DESIGN ASPECTS OF *SPA* AND *SPZ* TYPE V-BELT TRANSMISSIONS v2

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Abstract—The applicability area of the *SPA* and *SPZ* V-belt transmissions is referring on the transmissions which are loaded with small and medium loads and on the transmissions where the accuracy is not an important parameter. Due to design calculus, there are many variants in order to choose the design parameters; the aim is to obtain small distances between the V-belts wheels axes and a small number of belts. An important problem is represented by the cases when the designer, according to the design data, may choose both variants of the V-belts: *SPA* or *SPZ*. The paper presents the influence of the V-belts type on the axis distance and belts number values. A finite element analysis is made in order to find out which variants of belts – *SPA* or *SPZ* – are reliable to be chosen, according to the equivalent stresses.

Keywords—*ANSYS*, axis distance, design, finite element modelling, V-belt.

I. INTRODUCTION

THE V-belt are used in mechanical transmissions which are working with a power up to 1200 (kW), with a maximum peripheral speed of 50 (m/s) and with an axis distance up to 3 (m); the average efficiency of them is between 95% … 96% [1]. The V-belt transmissions are used in mechanical transmissions as links between the motors and the speed reducers and in friction transmissions, where the accuracy is not an important parameter.
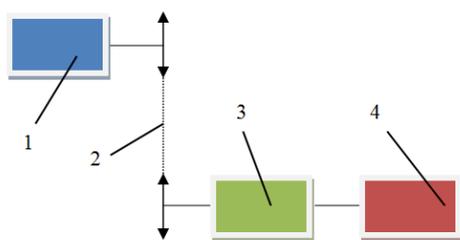

Fig. 1. Mechanical transmission with v-belt

Fig. 1 presents an application of a v-belts transmission *2* in a mechanical transmission composed by an electric motor *1*, a speed reducer *3* and a lifting machine *4*.

A problem is represented by the cases when, according to the input data, the designer may chose two variants of V-belts. The question is which of these variants is reliable according to the number of the belts, to the axis distance and to the equivalent stresses.

The paper presents some practical aspects of the design calculus of a V-belt transmission which is used as a link between an electric motor and a speed reducer and identifies the influences of the main parameters on the belts number, on the axis distance and on the equivalent stresses.

II. THE DESIGN PROCESS

The design process is presented for a V-belt transmission which convey a power P=5 (kW) and an input rotation n_1=500 (rpm), from a three phase induction motor [2]; the output rotation is n_2=350 (rpm) and represents the input rotation for a speed reducer which is acting a lifting machine; the lifting machine is working 16 hours a day.

The type of the V-belt is chosen according to the power and the input rotation; for the design data, the V-belt type is on the border between the *SPZ* and *SPA* type [3]. Due to this, the design calculus will be achieved for both variants with the values for the primitive diameter of the driver wheel D_{p1}=100 (mm) - *SPZ* belt and D_{p1}=112 (mm) - *SPA* belt [3].

The transmission's ratio is defined as

$$\mathbf{i = n_1 / n_2}. \tag{1}$$

According to the input data, i=1.42; the driven wheel primitive diameter is obtained with

$$\mathbf{D_{p2} = i\,D_{p1}}; \tag{2}$$

the values are chosen from [4]: the driver wheel primitive diameter D_{p2}=140 (mm) and the driven wheel primitive diameter D_{p2}=160 (mm).

The medium diameter of the wheels is

$$\mathbf{D_{pm} = (D_{p1} + D_{p2}) / 2}, \tag{3}$$

with the values 120 (mm) and 136 (mm).

The tensioning wheel's diameter is [5]

$$D_{p0} = (1...1.5)D_{p1}, \tag{4}$$

with the values 110 (mm) and 123 (mm).

The preliminary axis distance is established between the limits of [4]

$$0.7(D_{p1} + D_{p2}) \leq A \leq 2(D_{p1} + D_{p2}), \tag{5}$$

with the intervals $A \in [168, 480]$ (mm) for *SPZ* belt and $A \in [190.4, 544]$ (mm) for *SPA* belt.

The angle of the V-belt's branches is

$$\gamma = 2\arcsin\frac{D_{p2} - D_{p1}}{2A} \tag{6}$$

and the winding angles on the driver and the driven wheels

$$\beta_1 = 180^o - \gamma \tag{7}$$

and

$$\beta_2 = 180^o + \gamma. \tag{8}$$

The primary length of the belt is [4]

$$L_p = 2A + \pi D_{pm} + \frac{(D_{p2} - D_{p1})^2}{4A}. \tag{9}$$

Considering the variation of the axis distance as $A \in [168, 480]$ (mm) for *SPZ* belt and $A \in [190.4, 544]$ (mm) for *SPA* belt, the primary length of the belt is calculated for the two types of belts; Fig. 2 shows the variation the primary length with the axis distance. The values of the primary length are $L_p \in [715.37, 1337.82]$ (mm) for *SPZ* belt and $L_p \in [760.81, 1466.05]$ (mm) for *SPA* belt. From the standards, are adopted the values for the primary length L_p; $L_p \in \{710, 800, 900, 1000, 1120, 1250, 1400\}$ (mm) for *SPZ* belt and $L_p \in \{800, 900, 1000, 1120, 1250, 1400\}$ (mm) for *SPA* belt [5].

Fig. 3 presents the chosen possible variants of the primary length; the smallest value of 710 mm is accepted only for the *SPZ* belt.

The final axis distance is established with [4]

$$A = p + \sqrt{p^2 - q}, \tag{10}$$

where:

$$p = 0.25L_p - 0.393(D_{p1} - D_{p2}) \tag{11}$$

and

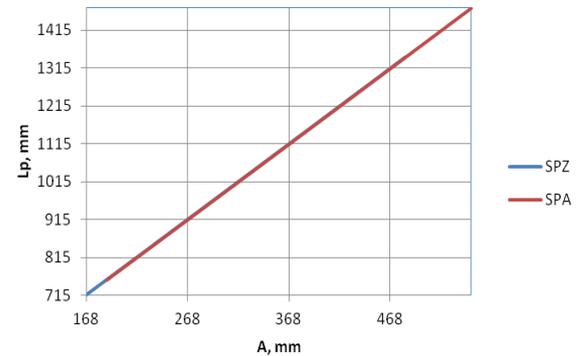$$q = 0.125(D_{p2} - D_{p1})^2. \tag{12}$$

Fig. 2. The variation the primary length with the axis distance
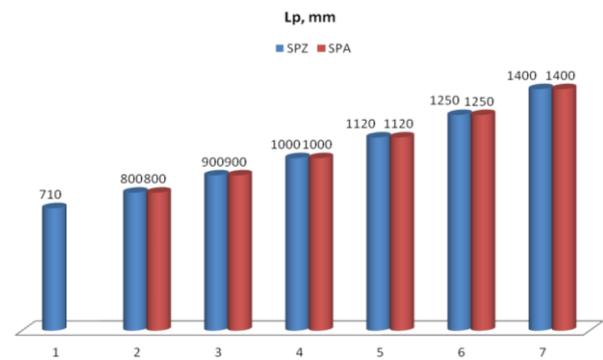

Fig. 3. The variants of the primary length

The values of the axis distances are presented in the Fig. 4; the *SPA* belts variants assures small axis distances (relative to the values obtained for the *SPZ* belts) do to the bigger values of the primitive diameters of the wheels.
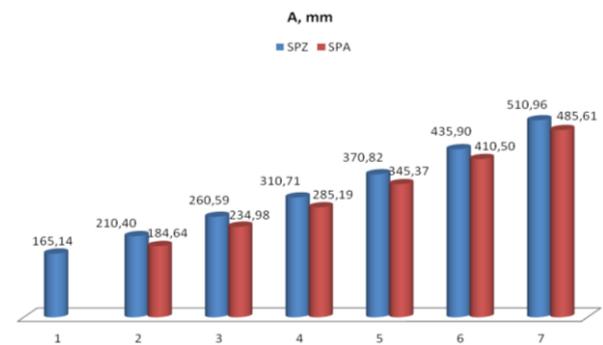

Fig. 4. The final values of the axis distances

The preliminary number of belts is established with [4]

$$z_0 = \frac{c_f P}{c_L c_\beta P_0}, \tag{13}$$

where: c_f is the functioning conditions coefficient, $c_f = 1.2$ [4]; c_L is the coefficient of the length, $c_L \in \{0.84, 0.86, 0.88, 0.90, 0.93, 0.94, 0.96\}$ for *SPZ* belts and $c_L \in \{0.81, 0.83, 0.85, 0.87, 0.89, 0.91\}$ for *SPA* belts [5]; c_β is the winding coefficient, $c_\beta \in \{0.965, 0.97, 0.975, 0.98, 0.988,$

0.992, 0.993} for *SPZ* belts and $c_\beta \in$ {0.965, 0.973, 0.976, 0.985, 0.991, 0.9925} for *SPA* belts [5]; P_0 is the nominal power transmitted by one belt, P_0=1 (kW) for *SPZ* belts and P_0=1.58 (kW) for *SPA* belts.

Fig. 5 presents the values of the preliminary belts number; due to the higher values of the nominal power which can be transmitted by one belt, the *SPA* type belt assures small values for the preliminary number of the belts (relative to the values obtained for the *SPZ* belts).
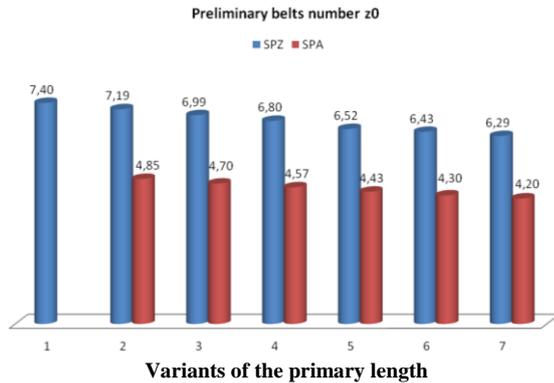

Fig. 5. The preliminary numbers of belts

The belts number is established by using [4]

$$z = z_0 / c_z , \tag{14}$$

where c_z represents the belts number coefficient, c_z=0.85 for *SPZ* belt and c_z=0.90 for *SPA* belt [4].
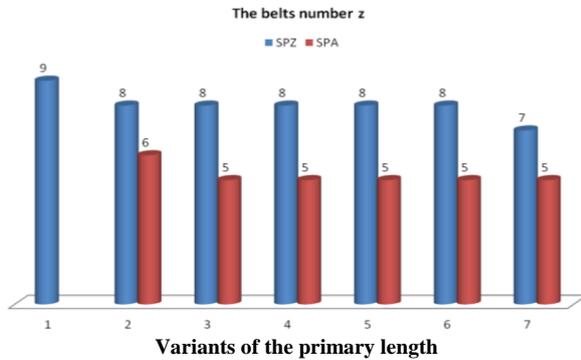

Fig. 6. The final number of the belts

Fig. 6 shows the final number of the belts z which is established by rounding z to the most appropriate integer value; small belts number are obtained for the *SPA* belts, with the primary length variants from 3 to 7 (which means $L_p \in$ {1120, 1250, 1400} (mm) – see Fig. 3).

An important parameter which influences the durability of the belt is the bending frequency ν. Depending on the belts number z, on the velocity of the belt v and on the primary length L_p, the bending frequency is defined as [6]-[8]

$$\nu = v\,z / L_p , \tag{15}$$

where the velocity of the belt is

$$v = \pi D_{p1} n_1 = \pi D_{p2} n_2 . \tag{16}$$

According to the calculus, the value of bending frequency – for all the cases – is situated bellow the allowable value of 60 Hz [6]-[8] – see Fig. 7. Small values of the bending frequency assure higher durability; in this case the variants with high values of the primary length, by considering the *SPA* type of V-belt, are preferable to be used.
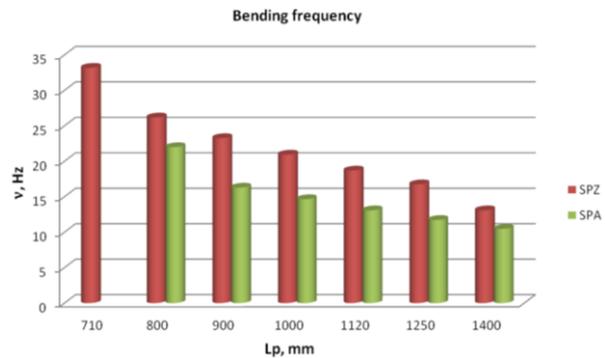

Fig. 7. The bending frequency

An important criterion which influences the V-belts usage is represented by the stress produced from the external load. There are analyzed one variant of *SPZ* belt and one variant of *SPA* belt, by using the finite element method, with the software *ANSYS 14.0* [9]. It is made a static structural analysis by considering the external load as the traction force F_1 which is acting on one belt. The boundary conditions are defined as considering the belt fixed on the wheel – the sliding phenomenon is not considered.

For the modelling is considered the variant *4* of belts with the following input data: for the *SPZ* V- belt – the primitive diameter of the driver wheel D_{p1}=100 (mm) and the number of belts z=8 and for the *SPA* V- belt – the primitive diameter of the driver wheel D_{p1}=112 (mm) and the number of belts z=5.

The external traction force which is acting on one belt is determined by [6]-[8]

$$F_1 = 2.2 \frac{M_{t1}}{z D_{p1}} , \tag{17}$$

where the torque is established with

$$M_{t1} = 9.55 \cdot 10^6 \frac{P}{n_1} . \tag{18}$$

By considering the power *P*=5 (kW) and an input rotation n_1=500 (rpm), it results the value of the force F_1=262.62 (N) for the *SPZ* belt and F_1=375.17 (N) for

the *SPA* belt; according to the calculated values, it is noticed that the *SPA* belt is higher loaded than the *SPZ* type.

The distribution of the equivalent stresses is presented in the Fig. 8 for the *SPZ* belt and in the Fig. 9 for the *SPA* belt.
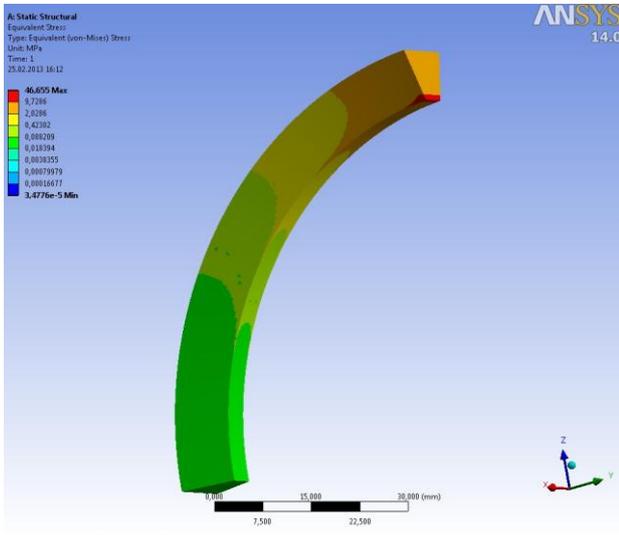

Fig. 8. The distribution of the equivalent stress, for the *SPZ* belt
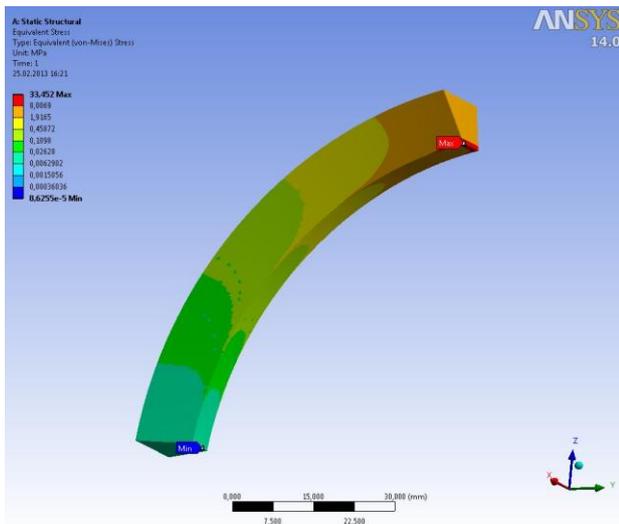

Fig. 9. The distribution of the equivalent stress, for the *SPA* belt

An interesting observation is that the *SPA* belt has a small value for the maximum equivalent stress 33.45 (MPa) even is higher loaded than the *SPZ* belt which has a big value for the equivalent stress 46.65 (MPa); so, by considering the maximum equivalent stress, the *SPA* belt type is preferable to be used.

III. CONCLUSION

The studies presented in the paper are referring on a particular case of the V-belts design process: according to the values of the transmitted power and of the input rotation, the designer can choose both of the V-belts variants – *SPZ* belts and *SPA* belts. The V-belt type is

influencing the axis distance (and indirectly the V-belts primary length) and the number of the belts; generally, the aim of the design process is to obtain small primary lengths and a small number of belts in order to reduce the costs and the overall dimensions.

According to the results presented in the Fig. 10, the *SPA* variant of V-belt assures a small number of belts; in order to obtain a small value of the of the axis distances (Fig. 4) there are chosen *SPA* belts, also.
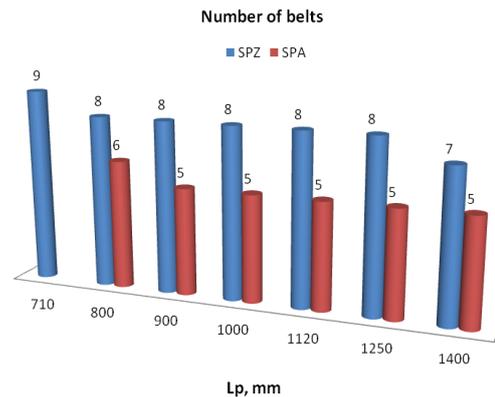

Fig. 10. The final number of the belts

By considering the loading and the equivalent stresses, the *SPA* type of belt can be loaded by higher forces than the *SPZ* variant even, in this case, the equivalent stresses are small.

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