non-continuous contact surface is comprised of a series of individual wings (also called fins). This construction results in the creation of open voids that are designed to allow loose material to fall away from the contact surface. Also known as self-cleaning pulleys, wing pulleys are primarily used on the tail end of bulk handling systems where loose materials have a tendency to reside on the underside of the conveyor belt, causing damage to one or both components. Robust wing construction typically incorporates support gussets, and sometimes outer support rings, both of which act as braces for the wing members under heavier loads.



Spiral Style Pulleys – a metal strip contact surface is fixed in a spiral pattern around the circumference of a drum or wing pulley to achieve continuous contact with the conveyor belt while enhancing material removal. Spiral style pulleys are primarily used on bulk handling systems where material buildup and continuous contact with the conveyor belt are operational concerns.



Angled Wing Pulleys – wing members are angled towards the edges of the pulley to achieve continuous contact with the conveyor belt while enhancing material removal. Angled wing designs are primarily used on bulk handling systems where material buildup, cleanout and continuous contact with the conveyor belt are operational concerns. To maximize material removal, some designs feature cleanout ports to enhance this effect.

STEP #5: Determine the Pulley Configuration (cont)

Component Thicknesses

In addition to selection of a pulley style, component thicknesses must be evaluated and selected for compliance with application demands. Below are a few components that require consideration of thickness:

Wall Thickness

In many applications, if a shaft has been properly sized for an application, calculation of appropriate wall thickness does not require additional consideration. Because of its pivotal role in pulley performance, the shaft diameter will largely dictate pulley load capacity and wall thickness plays a secondary role. In these cases, use of thin wall tubing in the construction of the cylinder will be sufficient. In any case, wall thickness should be sized so the rated load of the shaft does not cause a stress in the wall of more than 10,000 psi. (SEE APPENDIX A)

The following case examples require evaluation and special consideration of wall thickness:

Stub Shafts: In cases where a stub shaft is selected as the desired hub type, wall thickness requires special consideration. With a stub shaft design, the pulley wall is responsible for accommodating the load that would normally be supported by the shaft in a through shaft design.

Surface Modifications: Pulleys that require modification of the contact surface to achieve a desired profile (V-Groove, etc), tolerance, surface finish, or runout may also need evaluation of pulley wall thickness in order to accommodate the desired modifications.

Impact Loading: Applications in which the conveyor system will be experiencing impact loads require special consideration of appropriate pulley wall thickness. In these cases, the wall of the pulley will be subject to non-uniform loads that can affect the integrity of the pulley wall.

Loose Materials: Bulk handling applications subject to an increased risk of contact by the conveyed loose materials with the pulley wall require consideration of appropriate wall thickness. The presence of material between the pulley and conveyor belt causes increased friction and/or point loading between the two surfaces leading to increased pulley wear or catastrophic failure. If the wall is not sized appropriately for the material size, this contact can lead to collapse of the pulley wall and catastrophic failure.

Disk Thickness

Disks are used for two primary purposes in the construction of conveyor pulleys; in the end of the pulley as end disks and inside the pulley as center disks. Disks are sized by pulley manufacturers to compliment the requirements of other components such as shaft diameter, hub type and wall thickness.

End Disks: If the shaft is sized properly for application loads, end disk thickness does not play a significant role in premature failure. However, choice of a thicker end disk may add an additional safety factor to the design of a conveyor pulley up to a certain point. Sizing an end disk too thick though, could prevent the shaft from flexing through the disk, leading to shaft breakage.

Center Disks: In most cases, center disks are used in the manufacture of drum style conveyor pulleys with rolled cylinders as a means of creating a common center to fabricate the wall around. Center disks contribute to the stiffness of the cylindrical portion of the pulley but should not be selected as the proper method for accomplishing increased load capacity. In small diameter pulleys, center disks are welded via holes machined in the wall of the conveyor pulley. This process creates stress concentrations, affecting the integrity of the wall which can be seen as a design disadvantage. The proper method of increasing the load capacity of a conveyor pulley is properly sizing the shaft diameter and wall thickness for the loads of the application.

Common Configuration Options

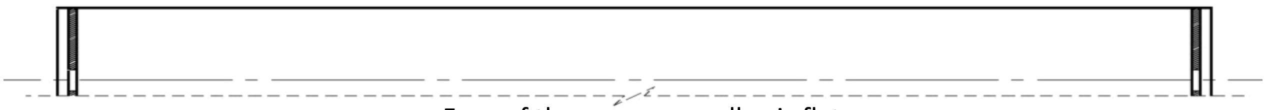
Although it is possible to select customized component thicknesses for an individual application, configuration standards are often available to help simplify the selection process. These configuration options may be pre-designed for application intent but do require review for compliance to application demands. Since there is no industry standard for component thicknesses, names and specifications will vary across manufacturers. Common terms include Heavy Duty, Mine Duty, Quarry Duty, Mill Duty, Extreme Duty and various Engineered Designs.

STEP #6: Determine the Profile of the Pulley Face

The profile of a conveyor pulley will impact its ability to effectively track the conveyor belt. The profile of a conveyor pulley should be selected based on the need for belt tracking as well as the desired life and performance of the belt. While many profiles could be utilized in pulley construction, the most common profiles are detailed below. A pulley profile may utilize multiple crowns on one common surface.

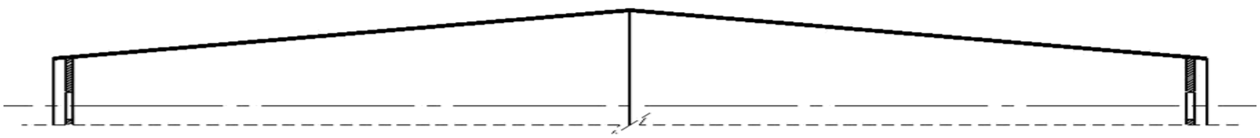
****NOTE** ALL PROFILES ARE EXAGGERATED FOR ILLUSTRATION PURPOSES.**

FLAT FACE



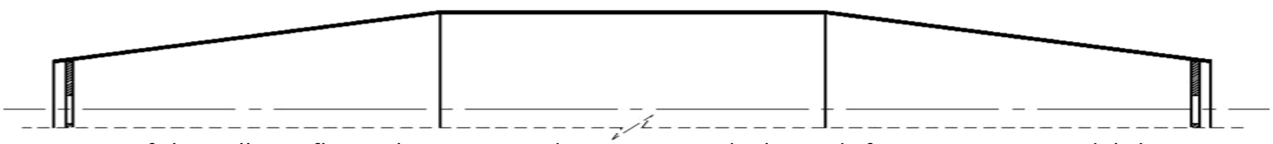
Face of the conveyor pulley is flat.
Does not contribute to belt tracking, but maximizes belt life by providing an even, consistent wear surface.

SINGLE CROWN



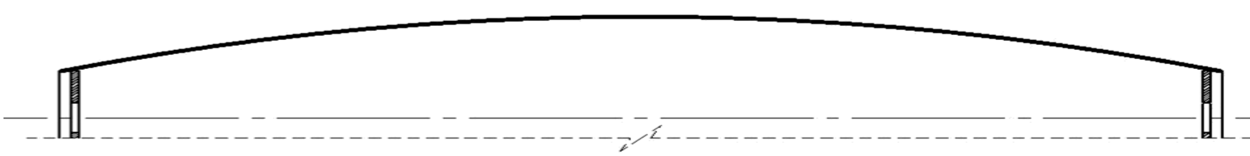
Face of the conveyor pulley is tapered with the high point located at the center and tapering toward each end. Provides belt tracking capability, but the peak at the center causes wear and stretching at the center of the belt, decreasing belt life.

TRAPEZOIDAL CROWN



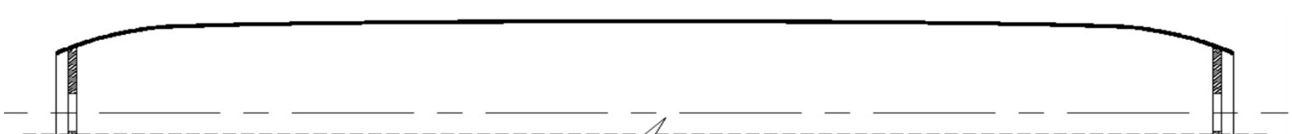
Face of the pulley is flat in the center and tapers towards the ends forming a trapezoidal shape. Provides enhanced belt tracking capability when compared to single crown while providing an even wear surface, lengthening belt life.

RADIAL CROWN



Face of the pulley is crowned in one continuous radius across the entire length of the pulley. Provides enhanced belt tracking when compared to trapezoidal crown, an even wear surface, and lengthened belt life.

PARABOLIC / HYPERBOLIC CROWN

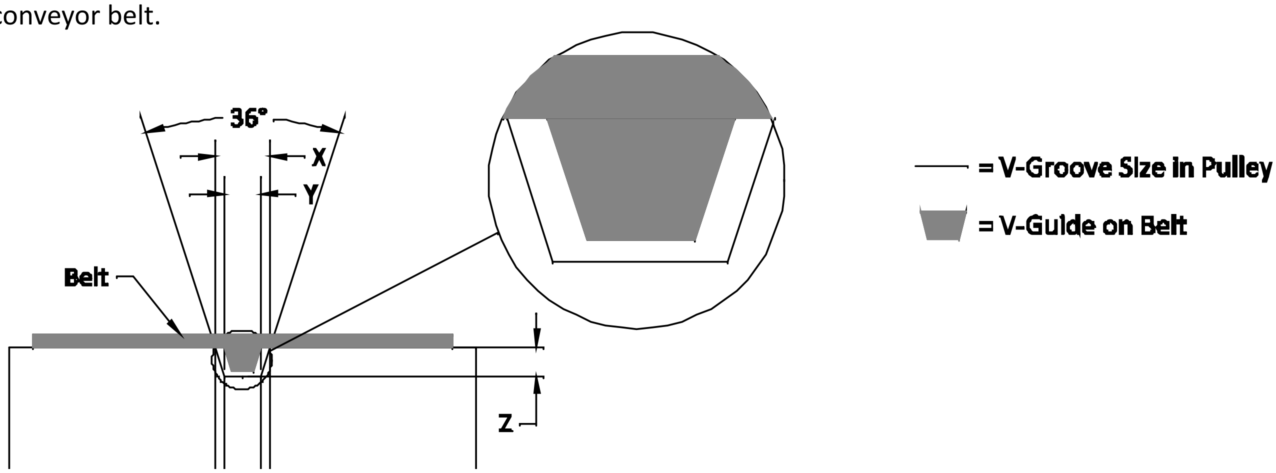


Face of the pulley is crowned in a parabolic or hyperbolic shape across the entire length of the pulley. Provides enhanced belt tracking when compared to radial crown, an even wear surface, and lengthened belt life.

STEP #6: Determine the Profile of the Pulley Face (cont)

V-Grooves

Conveyor systems which utilize v-guided conveyor belt to assist in belt tracking will require a pulley with a v-grooved profile. The v-groove profile in the pulley face is manufactured to allow for clearance of the v-guide around the circumference of the conveyor pulley. The v-groove provided in the profile of the conveyor pulley is *not* designed to assist in belt tracking and does *not* provide additional driving force for the conveyor belt.



V-Groove Dimensioning

The chart below contains typical v-section types and the recommended sizes for the corresponding v-grooves. The recommended minimum pulley diameter will vary by belt manufacturer, belt material, v-guide construction (solid, notched, serrated), v-guide type, belt size, etc. The minimum pulley diameter should always be verified with the belting manufacturer before specifying or purchasing a v-grooved pulley.

V-Guide Section Type	Groove Top Width "X"	Groove Bottom Width "Y"	Groove Depth "Z"
Z	0.644	0.450	0.299
O (3L)	0.625	0.422	0.313
A (4L)	0.750	0.506	0.375
B (5L)	0.906	0.602	0.469
C	1.125	0.739	0.594
D	1.500	0.972	0.813
E	1.750	1.121	0.969
K6	0.486	0.343	0.220
K8	0.565	0.397	0.259
K10	0.650	0.447	0.312
K13	0.762	0.516	0.378
K15	0.841	0.595	0.378
K17	0.919	0.595	0.496
K30	1.431	0.981	0.693

* All Dimensions in Inches

V-groove clearances on pulleys are typically up to ¼” wider and $^{1}/_{16}$” deeper than V-guide dimensions. When V-grooves are required, consult the belt manufacturer’s recommendations for minimum pulley diameter based on the type and style of belt being used.

STEP #7: Determine the Appropriate Component Materials

Conveyor pulleys can be constructed using a variety of materials. The choice of pulley material plays an important role in determining pulley construction and may substantially impact overall level of pulley performance in operation.

Mild Steel

Unless otherwise noted, conveyor pulley construction will be designed using mild steel materials. Because of a low resistance to corrosion in demanding environments, mild steel should be selected for environments where corrosion of surfaces is not a concern.

Stainless Steel

Pulleys constructed with stainless steel materials are commonly used in environments susceptible to corrosion or where pulley cleanliness or sanitation is a concern. If an environment demands ease of cleaning or sanitization, an upgraded surface finish may be desired. Additional standards for food handling equipment may be found through sources such as the FDA (www.fda.gov) and 3-A Sanitary Standards, Incorporated (www.3-a.org).

Aluminum

While mild and stainless steel are the most common materials used in conveyor pulley construction, other materials such as aluminum are also used. Aluminum, although light weight and corrosion resistant, does present disadvantages in product construction. A significant reduction in strength and component compatibility makes aluminum a less desirable material choice for conveyor pulleys in most belt conveyor applications.

Plastic/Non-Metallic

Non-metallic materials such as plastic, PVC, and even wood are sometimes used in the construction of conveyor pulleys. Although they are typically light weight and corrosion resistant, non-metallic materials do present disadvantages in traditional pulley product construction. A significant reduction in strength and component compatibility makes these materials a less desirable material choice for conveyor pulleys in most belt conveyor applications. These materials would typically only be used in systems where the application requirements did not allow the use of metal in pulley construction, perhaps where electrical or thermal conductivity is a concern.

STEP #8: Determine the Type of Contact Surface Required

The type of contact surface chosen for the pulley face will impact a number of application variables within the conveyor system. Unless an alternate surface is desired, pulleys are furnished with a plain steel or mill type finish comparable to that of a standard tube or pipe. The most common contact surface modifications are those designed to increase the traction or grip between the drive pulley and the underside of the conveyor belt. In addition to providing increased traction, an alternate contact surface may be utilized to impact a pulley's wear resistance, ease of cleaning, and aesthetics.

Lagging

Lagging is a term used to describe the variety of elastomers used to coat the contact surface of a conveyor pulley. The primary purpose of pulley lagging is to enhance the traction between the drive pulley and the underside of the conveyor belt by increasing the coefficient of friction between these two surfaces. The enhanced friction between pulley lagging and the conveyor belt may improve belt life by allowing lower belt tensions and reducing abrasive conditions between the pulley and belt. Pulley lagging is specified by communicating the preferred lagging material, durometer or hardness of the material, desired thickness, and subsequent finish diameter of the pulley after applying the lagging to the face. Lagged pulley surfaces may be plain wrapped (unfinished) or ground to a continuous, semi-smooth surface (rough ground). Proper selection of a lagging material should address the following variables:

Chemical & Environmental Compatibility – Resistance to temperature, light, oils, fats, acids, alcohols and water, as well as compatibility with food products, are all factors that need to be considered when selecting a lagging material. Select a lagging material that is compatible with the conveyed material and has resistance to the conditions of the intended environment.

Wear Characteristics – The durometer, strength, and abrasion resistance of the lagging material will impact its ability to provide traction, wear properly, and hold up to tearing, peeling, or eroding.

Maintenance – The type and style of lagging selected will impact the serviceability of the conveyor pulley when it requires recoating. Some styles allow for field installation of replacement lagging while others require that re-lagging services be conducted at a re-lagging facility.

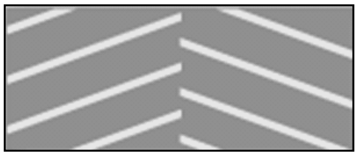
Belt Material – The type and style of lagging selected will not only impact the coefficient of friction that is achieved between the conveyor pulley and conveyor belt, but also may impact the likelihood of reversion (see troubleshooting guide for complete explanation). Consult belt manufacturer specifications when selecting a lagging material.

Release Properties – The type and style of lagging selected will impact its ability to prevent sticking or adherence of foreign particulate to the surface. If ease is desired in eliminating foreign material from exposed lagged surfaces, then a lagging compound with good release properties should be considered.

STEP #8: Determine the Type of Contact Surface Required (cont)

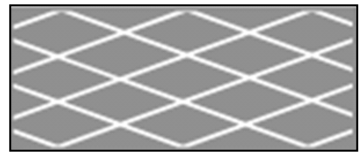
Grooved Lagging

The contact surface of most lagged pulleys can be modified from a rough ground finish to include several types of groove patterns. These groove patterns assist the conveyor pulley in dispersing or eliminating water and debris away from the center of the pulley, resulting in increased traction and enhanced belt tracking characteristics



HERRINGBONE
For drive pulleys where conveyor operation is one directional

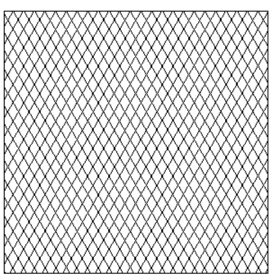
CHEVRON
For drive pulleys where conveyor operation is one directional



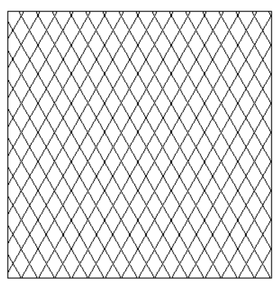
DIAMOND
For drive pulleys on reversing conveyor or when direction of rotation is unknown for displacement of materials

Knurling

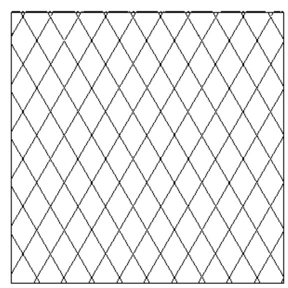
Knurling is a manufacturing process in which the surface of steel is altered by forming a pattern into the surface of the metal. The result of this process is a coarse pattern, typically diamond shaped, which gives the surface of the conveyor pulley excellent traction capabilities in most environments. However, because the surface is purposefully coarse, knurled pulleys can accelerate belt wear. Knurling is typically specified by communicating a pattern type (diamond, straight or diagonal) and level of coarseness using TPI, or Teeth per Inch as an indicator. Generally speaking, the lower the number of teeth provided per inch of surface area, the deeper the depth of groove provided, resulting in a rougher, coarser surface finish.



FINE DIAMOND KNURL
25 Teeth per Inch



MEDIUM DIAMOND KNURL
16 Teeth per Inch



COARSE DIAMOND KNURL
10 Teeth per Inch

Special Surface Finishes

The construction of most conveyor pulleys allows the contact surface to be machined, ground, media treated or polished if a more consistent finish is required. A special surface finish may be desirable for:

- Ease of Cleaning / Sanitary Needs
- Grooves
- Scratches or Pits
- Need for a More Consistent Surface Finish
- Specific Tolerances
- Other Performance Enhancing Features

STEP #9: Other Important Specifications to Consider

Concentricity

Concentricity is a term used to describe how closely two interrelated objects share a common center point. The outer surface geometry of the objects has no impact on their concentricity to one another. Aside from theoretical calculations and the use of a CMM-Coordinate Measuring Machine, concentricity can prove to be very difficult to measure.

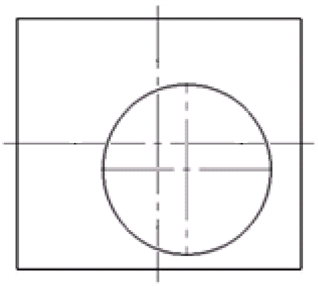


Figure 10

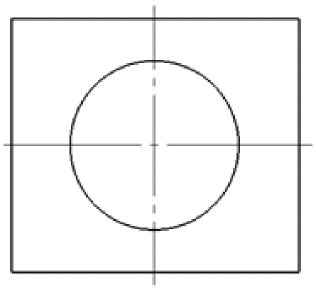


Figure 11

The circle and rectangle pictured in figure 10 are not concentric to one another in that they do not share a common center point. The measure of their concentricity to one another would describe the distance from the center point of the circle to the center point of the rectangle. The circle and rectangle in figure 11 are concentric to one another in that they share a common center point.

Circular Runout

Circular runout or runout, as it is often referred, is a term used to describe the degree of circular irregularity found at one location of a round object. Runout is measured on the outer diameter of the round object with a dial indicator while the object is rotating. The amount of runout measured on a conveyor pulley will impact application variables of the conveyor system such as the amount of effective belt tension and corresponding belt stretch.

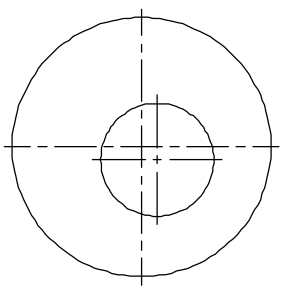


Figure 12

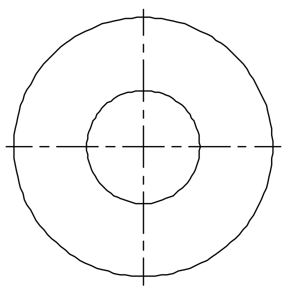


Figure 13

The two objects in figure 12 both appear to be round, but are not positioned such that they share a common center point. These circles would demonstrate both poor concentricity and poor circular runout. The two objects in figure 13 appear to be round and share a common center, therefore it could be said that they demonstrate both good runout and good concentricity.

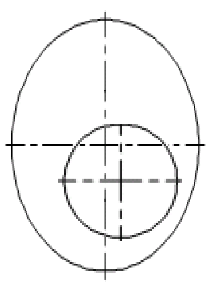


Figure 14

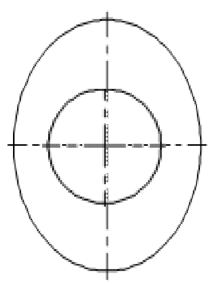


Figure 15

The two objects in figure 14 are not positioned such that they share a common center point. These shapes would demonstrate both poor concentricity and poor circular runout. The outer object in figure 15 appears to be egg shaped while the center object appears to be round, but both appear to share a common center. Therefore, it could be said these objects demonstrate both good concentricity but poor runout.

Concentricity versus Circular Runout

Runout and concentricity are separate measurements and communicate different characteristics. However, it is important to note that a satisfactory measurement of runout on a conveyor pulley also describes a degree of its concentricity but a measurement of concentricity does not ensure desirable runout. Because roundness may impact performance, when specifying performance requirements for conveyor pulley products be sure to specify the desired runout for the assembly as opposed to desired concentricity.

Other Important Specifications to Consider (cont)

Measuring Circular Runout

Circular runout is measured through use of a dial indicator on the outer diameter of an object while the object is rotating. By rotating the object, the dial indicator will measure the distance between a location of reference and the contact location on the outer diameter of the object for all of the locations located on the outer surface. The difference between the largest measurement and the smallest measurement will equal the total runout for that location on the object's length.

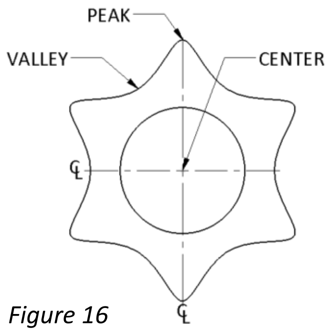


Figure 16

The runout or circular irregularity of the outer toothed object (Figure 16) with respect to its center point would be the distance from the highest peak of its teeth to its center point minus the distance from the lowest valley to its center point. This value would describe its circular runout at a given location along the object's length.

Maximum Circular Runout (MCR)

Maximum circular runout describes the maximum or greatest runout value taken when taking measurements at several locations across the entire face of an object, with respect to its center point.

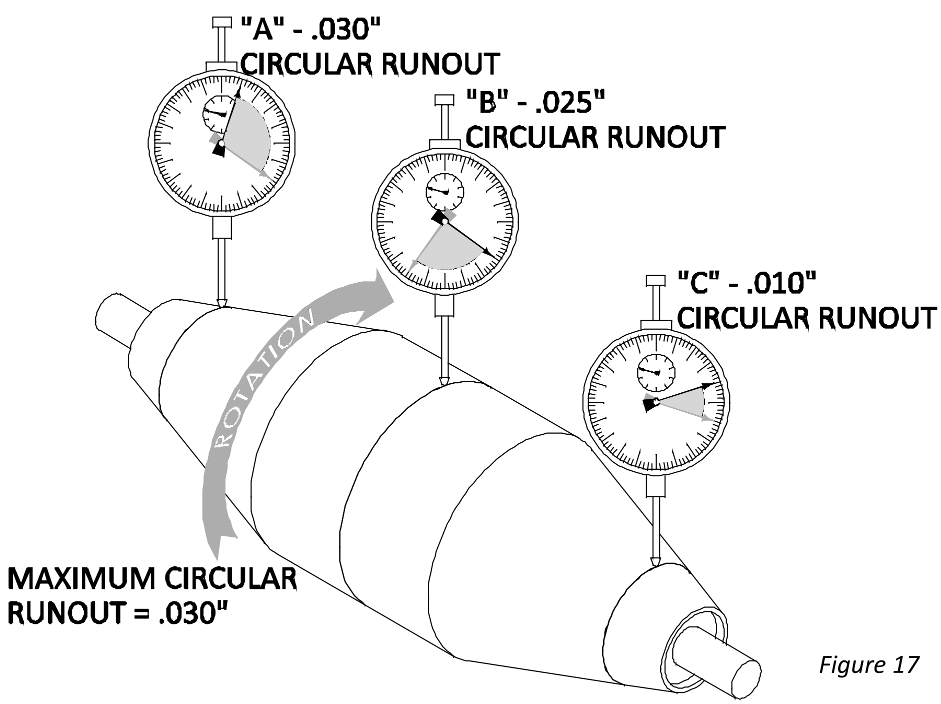


Figure 17

MCR Example

In this example, a dial indicator would be placed at location A on the face of the object, and then the object would be spun 360° to determine the runout of the circular section at location A. The same would then be done at locations B & C. The maximum runout for the object would be the largest measurement taken, which is .030" at location A.

Other Important Specifications to Consider (cont)

Total Indicated Runout – Total Indicator Reading (TIR)
TIR is a measurement specification which describes the difference between the highest measurement and the lowest measurement taken when measuring runout across the entire face of an object with respect to its center of rotation. TIR is measured from a fixed plane across the object's face. Because of this, it not only describes circular irregularity, but also takes in to account the object's straightness and taper. TIR can be difficult to measure, and is not normally a desirable specification when referring to pulleys with a profile other than a flat face.

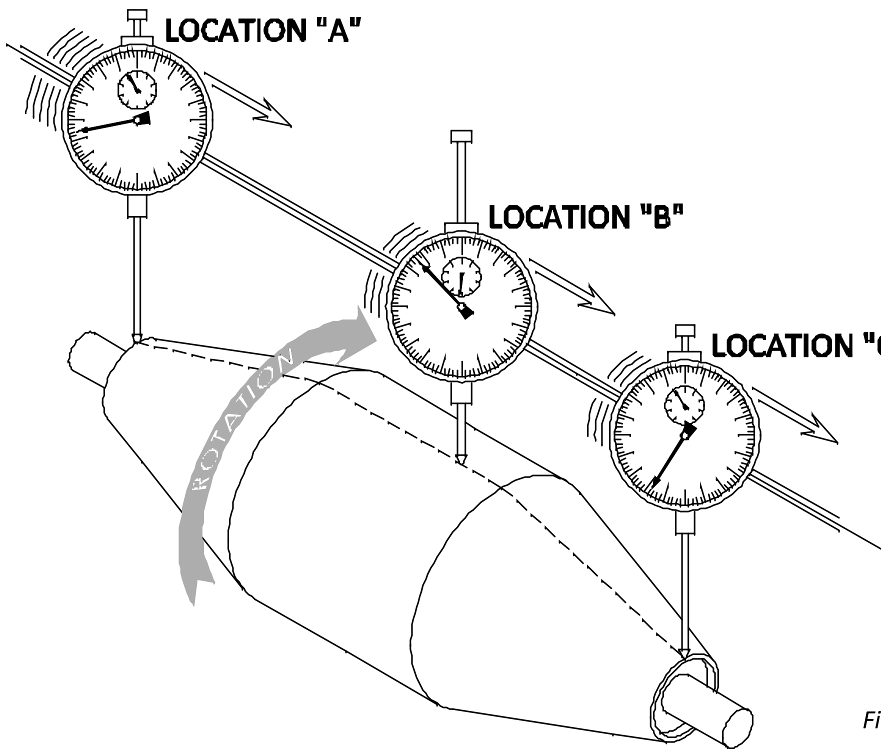


Figure 18

TIR Example
In this example, a dial indicator is positioned on a fixed plane across the face of an object which is intentionally given a tapered profile. While the object is rotated, the dial indicator would be moved continuously across the face of the object along a plane parallel to the object's center of rotation. Assuming that location "C" is the largest measurement taken across the face and location "B" is the smallest measurement taken across the face, the TIR of the object would be measurement at "C" minus the measurement at "B". The intentional tapered profile of the object will significantly impact TIR values.

Maximum Circular Runout (MCR) versus Total Indicated Runout (TIR)
Although both measurements describe the degree of circular irregularity and subsequent concentricity of two objects, maximum circular runout and total indicated runout are two entirely different measurements. Maximum circular runout is commonly an acceptable specification when attempting to dictate an object's circular irregularity and concentricity while TIR offers these two characteristics while taking into account an objects profile as well. Because conveyor pulleys are often given specific profiles to achieve application requirements, maximum circular runout is most desirable specification for communicating a pulleys desired circular irregularity and concentricity.

Other Important Specifications to Consider (cont)

Balancing

Balancing is a process of adding or removing weight from an object in order to achieve a uniform weight distribution about its rotational center. There are two primary types of balancing: static and dynamic. Static balancing provides an equal distribution of weight about an object's rotational center, but its centerline of mass may not be on the same axis as its rotational center. Static balancing may be verified while an object is at rest. Dynamic balancing brings an objects rotational center and its center of mass together on the same axis. An object with a center of mass on the exact same axis as its center of rotation would be perfectly dynamically balanced. Dynamic balancing must be verified with an object in motion, and offers an elevated level of performance versus static balancing. An object that is dynamically balanced would also be statically balanced by default, but a statically balanced object is not necessarily dynamically balanced. Balancing is not necessary in the majority of conveyor applications, but it should be considered for conveyors moving at elevated speeds (typically greater than 450FPM) or where vibration is a primary concern.

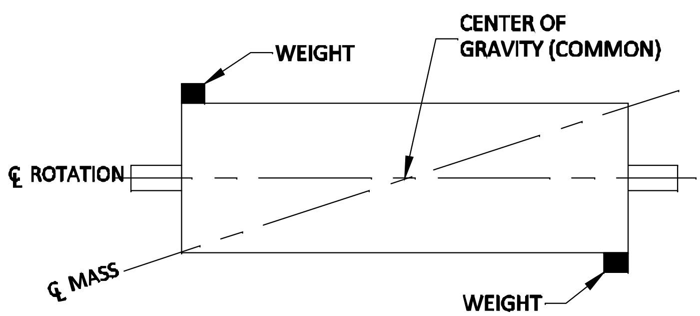


Figure 19 – **Statically balanced pulley**
Mass centerline crosses rotational centerline, but does not share an axis.

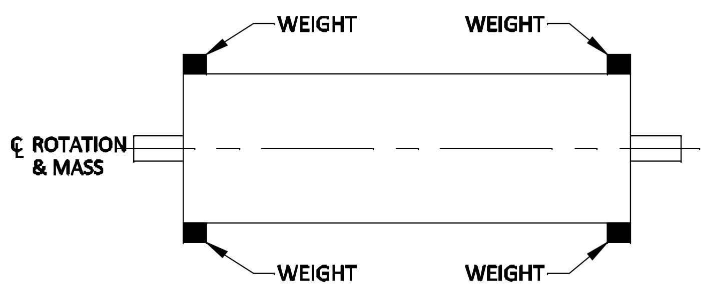


Figure 20 – **Dynamically balanced pulley**
Mass centerline and rotational centerline are on a common axis.

Balancing specifications are communicated by indicating a balance quality grade and the intended maximum service speed of the application. The balance quality grade is the product of specific unbalance and the rotor maximum service angular velocity. Service angular velocity is service RPM expressed in radians per second. (See Appendix B: Balance quality grades for various groups of representative rigid rotors – From ISO 1940/1)

For Example: Pulley is dynamically balanced to 1250RPM (G100)

INDEX

INDEX

APPENDIX A: Stress and Deflection Formulas

Maximum Shaft Load

Pulley shafts should be sized such that they do not reach a maximum bending stress greater than 8000 psi and they do not deflect more than 8 minutes (0.13°) or 0.00232711 inches/inch. Therefore the maximum load a shaft should be subjected to will be the lower result of the following two load calculations:

Max Load Based on Shaft Stress : **1000 πD^3/(Face Width + 4D – Hub Centers)**

Max Load Based on Shaft Deflection: **8435.77πD^4/((Face Width + 4D – Hub Centers)(Hub Centers))**

(The above formula applies to grades of steel shafts only)

MAXIMUM LOAD BASED ON SHAFT STRESS

[Based on 8000 psi maximum shaft stress]

F = 1000 πD^3/(Face Width + 4D – Hub Centers)

The above formula is derived from the Shaft Stress Formula **σ = My/I = 8000 psi (σ = My/I)** where:

- **I** = Moment of Inertia = $\pi D^4/64$
- **D** = The diameter of the shaft
- **M** = The bending moment = ½ F*A where:
  - **F** = The load on the pulley (lbs.).
  - **A** = The moment arm = ½ (Bearing Centers – Hub Centers).
- **y** = Perpendicular distance to the neutral axis = D/2

To determine the maximum load based on shaft stress, we need to work this formula backwards assuming a maximum recommended bending stress of 8000 psi.

Breaking out the formula, we get: **σ = My/I = 8000 psi**

σ = ½ FAy/I = FAy/(2(I)) = 8000 psi

Dividing both sides by FAy/2(I) to solve for F, we get:

F = 16000(I)/(Ay) = 16000(πD^4/64)/½(Face Width + 4D – Hub Centers)(D/2))

F = 250 πD^4/(D(Face Width + 4D – Hub Centers)/4)

F = 1000 πD^4/(D(Face Width + 4D – Hub Centers))

F = 1000 πD^3/(Face Width + 4D – Hub Centers)

MAXIMUM LOAD BASED ON SHAFT DEFLECTION

(Applies to grades of steel shafts only)

[Based on 8 minutes (.00232711" per inch) of maximum deflection]

$$F = 8435.77\pi D^4/((\text{Face Width} + 4D - \text{Hub Centers})(\text{Hub Centers}))$$

The above formula is derived from the Shaft Deflection Formula **$\tan\alpha = FA(B-2A)/(4EI)$** where:

- **α** = Shaft Deflection in minutes.
- **$\tan\alpha$** = The tangent of α, which is the Shaft Deflection in inches/inch.
- **F** = The load on the pulley.
- **A** = The moment arm = ½ (Bearing Centers – Hub Centers)
  - Hub Centers can be determined by hub style and Face Width
- **B** = Bearing Centers
- **E** = Young's Modulus of Elasticity (29,000,000 psi for steel)
- **I** = Moment of Inertia = $\pi D^4/64$

To determine the maximum load based on shaft deflection, we need to work this formula backwards assuming a maximum shaft deflection of 8 minutes or 0.00232711 inches/inch. Breaking out the formula we get:

$\tan\alpha = FA(B-2A)/(4EI) = 0.00232711$

Dividing both sides by A(B-2A)/(4EI) to solve for F, we get:

$F = 0.00232711(4EI)/(A(B-2A))$

$F = 0.00232711(4*29{,}000{,}000*\pi D^4/64)/(½(\text{Face Width} + 4D - \text{Hub Centers})(\text{Face Width} + 4D - (\text{Face Width} + 4D - \text{Hub Centers})))$

$F = 0.00232711(1{,}812{,}500\ \pi D^4)/(½(\text{Face Width} + 4D - \text{Hub Centers})(\text{Hub Centers}))$

$F = 8435.77\pi D^4/((\text{Face Width} + 4D - \text{Hub Centers})(\text{Hub Centers}))$

Maximum Tube Stress

The approximate tube stress in the pulley wall can be generated by performing a point load calculation based on the theoretical maximum load capacity of the shaft.

POINT LOAD FORMULA

$$\sigma = 8(OD)F(\text{Hub Centers})/(\pi(OD^4-ID^4))$$

The formula for point load is : **$\sigma = yF(B-2A)/(4I)$** where:

- **y** = Perpendicular distance to the neutral axis = OD/2 where:
- **OD** = The outer diameter of the tube
- **F** = The load on the pulley (lbs.). (Minimum of the maximum loads based on shaft stress and shaft deflection)
- **B** = Bearing Centers
- **A** = The moment arm = ½ (Bearing Centers – Hub Centers)
  - Hub Centers can be determined by hub style and face Width
- **I** = Moment of Inertia of the Tube = $\pi(OD^4-ID^4)/64$
- **ID** = The inner diameter of the tube = OD – 2*Wall Thickness

Breaking out the formula, we get:

$\sigma = ½(OD)F((\text{Face Width} + 4D)-2A)/(4\pi(OD^4-ID^4)/64)$

$\sigma = ½(OD)F(B-2(½((\text{Face Width} + 4D) - \text{Hub Centers})))/(4\pi(OD^4-ID^4)/64)$

$\sigma = 8(OD)F(\text{Hub Centers})/(\pi(OD^4-ID^4))$

It is recommended that the tube stress be kept under 10,000 psi for a standard drum style pulley and under 3400 psi for a pulley with a v-groove profile. If your estimated pulley load yields a tube stress greater than recommended, you may reduce this stress by increasing the pulley diameter or by increasing the wall thickness.

APPENDIX B: Balance quality grades for various groups of representative rigid rotors (From ISO 1940/1)

Balance Quality Grade	Product of the Relationship ($e_{per} \times \omega$) (1) (2) mm/s	Rotor Types - General Examples
G 4 000	4 000	Crankshaft/drives(3) of rigidly mounted slow marine diesel engines with uneven number of cylinders(4)
G 1 600	1 600	Crankshaft/drives of rigidly mounted large two-cycle engines
G 630	630	Crankshaft/drives of rigidly mounted large four-cycle engines Crankshaft/drives of elastically mounted marine diesel engines
G 250	250	Crankshaft/drives of rigidly mounted fast four-cylinder diesel engines(4)
G 100	100	Crankshaft/drives of fast diesel engines with six or more cylinders(4) Complete engines (gasoline or diesel) for cars, trucks and locomotives(5)
G 40	40	Car wheels, wheel rims, wheel sets, drive shafts Crankshaft/drives of elastically mounted fast four-cycle engines with six or more cylinders(4) Crankshaft/drives of engines of cars, trucks and locomotives
G 16	16	Drive shafts (propeller shafts, cardan shafts) with special requirements Parts of crushing machines Parts of agricultural machinery Individual components of engines (gasoline or diesel) for cars, trucks and locomotives Crankshaft/drives of engines with six or more cylinders under special requirements
G 6.3	6.3	Parts of process plant machines Marine main turbine gears (merchant service) Centrifuge drums Paper machinery rolls; print rolls Fans Assembled aircraft gas turbine rotors Flywheels Pump impellers Machine-tool and general machinery parts Medium and large electric armatures (of electric motors having at least 80 mm shaft height) without special requirements Small electric armatures, often mass produced, in vibration insensitive applications and/or with vibration-isolating mountings Individual components of engines under special requirements
G 2.5	2.5	Gas and steam turbines, including marine main turbines (merchant service) Rigid turbo-generator rotors Computer memory drums and discs Turbo-compressors Machine-tool drives Medium and large electric armatures with special requirements Small electric armatures not qualifying for one or both of the conditions specified for small electric armatures of balance quality grade G 6.3 Turbine-driven pumps
G 1	1	Tape recorder and phonograph (gramophone) drives Grinding-machine drives Small electric armatures with special requirements
G 0.4	0.4	Spindles, discs and armatures of precision grinders Gyroscopes

1) $\omega = 2\pi n/60 \approx n/10$, if n is measured in revolutions per minute and ω in radians per second.
2) For allocating the permissible residual unbalance to correction planes, refer to "Allocation of U_{per} to correction planes."
3) A crankshaft/drive is an assembly which includes a crankshaft, flywheel, clutch, pulley, vibration damper, rotating portion of connecting rod, etc.
4) For the purposes of this part of ISO 1940/1, slow diesel engines are those with a piston velocity of less than 9 m/s; fast diesel engines are those with a piston velocity of greater than 9 m/s.
5) In complete engines, the rotor mass comprises the sum of all masses belonging to the crankshaft/drive described in note 3 above.