MPTA B8i-2011 R2016

STANDARD FORMULA FOR THE DETERMINATION OF BENDING STRESSES IN V-BELT SHEAVE ARMS

MPTA STANDARD

Mechanical Power Transmission Association
5672 Strand Court, Suite 2, Naples, FL 34110
www.mpta.org

Contributors

Altra Industrial Motion – TB Woods Inc.	**Chambersburg, PA**	www.tbwoods.com
B&B Manufacturing, Inc.	**LaPorte, IN**	www.bbman.com
Baldor-Dodge	**Greenville, SC**	www.baldor.com
Carlisle Belts Business - Timken	**Springfield, MO**	www.carlstargroup.com
Continental ContiTech	**Fairlawn, OH**	www.contitech.us
Custom Machine & Tool Co., Inc.	**Hanover, MA**	www.cmtco.com
Gates Corporation	**Denver, CO**	www.gates.com
Goldens' Foundry & Machine Co.	**Columbus, GA**	www.gfmco.com
Lovejoy	**Downers Grove, IL**	www.lovejoy-inc.com
Martin Sprocket & Gear, Inc.	**Arlington, TX**	www.martinsprocket.com
Maurey Manufacturing Corp.	**Holly Springs, MS**	www.maurey.com
Regal Beloit America, Inc.	**Maysville, KY**	www.regalbeloit.com
Torque Transmission	**Fairport Harbor, OH**	www.torquetrans.com

Abstract
This standard provides a method for calculating bending stresses in v-belt sheave arms.

Foreword
This Foreword is provided for informational purposes only and is not to be construed to be part of any technical specification.

This version was reaffirmed in 2016 with updates in format, illustrations, and content.

Suggestions for the improvement of, or comments on this publication are welcome. They should be submitted to http://mpta.org/contact/.

Symbols

A_c	=	Arc correction factor
C	=	Drive center distance (in.)
D	=	Large sheave pitch diameter (in.)
d	=	Small sheave pitch diameter (in.)
Di	=	Inside diameter of sheave rim (in.)
Dn	=	Outside diameter of sheave hub (in.)
Dp	=	Sheave pitch diameter (in.)
e	=	Eccentricity of belt load to arm centerline (in.)
HP	=	Total drive horsepower, before SF is applied
N	=	Number of grooves or belts
n	=	Number of sheave arms
Q	=	Total drive torque (lb. · in.)
Sc	=	Combined bending stresses (psi)
Se	=	Bending stress by eccentric belt loading (psi)
St	=	Bending stress by torque (psi)
$(T_1 – T_2)$	=	Effective tension per belt (lb.)
$(T_1 + T_2)$	=	Total belt pull per belt (lb.)
SF	=	Service factor for the drive
V	=	Belt speed in feet per minute (FPM)
Z(x & y)	=	Section modulus at hub (in^3)

1. Determination of Loads

Effective Tension Per Belt:
Use Formula 1 to solve for power inputs or Formula 2 to solve for torque inputs.

Formula 1: $(T_1 - T_2) = \frac{33{,}000 \cdot HP \cdot SF}{V \cdot N}$ (lb.)

Or

Formula 2: $(T_1 - T_2) = \frac{2 \cdot Q \cdot SF}{D_p \cdot N}$ (lb.)

Where:

HP = Total drive horsepower, before SF is applied
SF = Service factor for the drive
If the end use of the sheave is unknown; SF = 1.0
V = Belt speed in feet per minute, (FPM)
If the end use of the sheave is unknown; V = 1000 FPM
N = Number of belts
Q = Total drive torque, in lb·in, before SF is applied
Dp = Sheave pitch diameter (in.)

If the end use of the sheave is unknown calculate total drive HP based on the highest applicable belt HP ratings per formula 3.

Formula 3: $HP = \begin{bmatrix} Basic\ HP\ per\ belt \\ at\ 1{,}000 fpm/belt \end{bmatrix} + \begin{bmatrix} Highest\ speed \\ ratio\ add{-}on \end{bmatrix} \cdot \begin{bmatrix} Highest\ belt\ length \\ correction\ factor \end{bmatrix} \cdot N$

Total Belt Pull (per belt):

Formula 4: $(T_1 + T_2) = \left[\frac{2.5 - A_c}{A_c}\right] \cdot (T_1 - T_2)$ (lb.)

Where:

A_c = Arc correction factor from Table 1
If the end use of the sheave is unknown; A_c = 1.0
(T1 – T2) = Effective tension per belt from Formula 1 (lb.)

Table 1 – Arc Correction Factors (A_c)

$\frac{D-d}{C}$	Correction Factor A_c
.00	1.00
.10	0.99
.20	0.97
.30	0.96
.40	0.94
.50	0.92
.60	0.90
.70	0.88
.80	0.87
.90	0.85
1.00	0.83
1.10	0.80
1.20	0.78
1.30	0.75
1.40	0.72
1.50	0.69

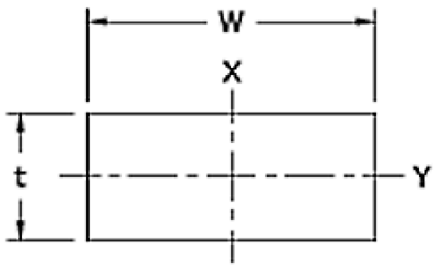
Where:

D = Large sheave pitch diameter (in.)
d = Small sheave pitch diameter (in.)
C = Drive center distance (in.)

2. Determination of Section Modulus

Figure 1: Zx and Zy Arm Dimensions, Measured at Hub

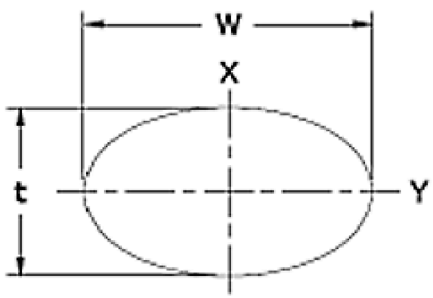
For Rectangular Arms



$$Zx = \frac{tW^2}{6} \quad (\text{In}^3)$$

$$Zy = \frac{Wt^2}{6} \quad (\text{in}^3)$$

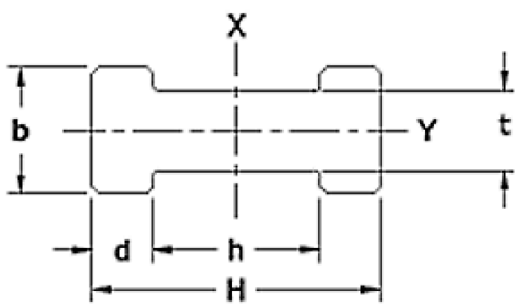
For Oval Arms



$$Zx = .098\, tW^2 \ (\text{in}^3)$$

$$Zy = .098\, Wt^2 \ (\text{In}^3)$$

For I Beam Arms



$$Zx = \frac{bH^3 - h^3(b-t)}{6H} \quad (\text{in}^3)$$

$$Zy = \frac{2db^3 + ht^3}{6b} \quad (\text{in}^3)$$

3. Determination of Bending Stress

Bending Stresses caused by torque. (St)

Formula 5: $$St = \left[\frac{(T_1 - T_2) \cdot N \cdot D_p}{2n \cdot Zx}\right] \cdot \left[\frac{Di - Dn}{Di}\right] \text{ (psi)}$$

Where:

$(T_1 - T_2)$ = Effective tension per belt from Formula 1 or 2 (lb.)
N = Number of grooves or belts
Dp = Sheave pitch diameter (in.)
n = Number of sheave arms
Zx = Section modulus at hub (in^3)
Di = Inside diameter of sheave rim (in.)
Dn = Outside diameter of sheave hub (in.)

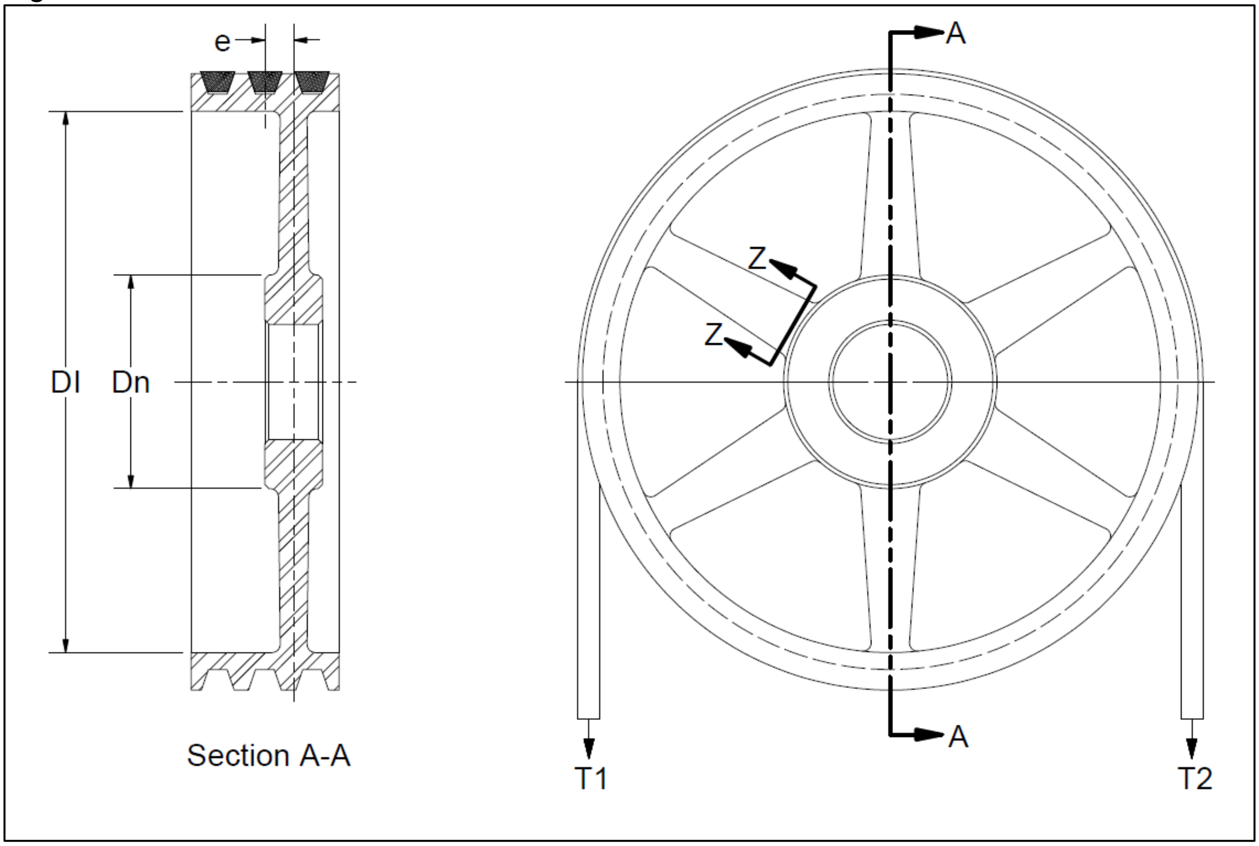
Bending Stresses caused by eccentric belt loading. (Se)

Formula 6: $$Se = \left[\frac{(T_1 + T_2) \cdot N \cdot e}{4.5 \cdot Zy}\right] \cdot \left[\frac{Di - Dn}{Di}\right] \text{ (psi)}$$

Where:

$(T_1 + T_2)$ = Total belt pull per belt from Formula 4 (lb.)
N = Number of grooves or belts
e = Eccentricity of belt load to arm centerline (in.)
Zy = Section modulus at hub (in^3)
Di = Inside diameter of sheave rim (in.)
Dn = Outside diameter of sheave hub (in.)

Figure 2: Illustration of Nomenclature



Combined bending stresses. (Sc)

Formula 7: For Rectangular & I-Beam Arms.

$$Sc = St + Se \quad \text{(psi)}$$

Or

Formula 8: For Oval Arms.

$$Sc = \sqrt{St^2 + Se^2} \quad \text{(psi)}$$

Where:

St = Bending stress by torque (psi)
Se = Bending stress by eccentric belt loading (psi)

The combined stress must be less than 10% of the minimum tensile strength of the material used. This 10% value is derived by assuming a 40% endurance limit and derating 50% for possible residual stresses and another 50% for a safety factor.