

DETERMINATION OF MINIMUM PULLEY DIAMETERS FOR BELT CONVEYORS

Dave Pitcher

Fenner Conveyor Belting (SA) (Pty) Ltd

INTRODUCTION

When a belt bends, the inner and outer surfaces change in length. Somewhere between the two surfaces is a neutral plane. The neutral plane does not change in length. Below the neutral plane the belt is compressed and above the neutral plane the belt is extended. The difference in path length between the inner and outer belt surfaces generates a difference in tension. This difference must be limited to ensure that the carcass reinforcement is not overstressed and that compression fatigue is not induced.

CONVEYOR BELT CONSTRUCTION

A conveyor belt comprises a carcass and covers. These two elements have very different elastic properties. Typically the modulus of carcass reinforcement material is at least 30 times greater than that of rubber, but it could be as much as 300 times greater. For this reason it is only necessary to investigate force changes in the carcass itself when considering minimum radius of bend.

Although the carcass would generally be made up of a material composite, this is very symmetrical about the centre line. Hence the neutral axis in a conveyor belt carcass lies in the centre of the carcass. The difference in force between inner and outer extremities of the carcass can be determined.

FORCES IN THE CARCASS

Consider a portion of the belt A, B with carcass thickness, e , that bends around a pulley of diameter D . Suppose also that the tension in the belt is T and the bottom cover thickness is δd . (Figure 1).

The distance from the centre of pulley to the inner edge of the belt carcass is $D/2 + \delta d$.

The distance to the outer edge of the belt carcass is $D/2 + \delta d + e$.

The arc length of the inner portion of carcass is $(D/2 + \delta d)\theta$ while the length along the outer portion of carcass is $(D/2 + \delta d + e)\theta$ which

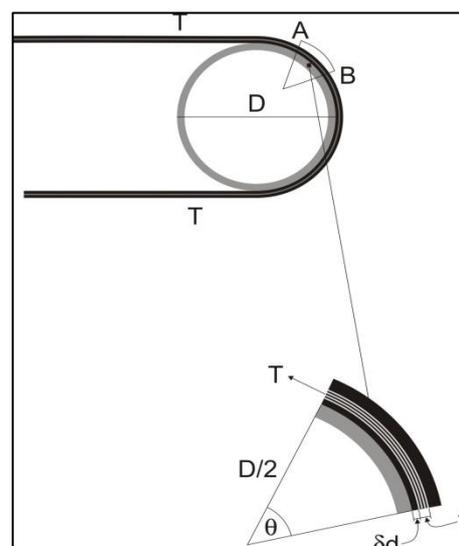


Figure 1. Belt wrapped on pulley

means the difference in length is $t\theta$ and the strain is

$$\epsilon = \frac{e \cdot \theta}{\left(\frac{D}{2} + \delta d\right) \theta}$$

Associated with the strain is tension gradient given by

$$\Delta T = \epsilon \cdot E$$

Or

$$\Delta T = \frac{2e \cdot E}{D + 2\delta d}$$

The bottom cover thickness will always be very small in comparison to the pulley diameter so the portion $2\delta d$ can be ignored. This means that the relationship between pulley diameter and tension gradient in the carcass is

$$D = \frac{2e \cdot E}{\Delta T} \quad 1$$

Where

D = pulley diameter

E = modulus of elasticity of the carcass (belt)

e = carcass thickness

ΔT = difference in tension between inner and outer surfaces of the carcass.

COMPARISON TO ISO 3684 STANDARD FOR DETERMINATION OF PULLEY DIAMETERS

The belt modulus for multi-ply textile reinforced belting, expressed in terms of the rated belt tension is

$$E = s \cdot t_r$$

Where

s = stretch factor at rated load of the belt.

The stretch factor is the reciprocal of the percentage elongation. Thus for 2% elongation at rated tension the stretch factor is 50.

The tension gradient can be expressed in terms of the rated tension of the belt

$$\text{i.e. } \Delta T = p \cdot t_r$$

Where

p = belt carcass bending factor. The range of magnitude for the bending factor is dependent on the carcass construction and falls between 1.0 and 6.0.

So Equation 1 can be written as

$$D = \frac{2s \cdot t_r \cdot e}{p \cdot t_r}$$

Or

$$D = \frac{2s}{p} \cdot e \quad 2$$

Let

$$C = \frac{2s}{p}$$

Then Equation 2 can be written as

$$D = C \cdot e \quad 3$$

Equation 3 is therefore the same as used by ISO 3684 standard for the determination of pulley diameters. The ISO 3684 standard provides seven values of C for seven different carcass materials. Using known stretch factors for the ISO listed materials, and assuming that all the textile materials should be based on the same carcass construction and therefore have the same bending factor, the values of each of the separate components of the factor C can be derived as shown in Table 1.

Following the ISO 3684 standard, the diameter of the high tension pulleys must be rounded up to the next diameter listed in Table 1 of the standard (attached as Addendum 1 for reference) above the value determined by means of Equation 3. Increase in tension across the carcass has been shown to be directly proportional to the pulley diameter (for any given carcass thickness and construction) therefore the pulley diameter can be reduced by the same percentage as the percentage difference between belt rated tension and actual tension at the pulley. The ISO 3684 standard allows reduction in pulley diameter for pulley location and conveyor tension relative to belt rated tension.

Carcass material	Belt factor C	Stretch factor s	Carcass bending factor p
Cotton	80	56	1.78
Nylon	90	80	1.78
Cotton / nylon	90	80	1.78
Cotton / polyester	98	110	1.78
Polyester	108	121	1.78
Rayon	118	133	1.78
Steel	145	400	5.52

Table 1. Components of belt factor

EXAMPLE OF PULLEY SELECTION

Consider a multi-ply textile reinforced belt with a polyester carcass of 6 mm thickness. Suppose that the tensions in the system are

$$T_1 = 78 \text{ kN/m}$$

$$T_2 = 31 \text{ kN/m}$$

$$t_r = 80 \text{ kN/m}$$

Using Equation 3 the calculated minimum pulley diameter is

$$\begin{aligned} D &= 108 \times 6 \\ &= 648 \text{ mm} \end{aligned}$$

Adopting the ISO 3684 method of determining pulley diameters, the next largest standard pulley diameter is 800 mm. If indeed the belt factor is correctly stated at 108 for the belt under consideration, then a 650 mm pulley diameter is adequate. When considering the low tension pulley, the ISO method returns a pulley size of 630 mm whereas direct application of the formula, and taking into account the fact that the tension at the pulley is only 39% of the rated belt tension, the diameter of this pulley could be reduced to 250 mm.

CONCLUSION

The use of a multiplier (belt factor) used in the ISO 3684 method of determining pulley diameters is based on sound reasoning. However, the ISO standard does not distinguish between different belt constructions. This places doubt on the applicability of the seven listed multipliers. All belt manufacturers would recommend smaller pulley diameters for a solid woven carcass construction even when woven with the same yarn material as an equivalent thickness multi-ply construction carcass.

If a standard method of measuring bending factors for belt carcasses were to be developed, the ISO 3684 could be enhanced to cater for every belt with a greater degree of accuracy.

ADDENDUM 1

Standard range of pulleys given in ISO 3684 Table 1

100	630
125	800
160	1000
200	1250
250	(1400)
315	1600
400	(1800)
500	2000

Table 1. Standard range of pulleys

REFERENCES

ISO 3684:1990 2nd edition. Conveyor belts - Determination of minimum pulley diameters

ABOUT THE AUTHOR

DAVE PITCHER

Dave Pitcher is the technology manager at Fenner Conveyor Belting. He has been involved in belt conveyor systems since 1974. His experience covers many different aspects of belt conveyors from design to application of all components. He has served on standards committees for standardisation of conveyor belting since 1976.

Dave wrote the first computer program for complete design and component selection of belt conveyor systems. He has previously presented papers at the International Materials Handling Conference and is currently serving on the organising committee. He is a board member of the Conveyor Manufacturers Association (CMA) and a member of the Conveyor Belting and Handbook work group of the CMA.

Dave Pitcher has a Diploma in Datametrics from UNISA and recently passed the CMA Diploma Course in Belt Conveyor Design and Operation.

Dave Pitcher

Fenner Conveyor Belting (Pty) Ltd

21 Diesel Road, Isando, 1600

Tel: +27 11 974 1902 Fax +27 11 974 1900

Cell +27 82 320 7324

dave.pitcher@fenner.com

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