Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 136 (2016) 365 – 369

Procedia Engineering

www.elsevier.com/locate/procedia

The 20th International Conference: Machine Modeling and Simulations, MMS 2015

Design of the tendon structure in timing belts

Grzegorz Domek[a,*], Andrzej Kołodziej[b]

[a]Kazimierz Wielki University, Chodkiewicza 30, 85-064 Bydgoszcz, Poland
[b]Higher Vocational State Schol in Kalisz, Nowy Świat 4, 62-800 Kalisz, Poland

Abstract

The paper presents the design issues of support layer of timing belts. The construction of the power transmission belts needs different manufacturing process. This requires a proper design of the carrier layer, single or bifilar reinforcement cords and it affects the mechanical properties of the cord. In addition, there are various cord materials, different weave and diameters. Cord can be differently pre-impregnated with material of the belt or similar. Another aspects of the considerations are the inclusion of additional elements in the support layer, uneven distribution of the cord in the belt and intentional removal of cord or electrical cable entry.

Peer-review under responsibility of the organizing committee of MMS 2015

Keywords: timing belts; power transmission belts; control and conveyor belts

1. Introduction

In modern technique driving belts are displaced by recently popular solution called “Direct drive”. Drop of engine prices, engines accessibility and adjustment ability of rotational speed allowed to mount directly the engines in power transmission systems [1]. This fact does not solve all problems in power transmission systems – in many cases there is a necessity of torque transfer for long distances and many wheels (Fig. 1). Friction between belt and pulleys and the stability of belt dimensions are the main problems for strand transmissions [2]. Strand elongation was the reason for the necessity of belt stretching or removing some part of the belt – due to this fact the surface state of the belt was worse. Another constructions of driving belts were characterized by lower elastic and plastic deformations and limited rheological effects [3, 4].

* Corresponding author. Tel.: +48 52 32 36 745.
E-mail address: gdomek@ukw.edu.pl

Peer-review under responsibility of the organizing committee of MMS 2015
doi:10.1016/j.proeng.2016.01.224

2. The influence of support layer construction on coupling between timing belt and pulley

For the first time the coupling in strand transmission was described by Euler. He presented the equation for the coupling between inextensible and weightless strand and pulley [5]:

$$\frac{S_1}{S_2} = e^{\mu\alpha} \tag{1}$$

In case of conveyor belts the stress values in active and passive strands are similar $S_1 \approx S_2$, angle of wrap is equal 180°, i.e. $\alpha = 1$, so friction coefficient μ has the main effect on the coupling. A part of the conveyor belt which transfers the products is supported by slide blocks – therefore, the solutions of limiting the friction coefficient for the passive strand are applied. Coupling can be presented as relationship of distortion of individual teeth Δl_z and belt pitch P:

$$\frac{S_1}{S_2} = f\left(\frac{\Delta l_c + \sum_{z=1}^{z_o} \Delta lz}{P} \right) \tag{2}$$

Internal stresses in teeth are responsible for tangent force transfer [6, 7]. For this case the equation can be given in the following form:

$$\frac{S_1}{S_2} = \frac{\sum_{z_1}^{z_o} \sigma_z}{E} \tag{3}$$

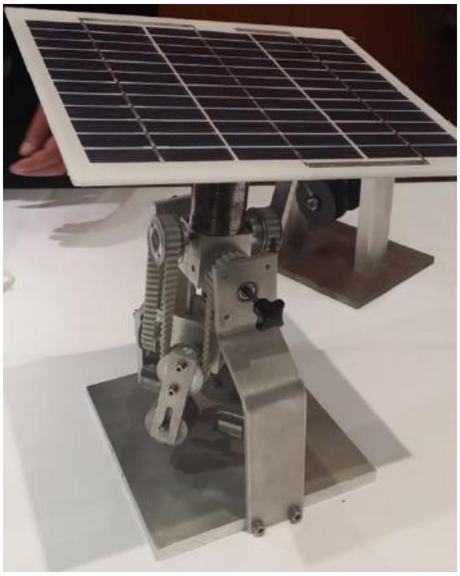

Fig.1. Timing belt for solar panel control.

It is assumed that belt polymer has the value of Young's modulus. In spite of the fact that some part of polymers is non-deformable we can find in handbooks the values of *E* for small deformations. So, substituting equation (1) into (3) we get the following form:

$$e^{\mu} = \frac{\sum_{z_1}^{z_o} \sigma_z}{E} \tag{4}$$

so internal friction coefficient μ_W can be calculated from the following relationship:

$$\mu_W = \ln\left(\frac{\sum_{z_1}^{z_o} \sigma_z}{E} \right) \tag{5}$$

On the basis of the investigations of teeth distortions on the arc of belt contact we can determine the stresses from first tooth z_1 to last tooth z_o which take a part in coupling. This equation allows us to estimate the coupling quality and it is useful for driving belts which have higher differences between stresses in active and passive strand. Teeth deformation is connected with the stress transfer between belt pulley and belt support layer – stretchability of the support layer has a decisive influence on the number of teeth which take a part in tangent force transfer.

3. Types of strand construction of timing belt

Timing belts are applied in many types of power transmission systems, conveyor systems, control systems and multifunctional systems e.g. power transmission and conveyor system or power transmission and control systems [8]. Depending on the belt function different values of initial belt tension and tangent force occur during the operation of the system. Different constructions of belts exist, but the users do not take into account this fact and they want to use one belt for all applications. Driving belts are the most common and available belts on the market. We can distinguish series of types of tooth shapes and pitches. The driving belts can be made of thermoplastic or thermosetting polymer.

Designers assume that the construction of support layer is optimally designed by manufacturers. Timing belt is made of polymer from chemical concern and its support layer – active surface coverage is made of fibres produced by fibre manufacturer. Timing belt manufacturer has an influence on connection and location of individual belt elements so as to get an optimal product. Unfortunately, depending on the responsible approach to the timing belt geometry different results are obtained (Fig. 2). Timing belts are most often produced for power transmission applications where high values of tangent forces exist and it is necessary to insert the initial belt tension. The belt is quite often bent. Good mechanical properties of support layer are essential for this case. In control systems higher values of dynamic forces exist. Rapid stops and starts, frequent direction variations of the motion and accuracy of displacement are the reasons of higher requirements for elastic deformations, creeping and stress relaxations. In case of conveyor belts the mechanical properties of the belt are less important than the properties of active surface of the belt, its contact with transported material or production process on the active surface. Timing belt manufacturers decide about materials and construction of support layer for specified function and series of types of belt. Tangent force is transferred by shape-frictional coupling between teeth of timing belt and belt pulley. It is assumed that safe elongation should not exceed 0.1% for high coupling quality and long belt life. Therefore, researchers look for low stretchable fibres such as carbon fibre for driving and control belts. A group of belts without fibres and support layer develops in timing belts for conveyors. This group of belts carries the products without initial belt tension. The belts for combined functions are designed with indirect solution of support layer construction (Fig. 3). Depending on production technology of timing belts, support layer consists of parallel support cords for belts produced in bands or spiral support cords for belts produced as "never-ending" ones. For this support layer due to initial belt tension the torsional force exists and it causes sliding down of the belt from the pulley. To reduce this problem, two cords with opposite weave are wound. Fibres for timing belts are made of different materials such as carbon steel, stainless steel, brass plating steel – there are also carbon fibres, glass fibres and polyester fibres. To keep the precise belt geometry, the cord with a constant diameter should be applied for defined production form, because the cord is supported on form core and cord axis is connected with the kinematics of timing belt. The defined diameter of the cord can be obtained if we use different types of weave or splicing the cord with different diameters of fibres. In this way we get different mechanical properties for the same cord material. Too tight splicing of the fibres can be a reason of problem with penetration of support cord by belt material. To improve the coherency between fibres and belt material, polymer impregnated fibres are applied during splicing process.

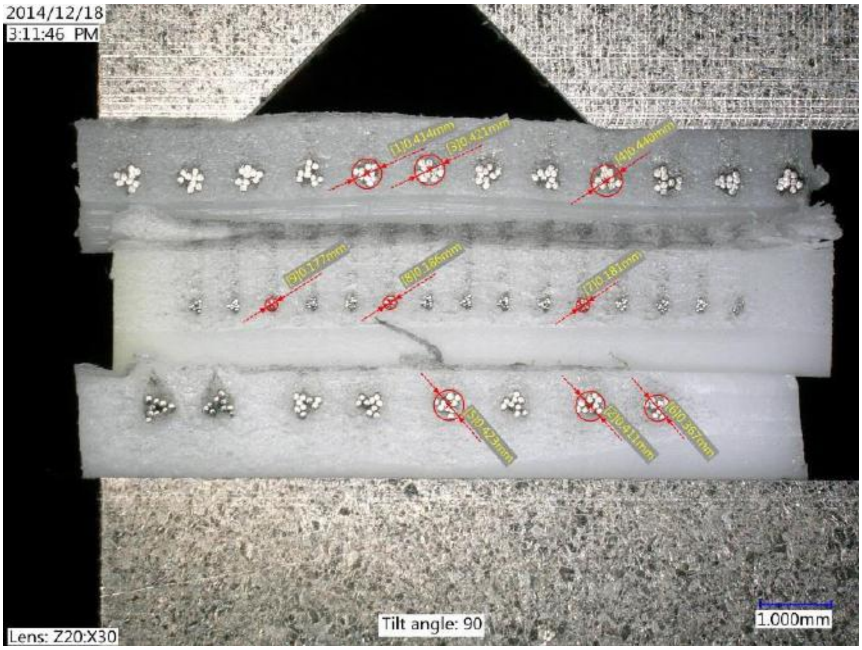

Fig. 2. Different types of cords for the same timing belt T2,5 from three different belt manufactures.

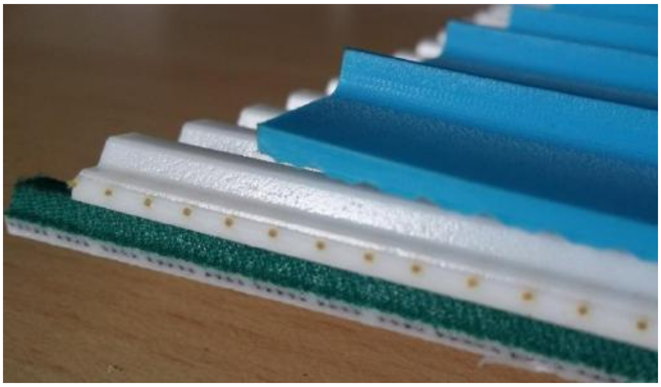

Fig. 3. Examples of timing belts with different constructions of support layer.

Construction of conveyor timing belts and belts for control systems and robotics is more complex. For these systems the following construction types are applied: the belts without cords and fibres, the belts with non-uniform distributed cord on the belt width and the belts with support layer made of thick plaited steel mesh. Non-uniform distribution of cord is applied to prepare the band to further processing. The support layer has some areas without the cord in order to make easy cutting along the belt length. Belt band is better adopted for perforation which often exists during transportation with negative pressure and it exists in belts for optical adjustment systems. Proper shape of support layer allows to place additional elements in the belt such as nuts, screws or signal cables (Fig. 4). The ends of these belts are specially shaped in order to properly mount the control belt in machine clamps.

In case of timing belts the ratio between the stresses in active and passive strand can be presented in function of teeth deformation on the arc of belt contact – one should also remember about the belt bending problem. Too high frequency of bending on small belt pulleys can lead to belt strand failure.

Fig. 4. Timing belt with signal cable.

Previous investigations have shown that the hardest conditions during bending exist under the support layer. Therefore, it is necessary to choose the belts with low teeth and small pitch for the constructions with small diameter of belt pulley. One should also remember about the elasticity of the cords and fibres in the support layer. The pursuit of solutions resistant to stretching has produced too rigid belts which cannot substitute old belts in existing transmissions. To improve the elasticity of the strand, ribbing is applied on active belt surface, but this solution in cooperation with tensioner causes a noisy work of the transmission.

4. Conclusions

Most of timing belt manufacturers who takes into account the mechanical properties of the support layer defines that maximally 15 teeth of timing belt can take a part in coupling with belt pulley. The increase of cord quality has decreased the maximal number of teeth in coupling to the value of twelve, and for the belts with carbon fibres this number will be lower. The increase of coupling quality has an effect on the increase of displacement accuracy and these types of belts have been positively verified in control systems (Fig. 1).

References

[1] M. Bodnicki, A. Pochanke, K. Szykiedans, W. Czerwiec, Experimental and Simulation Test of Dynamic Properties of Stepping Motors, Proc. 9th International Conference MECHATRONICS 2011, Recent Technological and Scientific Advances, Springer Verlag, 2011, pp. 25–34.

[2] G. Domek, Motion analysis of timing belt used in control systems, American Journal of Mechanical Engineering 1 (2013) 208–211.

[3] G. Domek, M. Dudziak, A. Kołodziej, Timing belt gear design for mechatronics system, Procedia Engineering 96 (2014) 39–43.

[4] G. Domek, Trends in development of timing belts for new application areas, Journal of Mechanical and Transport Engineering 66 (2014) 19–30.

[5] G. Domek, Meshing model in gear with timing belt, Journal of Advanced Materials Research 189–193 (2011) 4356–4360.

[6] G. Domek, Timing belts dynamics model approach, Journal of Mechanics Engineering and Automation 2 (2012) 495–497.

[7] H. Dressing, F. Holzweissig, Dynamics of Machinery, Theory and Applications, Springer Verlag, Berlin Heidelberg, 2010.

[8] T. Nagel, Zahnriemengetriebe, Carl Hanser Verlag, Munchen-Wien, 2008.