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ANALYTICAL-GRAPHICAL ANALYSIS OF VARIOUS INFLUENCES IN THE CARRYING ABILITY OF V-BELTS WITH NARROW PROFILE

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Abstract: In this paper is analyzed in detail influential that have important role in carrying ability of transmitters with trapezoid belts, better known as V-belts with narrow profile. While belt is determinate element for power, which V-belt transmitters can carry, then in detail is analyzed all constructive influential in their carrying ability. For analysis purpose are taken V-belts of type: SPA, SPB and SPC. In the work are given analytical formulae for the calculation of nominal and corrected carrying ability for these types of belts manufactured with coating. Corrected carrying ability is gained when nominal carrying ability is corrected through addition of Power, as a result of influential of these parameters: contact angle between belt and guiding wheel (α_1), transmission ratio (i) and length of belt (L). These influential are presented in this work in analytical and graphical form.
Keywords: V- belt, Nominal ability, Belt drive, Graphic analysis

INTRODUCTION

V-belt transmitters have high application for carrying of power in all types of machines. Main criterion for belt selection is nominal carrying capacity. It represents power, which can be carried by determined profile of belt in laboratory conditions for long time, and transmission ratio i =1. While conditions in field are different from laboratory conditions, then nominal carrying capacity needs to be corrected according to concrete conditions. This carrying ability is known as corrected carrying ability.

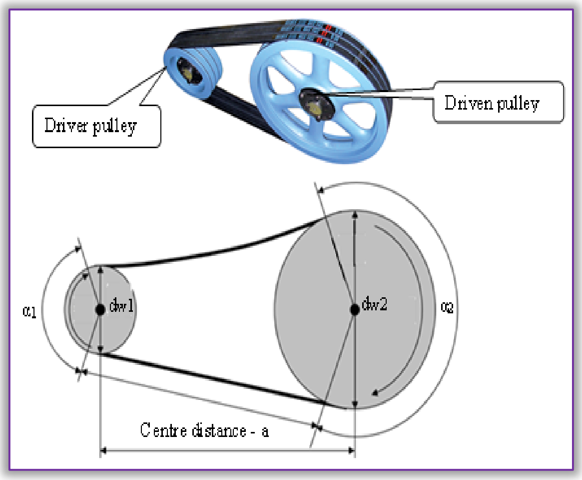

Figure 1. Belt drive

NOMINAL CARRYING ABILITY

Various manufacturers of V-belts give empirical expressions for calculation of power that can be carried by the belt, depending in type of belt, materials used, and forms of production and other parameters of technological process.

Mathematical expression for calculation of nominal carrying ability is:

$$P_{n1}(n_1) = d_{w1} \cdot n_1 \cdot \left[K_1 - \frac{K_2}{d_{w1}} - K_3 \cdot (d_{w1} \cdot n_1)^2 - K_4 \cdot \log(d_{w1} \cdot n_1) \right] \quad (1)$$

According to expression (1), it can be concluded that nominal carrying ability P_n depends on kinematic diameter (d_{w1}), number of rotations of guiding wheel (n_1) and coefficient of carrying ability K_x (x=1,2,3,4), which depends on: physical-chemical properties of materials as main components of belt, recipes of manufacturing and technological process of manufacturing.

CORRECTED CARRYING ABILITY

In practice, conditions in which transmitter with belt works are greatly different from testing conditions (in the laboratory). Therefore, in this work will be analyzed corrected carrying ability for 5 cases with various input data of: kinematic diameter of transmission wheels (d_{w1i}, d_{w2i}). Changing of these two geometrical parameters with high importance results in change of other parameters that determines geometry and kinematics of transmitter, such as: angle of contact between belt and guiding wheel (α_{1i}), angle that create branches of belt with line that passes through centers of transmitter wheels (β_{1i}), length of belt (L), transmission ratio (i_i)(i = 1,2,3,4,5).

Carrying ability of belt in practice is different from nominal calculated with expression (1). This difference appears due to influential in carrying ability of:

- Angle of contact of belt with guided wheel (α_1),
- Transmission ratio (i),
- Length of belt (L)

Carrying ability that takes in consideration influential of mentioned parameters is called corrected carrying ability, and it represents power that can be carried by transmitter with trapezoid belts in the relevant conditions. It is calculated with expression:

$$P_1 = K_\alpha \cdot (P_{n1} + \Delta P_i + \Delta P_L) \tag{2}$$

Influential of contact angle between belt and guiding (traction) wheel

Expression for nominal carrying ability is achieved for the angle of embrace between belt and guiding wheel of value 180°. In practice this angle has various values, depending on concrete case. Influential of contact angle in carrying ability is considered through factor of contact angle, which is calculated with formula:

$$K(\alpha) = 1.25 \cdot (1 - 5^{\frac{-\alpha}{180}}) \tag{3}$$

Influential of transmission ratio

In practice are used belt transmitters that have transmission ratio i≠1. Additional power that is added to nominal carrying ability, because of transmission ratio, is calculated with formula:

$$\Delta P(i) = d_1 \cdot n \cdot K_4 \cdot \log\left(\frac{2}{1 + 10^{x(i)}}\right) \tag{4a}$$

$$x(i) = \frac{K_2}{d_1 \cdot K_4} \cdot \left(\frac{1}{i} - 1\right) \tag{4b}$$

Influential of belt length

For every belt profile is defined length of belt by manufacturer, for which is determined nominal carrying ability. This length is called *Basic Length* and has symbol L_o. For other values of belt length, influential of belt length in carrying ability I calculated with formula:

$$\Delta P(L) = d_1 \cdot n \cdot K_4 \cdot \log\left(\frac{L}{L_o}\right) \tag{5}$$

If all the influences mentioned above appear in analytical way in expression (3.1), then mathematical model for the calculation of power which can be carried by the transmitter with trapezoid belts will be:

$$P_1(n_1) = 1.25 \cdot \left(1 - 5^{\frac{-\alpha}{180}}\right) \left\{ \begin{array}{l} d_{w1} \cdot n_1 \cdot \left[K_1 - \frac{K_2}{d_{w1}} - K_3 \cdot (d_{w1} \cdot n_1)^2 - K_4 \cdot \log(d_{w1} \cdot n_1)\right] + \\ + d_{w1} \cdot n_1 \cdot K_4 \cdot \log\left(2 \cdot \left(1 + 10^{\frac{K_2}{d_{w1} \cdot K_4} \cdot \left(\frac{1}{i} - 1\right)}\right)^{-1}\right) \\ + d_{w1} \cdot n_1 \cdot K_4 \cdot \log\left(\frac{L}{L_o}\right) \end{array} \right\} \tag{6}$$

Based on expression (6), it can be noticed that in mathematical model for calculation of power that can be carried by the V-belt transmitter, besides technological factors K_x, other constructive parameters have also influence. These parameters in this work are classified as: *primary* and *secondary.* As a constructive parameters are named geometrical and kinematic parameters that have great influence in the power carried by transmitter, which are: angle of contact between belt and guiding wheel (α_1), kinematic diameter of guiding wheel (d_{w1}) and its number of rotations (n_1). Secondary Constructive parameters are geometric and kinematic parameters that appear partially in the mathematical model given by expression (6), such us: transmission ratio (i) and length of belt (L).

GRAPHICAL REPRESENTATION OF CARRYING POWER OF TRANSMITTER

Influential of kinematic diameter of the guiding wheel

Using expression (6) and with the help of Mathcad Software is represented carrying power of transmitter with 3 different profiles of trapezoid belts (SPA, SPB and SPC) and for 5 various combinations of parameters qw define transmitter. Analysis of Geometric and kinematic parameters represented in Figure 2 are given in Table 1.

Table 1. Geometric and kinematic parameters of transmitter analyzed on trapezoid belts SPA, SPB and SPC

	d_{w1} (mm)	d_{w2} (mm)	a (mm)	L (mm)	α_1 (°)	β (°)	i (-)
Profile SPA							
1.	100	224	300	1122	156.146	11.927	2.286
2.	112	200	600	1693	171.589	4.205	1.822
3.	125	180	900	2280	176.498	1.751	1.469
4.	132	160	1000	2459	178.396	0.802	1.237
5.	140	150	1200	2856	179.523	0.239	1.093
Profile SPB							
1.	125	355	600	1976	157.9	11.05	2.898
2.	132	315	800	2313	166.865	6.568	2.435
3.	140	236	1000	2593	174.497	2.751	1.72
4.	160	224	1200	3004	176.944	1.528	1.429
5.	190	200	1400	3413	179.591	0.205	1.074
Profile SPC							
1.	224	630	800	2993	150.601	14.70	2.870
2.	250	560	1000	3296	162.166	8.917	2.286
3.	265	500	1200	3613	168.762	5.619	1.925
4.	280	450	1500	4151	173.503	3.249	1.640
5.	355	400	1800	4786	178.568	0.716	1.150

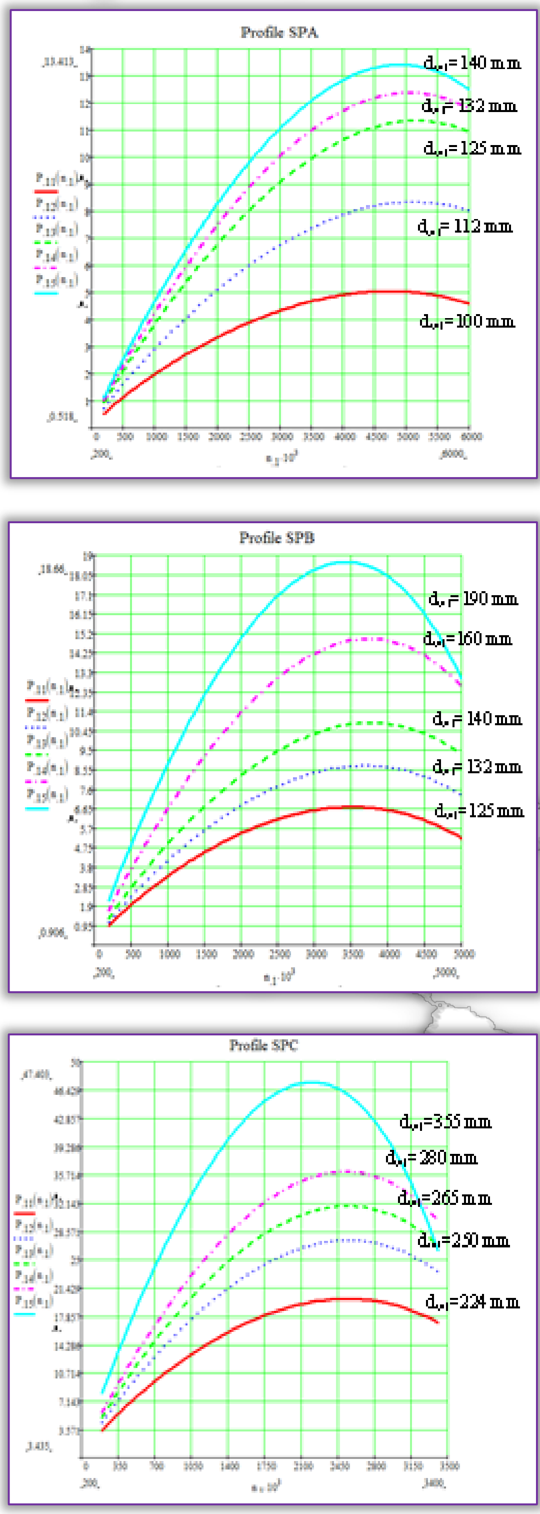

Figure 2. Graphical representation of power P_{1i} (kW) for the trapezoid belt transmitter SPA, SPB and SPC depending on the number of rotations of guiding wheel n_1 (min^{-1}).

Influential of contact angle between belt and guiding (traction) wheel

According to expression (6), for the values of angle of contact: α = 120°, 130°, 140°, 150°and 160°, in Figure 3 are shown curves of power which can be carried by transmitter with trapezoid belts of the profile SPA with guiding diameter of wheels d_{w1} = 100 mm.

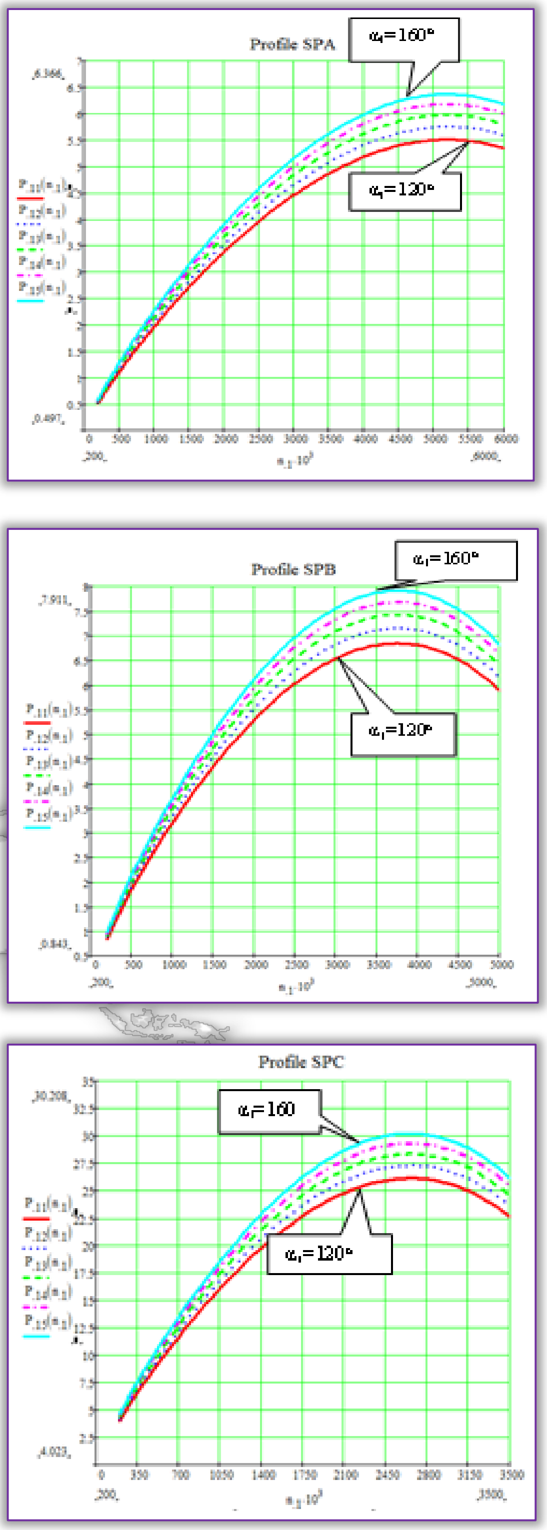

Figure 3. Graphical representation of power P_{1i} (kW) for the trapezoid belt transmitter SPA, SPB and SPC depending on the number of rotations of guiding wheeln_1 (min^{-1}) for various contact angles between belt and guiding wheel

According to Figure 3, it can be noticed that increase of contact angle between belt and guiding wheel results with increase of power that can be carried by transmitter. This increase is higher expressed with higher number of wheel 1 rotations.

Influential of transmission ratio

In order to see the influential of transmission ratio in the power that can be carried by transmitter, in the expression (6) are given these input values: kinematic diameter d_{w1} = 100 mm, α_1 = 140°, n_1 = 1000, 1500, 2000, 2500 and 3000 min^{-1}. Results are shown in forms of diagrams in Figure 4.

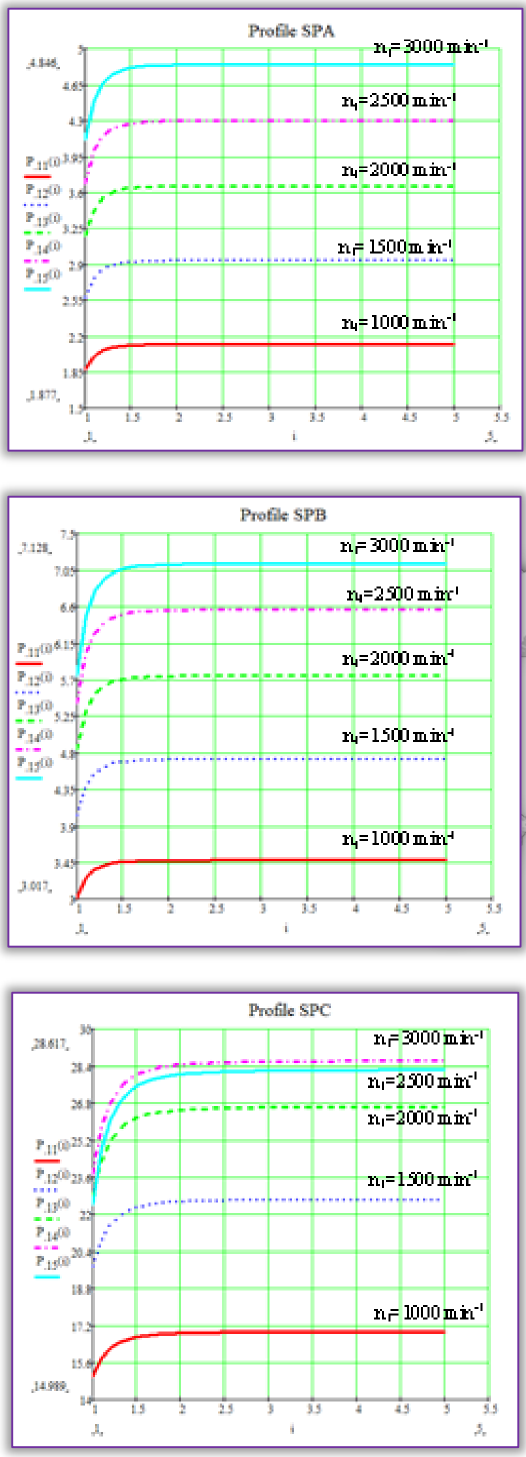

Figure 4.Graphical representation of power P_{1i} (kW) for the trapezoid belt transmitter SPA, SPB and SPC depending on the transmission ratio i (-), for various number of rotations of guiding (traction) wheel

Based on Figure 4, it can be noticed that transmission ratio has high influence in power that is carried by transmission with trapezoid belts for the values between 1...2. After the value i=2 this influence is constant.

Influence of belt length

For the belt profiles SPA, SPB and SPC, in the expression (6) are given input data: d_{w1} = 100 mm; α_1 = 140°; n_1 = 1000, 1500, 2000, 2500 and 3000 min^{-1}; i = 1.633; L_o = 2240 mm- SPA; L_o = 3150 mm – SPB; L_o = 5000 mm – SPC. Results are shown in forms of diagrams in Figure 5.

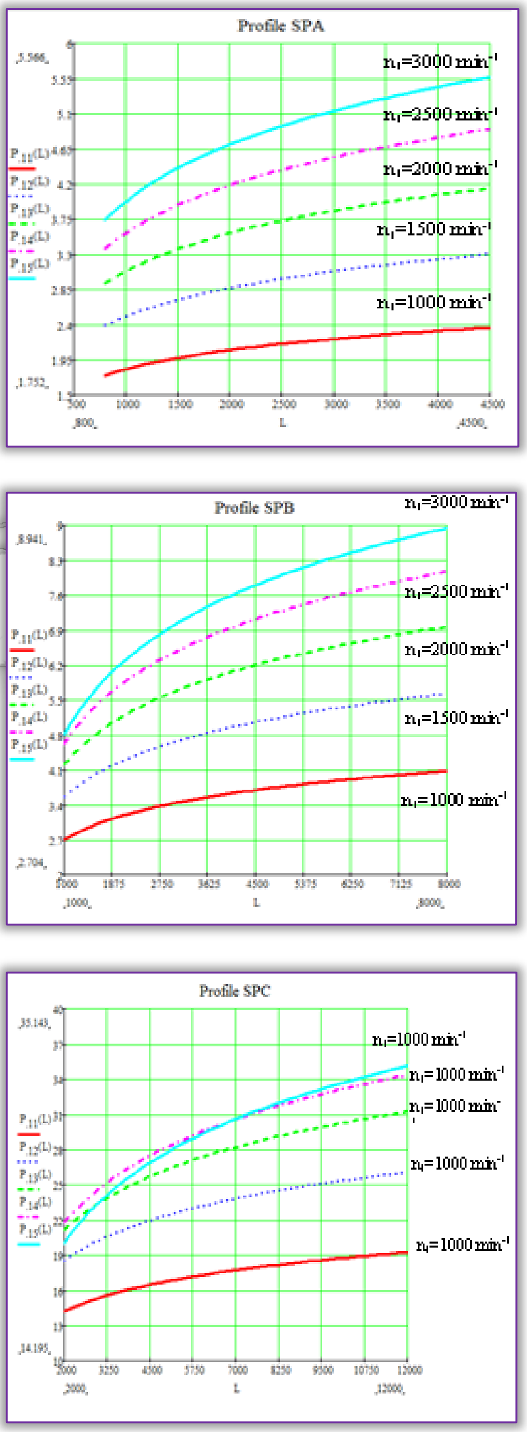

Figure 5. Graphical representation of power P_{1i} (kW) for the trapezoid belt transmitter SPA, SPB and SPC depending on the belt length (L), for various number of rotations of guiding (traction) wheel.

CONCLUSIONS

Based on mathematical expression given in this work, and diagrams gained based on these expressions, can be concluded as follows:

- ≡ Nominal carrying ability of trapezoid belts depends on technological factors which are represented through coefficients K_i (i=1,2,3,4) and other constructive coefficient, represented through kinematic diameter of guided wheel d_{w1} and number of rotations n_1.
- ≡ Corrected carrying ability, respectively the power that can be carried by the transmitter in the field, besides mentioned factors depends also from: contact angle between belt and guiding wheel α_1, transmission ratio i and length of belt L. These 3 factors have secondary importance, while kinematic diameter d_{w1} and number of rotations n_1 have primary importance.
- ≡ With the increase of embrace angle between belt and guiding wheel, carrying ability will increase.
- ≡ Increase of transmission ratio in the interval i=1...2 impacts significantly in the carrying ability.
- ≡ With the increase of belt length for ($L>L_0$), will increase carrying ability. This increase is more expressed for higher numbers of rotations.
- ≡ Length of belt can have negative impact in carrying ability if $L<L_0$.
- ≡ Graphical representation of these influences in the power that is carried by the transmitter with V-belts has practical importance for designer, because it enables him to make right selection of kinematic and geometric parameters of the transmitter to carry required power.
- ≡ During this selection should be used only the first part of curves – up to the point where power curve gains maximal value.

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