

CROSS-SECTIONAL AREA OF THE BELT CONVEYOR WITH A THREE-IDLER SET

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Summary: This contribution describes a determination of maximum height of the cap of cross-sectional area of the belt conveyor with one-idler set on the basis of known value of useable conveyor belt width. At the same time is determined the biggest cross-sectional area of belt conveyor with three-idler set assuming that the values of surcharge angle, conveyor belt width, troughing angle and length dimensions of idlers are known as well.

Key words: cross-sectional area, belt conveyor, three roll troughed idler set

INTRODUCTION

Maximum conveying capacity of the belt conveyor I_v [m³/s] is determined as the multiplication of the belt velocity v [m/s], slope coefficient of the belt conveyor k [-] and the biggest cross-sectional area S [m²].

The biggest cross-sectional area of the belt depends on usable conveyor belt width b [m] which is the function of conveyor belt width B [m], moreover on the trough shape, i.e. on the number of idlers and their proportions (centre idler length l_3 [m] and troughing angle λ [deg]), and on spherical cap shape of the cross-sectional area, which is limited by parabolic curve. This parabolic curve is characterized by surcharge angle Θ [deg] of the conveying material.

1. CROSS-SECTION AREA OF THE BELT CONVEYOR

If the value of surcharge angle Θ [deg] of conveying material is known as well as conveyor belt width B [m], it is possible to express useable conveyor belt width b [m] (see Fig. 1) according to equation (1).

$$\begin{aligned} b &= 0,9 \cdot B - 0,05 \quad \text{for } B \leq 2 \text{ m} \\ b &= B - 0,25 \quad \text{for } B > 2 \text{ m} \end{aligned} \quad (1)$$

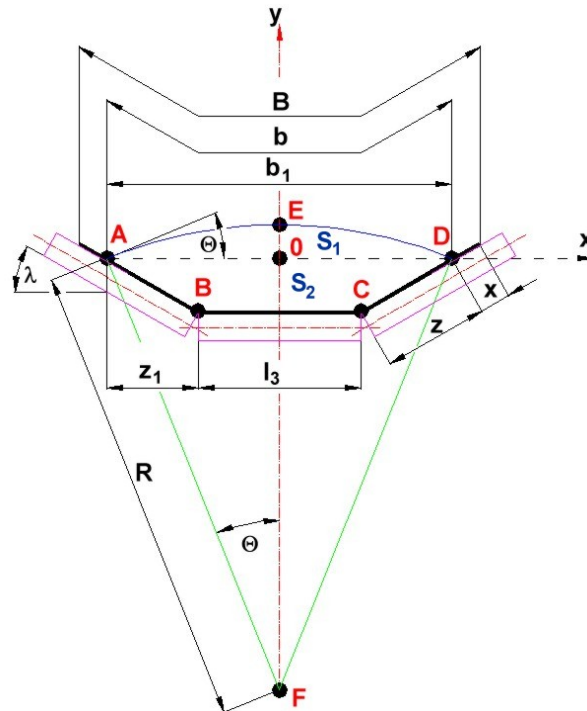
Distance of point **D** (see Fig. 2) from point of origin **O** of the specified coordinate system **xy** is defined as $b_1/2$ [m], whereas the horizontal projection of usable conveyor belt width b_1 [m] can be expressed according to equation (4). Follow from Fig. 1, for a partial dimensions b [m] and z [m] is valid the equation (2), for length of line segment z_1 [m] is valid the equation (3).

$$b = z + l_3 + z = 2 \cdot z + l_3 \Rightarrow z = \frac{b - l_3}{2} \text{ [m]} \quad (2)$$

$$z_1 = z \cdot \cos\lambda = \frac{b - l_3}{2} \cdot \cos\lambda \text{ [m]} \quad (3)$$

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$$b_1 = 2 \cdot z_1 + l_3 = 2 \cdot \frac{b - l_3}{2} \cdot \cos\lambda + l_3 = b \cdot \cos\lambda + l_3 \cdot (1 - \cos\lambda) \text{ [m]} \quad (4)$$



Source: Author

Fig. 1 Cross-section through troughed conveyor

For the purpose of parabola construction, it is necessary to express parameter p [m] and parabola height h_{\max} [m]. From descriptive geometry is known, that if we draw tangent t to a parabola, see Fig. 2, and at point of intersection of parabola and tangent line (given by point **D**) we draw the vertical line to parabola axis y , then is the distance between intersection of vertical line with parabola axis and normal line n against the tangent line t of parabola given by parameter size $2 \cdot p$ [m].

$$\text{Follow from Fig. 2, } \cotg\Theta = \frac{2 \cdot p}{\frac{b_1}{2}} \Rightarrow p = \frac{b_1}{4} \cdot \cotg\Theta \text{ [m]} \quad (5)$$

From descriptive geometry is further known, that the vertical distance of directrix d from parabola vertex **E** is given by size of parabola parameter p [m], as well as vertical distance of parabola focus **H** from parabola vertex **E** is given by size of parabola parameter p [m] because of parabola definition validity: „given a point (the focus) and a corresponding line (the directrix) on the plane, the locus of points in that plane that are equidistant from them is a parabola“.

By using known value of parabola parameter p [m] (equation 5) we can depict points **H**, **E**, **G**, according to procedure in Fig. 3.

From Fig. 2 can be determined that the parabola intersects itself with the x -axis in point **D**, whereas the distance of parabola from point of origin of the specified coordinate system is given by $b_1/2$ [m]. If we draw a parallel r to the y -axis, after the parabola depicting is the point of intersection of this parallel to the parabola just point **D**.

2. DERIVATION OF BELT CAPACITY

This derivation is performed on the basis of [2, p. 168 - 170]. The belt capacity is derived by simple geometry from a diagram such as Fig. 1, in which there are three rollers of equal length and where Θ [deg] is the angle of surcharge, λ [deg] is the troughing angle, B [m] is the width and l_3 [m] is the length of the centre roller.

All calculation methods assume that the belt is filled uniformly along its length and that the load extends to within a distance x [m] of the edge of the belt. This distance has been derived empirically and is expressed as a fraction of the belt width plus a constant, e.g.

$$2. x = B - b = B - (0,9. B - 0,05) \Rightarrow x = \frac{0,1. B + 0,05}{2} = 0,05. B + 0,025 \text{ [m]} \quad (9)$$

The cross-section of the load consists of a trapezium **ABCD** and a segment of a circle **AED**. To calculate the area of the trapezium we need to know the length z [m] along the wing idler to the limit of the load.

$$z = \frac{B}{2} - \frac{l_3}{2} - x \text{ [m]} \quad (10)$$

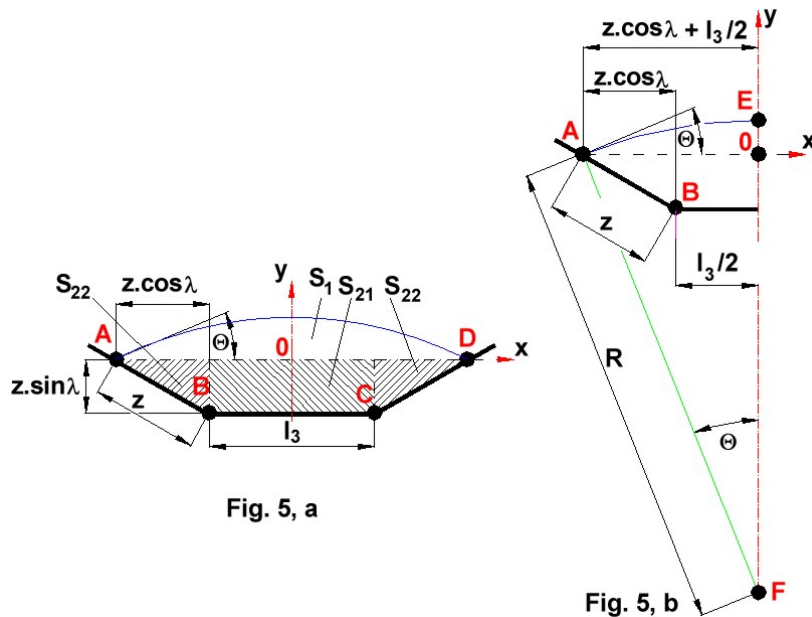


Fig. 5 - a) The area of trapezium, b) The area of the segment we need to know the radius R [m] of the arc **AED**

The area of trapezium S_2 [m²] is, see (11) and Fig. 5, a.

$$S_2 = S_{21} + 2. S_{22} = l_3. z. \sin \lambda + 2. \frac{1}{2}. z. \sin \lambda. z. \cos \lambda \text{ [m]} \quad (11)$$

Which reduces to, see (12).

$$S_2 = z. \sin \lambda. (l_3 + z. \cos \lambda) \text{ [m]} \quad (12)$$

To obtain the area of the segment we need to know the radius R [m] of the arc **AED**, which is given by (13) and Fig. 5, b.

$$R = \frac{z \cdot \cos \lambda + \frac{l_3}{2}}{\sin \Theta} = \frac{2 \cdot z \cdot \cos \lambda + l_3}{2 \cdot \sin \Theta} \text{ [m]} \quad (13)$$

The area **FAEDF** is area of the sector, see (14).

$$\pi \cdot R^2 \cdot \frac{2 \cdot \Theta}{2 \cdot \pi} = R^2 \cdot \Theta \text{ [m}^2\text{]} \quad (14)$$

When Θ is in radians, or $\frac{\pi \cdot \Theta}{180} \cdot R^2$ when Θ is expressed in degrees.

The areas of each of the two triangles **FAO** and **FD0** are, see (15) and Fig. 1.

$$\frac{1}{2} \cdot R \cdot \sin \Theta \cdot R \cdot \cos \Theta = R^2 \cdot \sin \Theta \cdot \cos \Theta \text{ [m}^2\text{]} \quad (15)$$

Hence the area S_1 [m²] of the segment AED is (16), with application [3, page 45].

$$S_1 = R^2 \cdot \frac{\pi \cdot \Theta}{180} - R^2 \cdot \sin \Theta \cdot \cos \Theta = \frac{1}{2} \cdot R^2 \cdot \left(\frac{2 \cdot \pi \cdot \Theta}{180} - \sin 2 \cdot \Theta \right) \text{ [m}^2\text{]} \quad (16)$$

Substituting for R [m], see aspect (13), obtaining (17).

$$S_1 = \frac{1}{2} \cdot \left(\frac{2 \cdot z \cdot \cos \lambda + l_3}{2 \cdot \sin \Theta} \right)^2 \cdot \left(\frac{2 \cdot \pi \cdot \Theta}{180} - \sin 2 \cdot \Theta \right) \text{ [m}^2\text{]} \quad (17)$$

And the total area S [m²] of the load is, see (18).

$$S = S_1 + S_2 = \frac{1}{2} \cdot \left(\frac{2 \cdot z \cdot \cos \lambda + l_3}{2 \cdot \sin \Theta} \right)^2 \cdot \left(\frac{2 \cdot \pi \cdot \Theta}{180} - \sin 2 \cdot \Theta \right) + z \cdot \sin \lambda \cdot (l_3 + z \cdot \cos \lambda) \text{ [m}^2\text{]} \quad (18)$$

3. CONCLUSION

In this contribution is expressed maximum height of the cap of the cross-sectional area of the belt conveyor on the basis of known value of useable conveyor belt width. At the same time is determined the biggest cross-sectional area of the belt conveyor with three roll idler set assuming that the values of surcharge angle, conveyor belt width, troughing angle and length dimensions of idlers are known as well.

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