

MPTA-B8i-2011

Standard Formula for the Determination of
Bending Stresses in V-Belt Sheave Arms



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Abstract

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

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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 2011 with updates in format and illustrations.

Suggestions for the improvement of, or comments on this publication are welcome. They should be mailed to Mechanical Power Transmission Association, 5672 Strand Court, Suite 2, Naples, FL 34110 on your company letterhead.

Scope

This standard is intended to provide a method to provide consistency and accuracy in determining bending stresses in sheave arms caused by torque and eccentric belt loading.

Symbols

A_c	=	Arc correction factor
C	=	Drive center distance (in.)
D	=	Large sheave pitch diameter (in.)
d	=	Small sheave pitch diameter (in.)
D_i	=	Inside diameter of sheave rim (in.)
D_n	=	Outside diameter of sheave hub (in.)
D_p	=	Sheave pitch diameter (in.)
e	=	Eccentricity of belt load (in.)
HP	=	Total drive horsepower, before SF is applied
N	=	Number of grooves or belts
n	=	Number of sheave arms
S_c	=	Combined bending stresses (psi)
S_e	=	Bending stress by eccentric belt loading (psi)
S_t	=	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)
$Z(x \text{ \& } y)$	=	Section modulus at hub (in ³)

1. Determination of Loads

Effective Tension Per Belt

$$\text{Formula 1: } (T_1 - T_2) = \frac{33,300 (HP) (SF)}{V N} \quad (\text{lb.})$$

where:

- HP = Total Drive horsepower, before SF is applied
- SF = Service factor for the drive
- V = Belt speed in feet per minute, (FPM)
- N = Number of belts

If the end use of the sheave is unknown calculate total drive HP based on the highest applicable belt HP ratings per formula 2.

$$\text{Formula 2: } HP = \left[\begin{array}{l} \text{Basic HP per belt} \\ \text{at 1,000 fpm/belt} \end{array} + \begin{array}{l} \text{Highest speed} \\ \text{ratio add-on} \end{array} \right] \bullet \left[\begin{array}{l} \text{Highest belt length} \\ \text{correction factor} \end{array} \right] \bullet N$$

Also, use V = 1,000 FPM and SF = 1.0 in formula 1.

Total Belt Pull (per belt)

$$\text{Formula 3: } (T_1 + T_2) = \left[\frac{2.5 - A_c}{A_c} \right] \bullet [T_1 - T_2] \quad (\text{lb.})$$

where:

- A_c = Arc correction factor from Table 1
- $(T_1 - T_2)$ = Effective tension per belt from Formula 1 (lb.)

If the end use of the sheave is unknown, use $A_c = 1.0$ in Formula 3.

Table #1 – Arc Correction Factors (A_c)

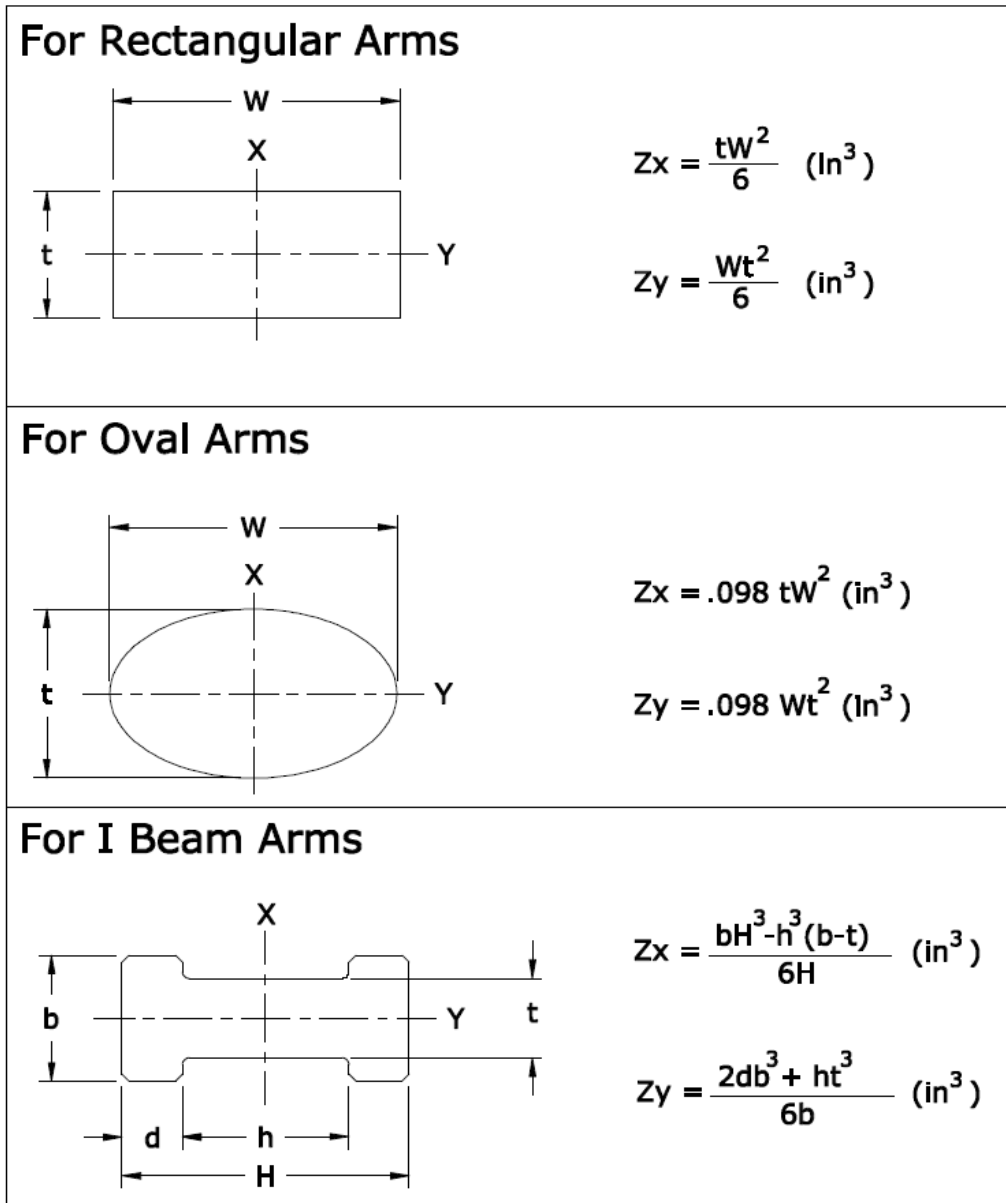
$\frac{D-d}{C}$	Correction Factor (A_c)
.00	1.00
.10	0.99
.20	0.97
.30	0.96
.40	0.94
.50	0.92
.60	0.90
.70	0.88
.80	0.87
.90	0.85
1.00	0.83
1.10	0.80
1.20	0.78
1.30	0.75
1.40	0.72
1.50	0.69

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



3. Determination of Bending Stress

Bending Stresses caused by torque. (St)

$$\text{Formula 4: } St = \left[\frac{(T_1 - T_2) N Dp}{2n Zx} \right] \bullet \left[\frac{Di - Dn}{Di} \right] \quad (\text{psi})$$

where:

$(T_1 - T_2)$ = Effective tension per belt from Formula 1 (lb.)

N = Number of grooves or belts

Dp = Sheave pitch diameter (in.)

n = Number of sheave arms

Zx = Section modulus at hub (in³)

Di = Inside diameter of sheave rim (in.)

Dn = Outside diameter of sheave hub (in.)

Bending Stresses caused by eccentric belt loading. (Se)

$$\text{Formula 5: } Se = \left[\frac{(T_1 + T_2) N e}{4.5 Zy} \right] \bullet \left[\frac{Di - Dn}{Di} \right] \quad (\text{psi})$$

where:

$(T_1 + T_2)$ = Total belt pull per belt from Formula 3 (lb.)

N = Number of grooves or belts

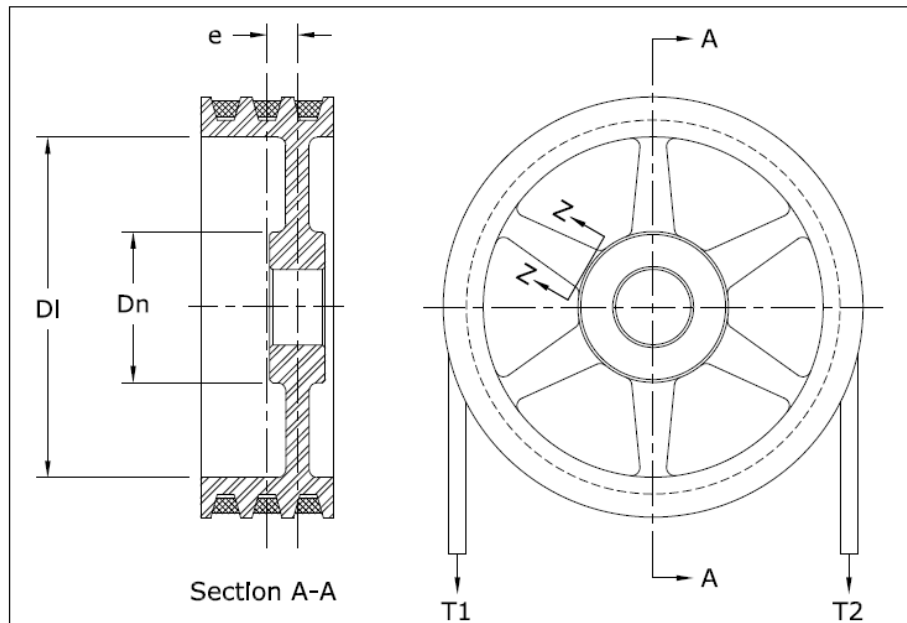
e = Eccentricity of belt load (in.)

Zy = Section modulus at hub (in³)

Di = Inside diameter of sheave rim (in.)

Dn = Outside diameter of sheave hub (in.)

Figure #2: Illustration of Nomenclature



Combined bending stresses. (S_c)

Formula 6: For Rectangular & I-Beam Arms.

$$S_c = S_t + S_e \quad (\text{psi})$$

where:

S_t = Bending stress by torque (psi)

S_e = Bending stress by eccentric belt loading (psi)

Formula 7: For Oval Arms.

$$S_c = \sqrt{S_t^2 + S_e^2} \quad (\text{psi})$$

where:

S_t = Bending stress by torque (psi)

S_e = 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.