RESEARCH AND ANALYSIS OF DYNAMIC PARAMETERS IN V-BELTS

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Abstract: *In this work is presented research about main dynamic parameters that have influence in the efficiency of trapezoid belts (V-Belts). Research is done in the testing machine with 3 wheels. Two main parameters analyzed are important dynamic parameters: Force of preliminary belt tightening (F_{pr}), and Coefficient of elastic slipping (K_{es}). Last coefficient is important factor for dynamic analysis of belt transporters while it defines clearly level of carrying capacity vs. defined force of preliminary belt tightening. Through laboratory testing has been researched influence of power that is transmitted and force of preliminary tightening in the coefficient of elastic slipping, with the aim to determine optimal limit of this coefficient. In practice it is recommended that values of this coefficient not to be higher than 2%.*

***Keywords**: TRAPEZOIDAL BELT, DYNAMIC ANALYSIS, COEFFICIENT OF ELASTIC SLIPPING, FORCE OF PRELIMINARY BELT TIGHTENING, BELT DRIVES*

1. *Introduction*

V-Belts or trapezoid belts are in the group of mechanical indirect transmitters, which are heavily applied for power transmission in all kinds of machines, industrial devices and motor vehicles. A specific problem during power transmission appears to be the non-constant value of transmission ratio because of the elastic slip of the belt. The elastic slipping appears on a part of the angle where belt embraces the pulley. The elastic slipping is a result of the action of forces with varying intensities on the belt embranchments.

2. *Determining Force of preliminary belt tightening*

In order to accomplish the work as required by the transmitter, the belt laying above its wheels needs to be fastened with appropriate force. This force that is created in the branches of belt in the condition when transmitter doesn't work is called *Force of preliminary belt tightening (F_{pr}).* Creation of this force is important to have friction in the surface of contact between belt and wheels of transmitter, and this force carries load from guiding (traction) wheel to guided wheel. No matter how tightening of belt is achieved, it is important to determine this force, while it matters for the carrying capacity of transmitter, respectively it matters for the power which can be carried by the V-belt transmitter.

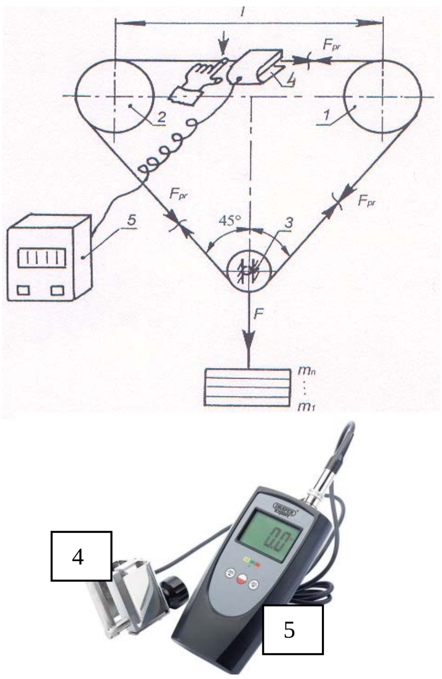


Fig.1. Methodology for measurement for preliminary tightening of the belt. 1- Guiding wheel, 2- Guided wheel, 3-Tightening Wheel, 4 – Sensor for measurement of frequency , 5-Digital measuring instrument

During the experiment are placed various masses in the wheel 3. Their placement has increased force F which acted in the tightening wheel 3, and at the same time the force of preliminary tightening of belt has increased. For various values of acting force in the wheel 3 are measured frequencies of belt oscillations, and their value is registered in the digital instrument 5 (Fig.1). Values measured are shown in Table.1

Mathematical dependence between force of preliminary tightening and frequencies of belt oscillations is given by the formula:

$$F_{pr} = 4 \cdot m_b \cdot (l \cdot f_L)^2 \qquad (1)$$

Parameters in the formula are:

m_b (g/m) – Linear mass of belt, *l(mm)* – distance between center of wheels 1 and 2 of transmitter; *f_L(Hz)* – frequency of belt oscillations

Experiment is conducted with Belt type AV10x1200La, with linear mass m_b = 71.87 9g/m and l = 350 mm.

Force in wheel 3, F(daN)	42	48	56	68
Frequency of belt, f_L(Hz)	78	87	110	120
Force in the belt, F_{pr} (daN)	21.5	26.7	42.6	56

Table 1. Dependence of force F_{pr} from F and f_L.

3. *Changes in the Force of preliminary tightening in dependence of time*

With experimentation is researched the issue of changes in the Force of preliminary tightening through time. With experiment has been concluded that this force decreases after few minutes and then stabilizes. This occurrence that happens in the belt is known as *relaxation of belt.*

Values gained with experiment for Force of preliminary tightening are shown in table 2, and diagram in fig.2.

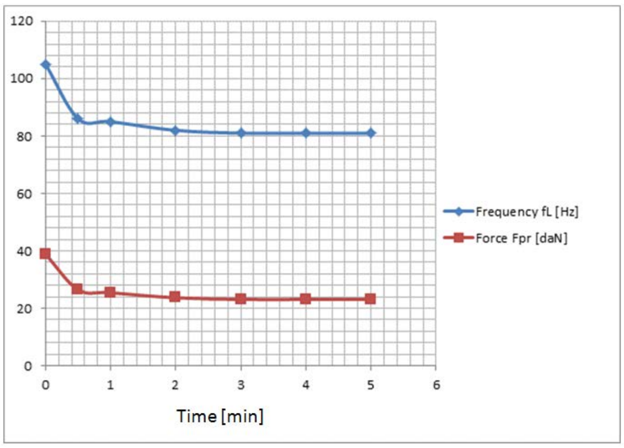


Fig.2. Changes of Force of preliminary tightening F_{pr} in time

Based on result from experiment it is concluded that *Force of preliminary tightening* in the belt drops increasingly in first 3 minutes and then stabilizes in the value 60% of initial value. this occurrence (relaxation) of belt has practical importance in the case of mounting of new belt in the transmitter.

Time [min]	0	0.5	1	2	3	4	5
Frequency [Hz]	105	86	85	82	81	81	81
Force of preliminary tightening, F_{pr} [daN]	38.83	26.45	25.45	23.68	23.11	23.11	23.11

Table 2. Changes of Force of preliminary tightening and frequency of belt oscillations in time

4. *Determination of Elastic slipping coefficient*

While angle of elastic slipping (γ) cannot be determined experimentally, then the phenomenon of elastic slipping is analyzed through the *Coefficient of Elastic Slipping K_{es}*. This coefficient represents the ratio between difference of the speed of belt in the traction branch and free branch compared with speed in the traction branch of belt:

$$K_{es} = (v_1 - v_2)/v_1 \qquad (2)$$

Mathematical model that represents influence of Elastic slipping coefficient in the ratio of the transmission is given through formula (3):

$$i = \frac{n_1}{n_2} = \frac{d_{p2}}{d_{p1}(1 - K_{es})} \qquad (3)$$

Based on the formula (3), for the defined number of rotations of guiding (traction) wheel n_1, depending in the values of elastic slipping coefficient K_{es}, various number of rotations of guided wheel n_2 will be gained. As a result, during work there will be changes in the transmission ratio, depending on the dynamic conditions created in the transmitter.

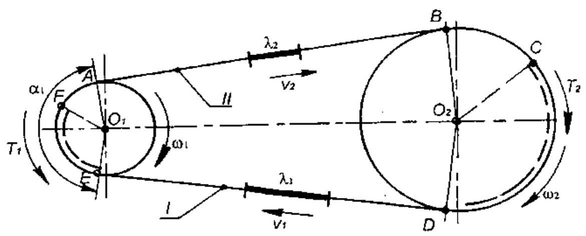


Fig. 3. Elastic Slipping of the belt during work

One element of the belt during the work of transmitter, in the traction branch has length λ_1 and speed v_1. While free branch will have length λ_2 and speed v_2 (Fig.3). Field of elastic slipping is determined with angle of elastic slipping (γ). With the increase of difference of forces in the belt branch, angle of elastic slipping will increase.

5. *Determination of Elastic slipping coefficient K_{es} with experiment*

In order to better analyze influential of this coefficient in the work of transmitter, and dynamic conditions of changes on this coefficient, in the laboratory of dynamic research are conducted some experimental testing. Based on conducted research it it concluded that this coefficient depends on the power that is transmitted P and Force of preliminary tightening F_{pr}. Frequency of oscillations of induced belt is measured with digital tensiometer (Fig.1). Force of preliminary tightening is calculated based on frequencies of belt oscillations, with formula (1). Experimentations are conducted in transmitter with three and two wheels. Also, research is done for the Elastic slipping coefficient of the belts if coating and with cutting. Research device had the option to change the carrying Power from 5 to 20 kW and Force of preliminary tightening thorugh addition of masses m_1… m_n in the tightening wheel 3. Increase of carrying power is accomplished through loading of guided wheel 2. Results gained with experiments are presented in Tables 3 and 4, respectively in diagrams Fig.4, Fig.5, and Fig.6.

Belt AV10x1200 L_a (producer“Ballkan”) $d_{p1}=d_{p2}=117.3$ mm, $d_{p3}=57$mm $n=4900$ min^{-1}, $t=20^0C$, $\varphi=60\%$, $P_{EM}=20$ kW, $n_M=3000$ min^{-1}						
Carrying power P(kW)	F (daN)	68	56	48	40	32
	f_L (Hz)	123	112	102	96	86
	F_{pr} (daN)	53.28	44.18	36.64	32.46	26.06
5		0.25	0.25	0.32	0.32	0.34
6		0.35	0.38	0.50	0.55	0.65
7		0.47	0.50	0.70	0.75	0.80
8		0.61	0.64	0.90	1.0	1.2
9		0.77	0.82	1.2	1.5	6.0
10		1.0	1.1	1.6	4.7	
11		1.2	1.4	2.2	10	
12		1.5	1.8	7		
13		1.8	2.6			
14		2.2	4.7			
15		3.3	45			
16		4.0				

Table 3. Elastic slipping coefficient K_{es} *[%] for working belt with coating.*

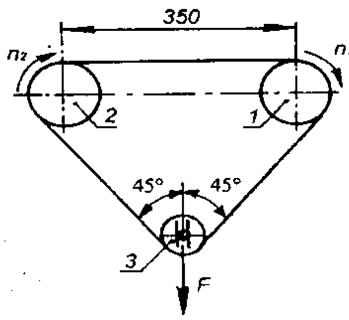


Fig.4. Scheme of experiment

Based on experimantal results gained in table3, graph is shown in fig.4. From the recommendations in the literature [1] and [2], Elastic slipping coefficient K_{es} at the transmitters with V-belts should not past the value 2% during work. Therefore, based on fig.4, can be determined up the power of engagement in belt transmitters AV10 for given forces of preliminary tightening. These powers will be:

- For F = 32 daN….. P = 8.27 kW,
- For F = 40 daN….. P = 9.10 kW,
- For F = 48 daN….. P = 11.00 kW,
- For F = 56 daN….. P = 12.50 kW,
- For F = 68 daN….. P = 13.90 kW.

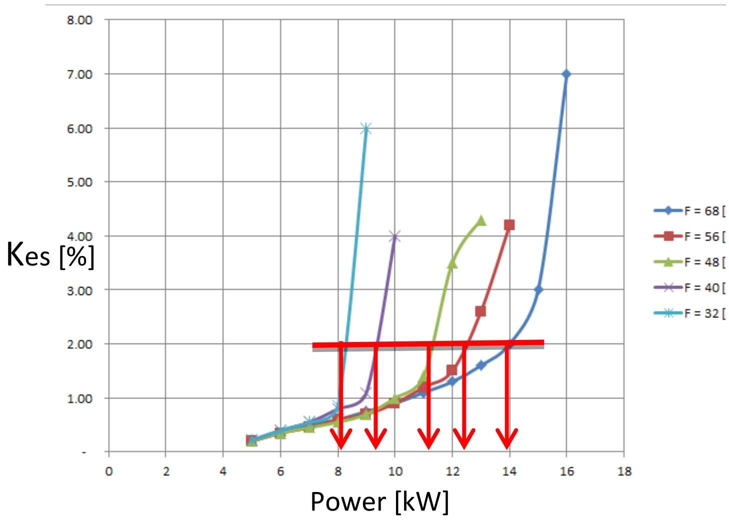
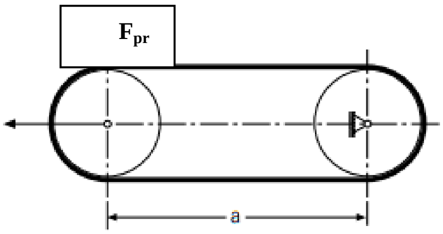


Fig. 5. Elastic slipping coefficient for the belt AV10 manufactured through cutting.

Power that can carry transmitter with V-belts AV10 manufactured through cutting, in order to gave stabile work, will be:

- For F = 32 daN….. P = 8.27 kW,
- For F = 40 daN….. P = 9.10 kW,
- For F = 48 daN….. P = 11.00 kW,
- For F = 56 daN….. P = 12.50 kW,
- For F = 68 daN….. P = 13.70 kW.

According to table 4 and diagram 5, for the belts manufactured through cutting, it can be concluded that same conclusion applies as for belts with coating, about the influential of Power that is transmitted and Force of preliminary tightening F_{pr} in the *Elastic slipping coefficient* but K_{es} for belts manufactured through cutting has smaller values. E*lastic slipping coefficient* K_{es} is researched also on the transmitter with two wheels and transmission ratio i = 1. results of the experiment are presented on the diagram fig.6.



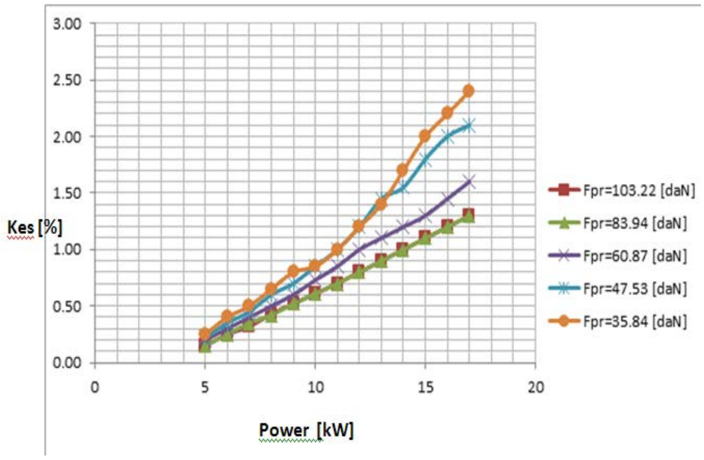


Fig. 6. Elastic slipping coefficient for the belt AV10 manufactured through cutting and transmitter with two wheels and i =1.

6. Conclusions

Analyzing results gained through experimentation, which were represented in table and graphical form, can be concluded as follows:

- Measurement of Force of preliminary tightening first mounted in V-belts in the transmitter should be done after time of 3 minutes, while if this measurement is done immediately, results will not be accurate. Higher values of forces will be measured which are not real.
- By the increase of Force of preliminary tightening F_{pr}, will increase power that transmitter will need to carry,
- Elastic slipping coefficient increases with the increase of power that transmitter carries,
- This coefficient increases with decrease of Force of preliminary tightening,
- Belts manufactured through cutting have smaller Elastic slipping coefficient than Belts manufactured with coating,
- Angle of contact between belt and transmitter wheels has considerable influence in the Elastic slipping coefficient of the belt,
- Transmitters with transmission ratio i = 1 have greater carrying capacity than Transmitters with transmission ratio i > 1.

7. References

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