Testing functional features of V-belt transmissions

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Abstract. The development of belt transmissions with wedge belts and new materials used to produce belts inspire designers and people who deal with the exploitation of belt drives to carry research on the possibilities of increasing the load and durability of the belts. It is necessary to know the actual mechanical and rheological characteristics of the belts in the range of their durability features and to comply with the conditions of proper transmission work. It is possible to find in literature many information referring to classic, single rubber belts. In case of polyurethane heat-sealed belts obtaining such information is not easy. It has been a starting point to carry out experimental research in order to determine the material characteristics of belt PU 75 A (red colour). The article presents experimental research results on creeping, cyclical squeezing and stretching of the belt; also the subjection of a side-slip and transmission efficiency in the torque function for PU 75 A belt was determined. The research results will be used to create a transmission model in Abaqus Explicit programme.

1. Introduction

Due to the development of strand transmissions with V-belts and the introduction of new materials for the production of belts, designers and people involved in the operation of strand transmission drives undertake studies on the possibilities of increasing the load capacity and durability of belts. Because it is important to know the latest mechanical and rheological belt characteristics in terms of their strength features and meeting the conditions for the correct transmission operation [1–5]. As a result of them, it will be possible to conduct functional analyses of transmission using FEM [6]. The advantages of heat-sealable belts include the possibility of welding their ends, which allows to obtain a strip of any length and its quick replacement in case of damage [7–9]. The valuable analysis of these materials connected with testing its various strength properties, was presented in following papers [10, 11]. Examples of the use of belt transmissions in various devices and drives are included in the works [12–16]. The forming methods of geometrical features and surface stereometry for noncircular cogbelt pulleys were presented in the works [17–23].

In the literature, you can find a lot of information about standard single rubber belts; however, there is little data on polyurethane thermo-weldable belts. This became the reason to undertake experimental research aimed at determining the material characteristics of the PU 75 A (80 Shore A) type (red) V-belt with a cross section of 17 × 11 mm and a length of 50 mm. The results of these tests will allow determining the scope of applicability of these flexible connectors in drive and transporting technology, and will also be used to build a transmission model in the Abaqus Explicit program (figure 1).
2. Tests of mechanical characteristics of the PU 75 A type V-belt

As the first, the task of determining the characteristics of the belt material during the creep test was undertaken. A belt sample was loaded with a mass of 20 kg. The tests were carried out for about 1200 hours (figure 2).

Based on the recorded values of belt elongation, changes in creep values as a function of time, illustrated in figure 3, were determined. It shows that after loading the belt, the ratio of its elongation to its total length assumed very quickly a value of 0.08. After one hour, there was a progressive, but much slower, relative belt elongation increasing up to 0.1. From that moment, the belt elongation increased slightly – during 200 hours – up to the value of 0.125. After that period, the elongation value was stabilized until it became constant after about 800 hours.

In the next stage of tests of thermo-veldable belts, hysteresis loops were determined during cyclic compression and cyclic stretching of the PU 75 A type belt. The tests were carried out on a Zwick testing machine. The samples to be compressed were 20 mm long. They were cut from a belt with a cross-section of 17 × 11 mm. The samples were subjected to cyclic compression. A number of tests were performed; examples of their results are presented in figure 4. The deformation measure, which is the surface area of the hysteresis loop, indicates low energy losses during deformation of the samples.

The second part of the research involved the cyclic stretching of a 17 × 11 mm belt sample with a length of 750 mm. Examples of results are shown in figure 5. The graph shows that the belts stabilize after the first stretching cycle.
3. Research object Tests of the efficiency of the transmission with PU 75 A type V-belt

For designers of strand transmissions both with flat and V-belts, belt features such as efficiency, slip, strength and durability are important. These parameters are interrelated and interdependent. In literature [24–27], values of efficiency of rubber V-belts are given, however there is no such information regarding thermo-weldable polyurethane belts. Hence, the authors attempted to determine them as a result of an experiment. For this purpose, the testbed shown in figure 6 was built.

A hydraulic motor driving the active shaft is built on the basis of the testbed; the passive shaft is connected to the brake by means of elastic couplings. Shafts with mounted torque meters are mounted on supports provided with radial ball bearings. A dynamometer is used to apply a load to the transmission unit under test. Signals from torque meters and rotary code sensors are transmitted to an amplifier and then to a computer. A regulator enables setting load value on the dynamometer. The design of magnetorheological brake used requires continuous water cooling.

At the testbed, kinematic and dynamic tests of a two-wheel transmission with a transmission ratio of 1 were carried out with or without transmitted useful torque (the torque meters record then momentary moments of inertia only).
Instantaneous angles of rotation of the wheel shafts of the transmissions tested were recorded by rotary code sensors mounted on the shaft ends by means of bellows couplings. In order to uniquely determine the angular position of the shaft, the sensors were equipped with diodes enabling the start of recording of rotation angles of all shafts in the initial angular position at an angle of 0°. In addition, in order to quickly determine the rotational speed of the active shaft, an inductive sensor was mounted next to it. The second task, for which the designed testbed was to be used, was the torque measuring. To ensure required precision of such a measurement, torsional torque meters are most often used in devices and drives, in which elastic deformation of a flexible mechanical transducer occurs under the load influence. The measuring signal is shaped in the electric transducer of the torque meter.

In rotary torque meters, the torsion element is part of a rotating unit. This makes it possible to directly measure the torque transmitted by the shaft of the drive system. Based on the analysis of the design of available torque meters, their measuring capabilities and prices, it was demonstrated the need to design a set of strain gauge torque meters, in which signals are contactless transmitted to fixed coils placed in their housings. The design of such torque meters is universal and allows them to be used for measurements in other gears or drive units.

The dynamometer function is performed by a specially developed magnetorheological brake structure. It uses the possibility of changing the viscosity of liquids under the influence of an external electrostatic or magnetic field. This is an unusual and original solution. Controlling the properties of rheological liquids enables stepless adjustment – changing the torques transmitted under variable load conditions. Torque changes can be made via electrical control signals, which allows them to be connected to computers or microprocessor controllers.

The measurement procedure consists of several stages. After starting the motor, its required driving speed is determined by means of an oil flow regulator and a specific loading torque is set on the dynamometer. After determining the load and temperature, angular displacements and torques are measured. Signals from rotary-code and strain gauges are processed to a discrete form using a multi-channel A/C card and then sent to the computer memory.

The measurements are carried out automatically using a control program written in C++ language. It allows to start recording the measurement results at a specific angular position of the drive wheel and to conduct the measurements at a selected frequency and determined time, usually corresponding to one rotation of the driven wheel. The program saves the measurement results in a text file, which is then properly elaborated using MS Excel and Statistica programs.

The tests were carried out at an ambient temperature of 22 °C. The rotational speed of the active shaft was 500 rpm and the braking torque was 8.4 Nm. The average initial belt tension force, determined from five measurements, was 120 N. The belt tension force after the last measurement, also determined as an average of five measurements, was 121 N.

Based on the experiment carried out, changes in transmission efficiency as a function of time were determined. The figure shows that the time 0–10 min is very important, after which the value of efficiency stabilizes and the passage of time has no more significant impact on its value. The curve shown in figure 7 is the average result of ten experiments.

![Figure 7](image.png) **Figure 7.** Changes in the efficiency of the PU 75 A type V-belt as a function of time.
The second task was to determine the relationship between efficiency and rotational speed of the active shaft. The graphs presented in figure 8 show that the efficiency of such a transmission stabilizes after reaching a value of 90% for a braking torque of 4 Nm. A further increase in the braking torque load (above 10 Nm) causes a slight decrease in the efficiency value. For the lowest rotational speeds (150 rpm and 250 rpm), the efficiency is slightly higher than for 1000 rpm and 1500 rpm.

Figure 8. Changes in the efficiency of the PU 75 A type V-belt as a function of torque changes.

The next evaluated feature of the transmission was belt slip. Figure 9 shows the changes in its value as a function of time. The graph shows that after starting the transmission and stabilizing its operation, the slip value becomes 0.06, then increases to 0.08 and stabilizes at this level after about 60 minutes.

Figure 9. Changes in the slip value of PU 75 A type V-belt as a function of time.

Figure 10 presents changes in belt slip values as a function of passive shaft torque changes. The graphs visible in it show that significant changes in the slope of the slip curve occur at a torque of approx. 2 Nm and a slip value of approx. 0.01. The slip curve then bends and the slip value increases to approx. 0.12. As the rotational speed of the active shaft increases, the slip value increases too and at the same time the efficiency value decreases.
Figure 10. Changes in the slip value of the PU 75 A type V-belt as a function of torque.

4. Conclusion
The results of experimental studies presented in this chapter regarding thermo-weldable belts do not fully cover the issue of assessing their useful features. They can be useful for both designers of drives with this type of belts and for students. The testing procedure adopted by the authors will be used to evaluate other types of belts. In the first place they will be flat belts, then cogbelts and finally special belts, e.g. perforated ones, because the literature concerning their features is relatively poor.

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