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Research on the Contact Area between the Timing Belt and the Toothed Pulley

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Abstract— **Modern timing belts should not only be durable or effective but also safe for users and their environment. While designing timing belt much attention should be paid to selection of materials, which have significant influence on mechanical properties of belts. Design of composites and usage of new polymer materials allows for improvement of constructional properties of belts. Depending on application: transmission, conveying or controlling, is different meshing in gear. The work presents meshing model between timing belt and pulley and in it constructional features of transmission timing belts depending on materials used for their production.**

Index Terms— **synchronous drives, timing belts, timing pulleys.**

I. INTRODUCTION

MODERN toothed belts are made of different types of polymers and composites with random special bonding lattice(Fig.1). Numerous experimental studies have shown that those materials are characterized by strongly non-linear and rheological properties depending on applied polymer, the structure of the composite or the manufacturing technology (Fig.2). Currently assumed physical and, as a consequence, mathematical model do not allow to simulate and to calculate technical parameters of the toothed belts[4]. The assumption that the toothed belt transmission is characterized by form-fitting coupling caused the omission of the structural friction between the belt and the pulley as well as the internal friction of the belt [1,5]. Change of properties and change of internal structure due to temperature rise or drop are one of the main properties of high-molecular materials used to manufacture drive belts. Intermolecular forces (Van der Waals forces) of those materials significantly influence their mechanical and rheological properties which can vary e.g. from immediate tenacity value R_m, up to variable values of the Elastic (Young's) modulus. Many fundamental phenomena which are important for friction coupling of the belt transmission, such as the structural friction force, the circumferential and radial slip, stress distribution in the belt cord on the arc of contact or the change of the belt cross-section shape result from qualitatively and quantitatively different belt deformations on the arc of contact [3,6].

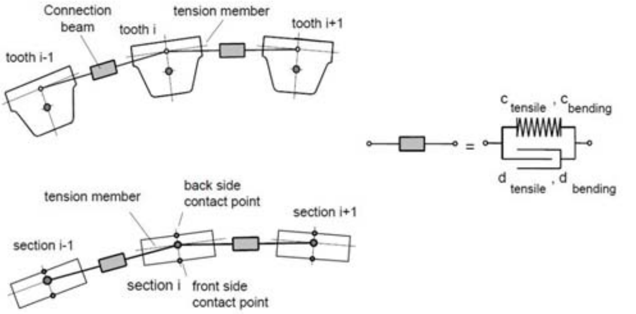

Fig. 1. Rigid body representation of synchronous and non-toothed belt[12]

II. CONTACT BETWEEN THE TOOTHED BELT AND TOTHED PULLEY

It has been empirically confirmed that periodical deformation of the belt cross-section during bending at the pulley significantly influences the value of energy loss due to internal friction in the belt material and rises the belt temperature [2,7]. The highest value of internal friction and energy dissipation occurs in the compressed layers of the belt, below the neutral axis. Main friction types between the toothed belt and the pulley are associated with belt movement within the tooth space as well as the coupling and decoupling process. The abovementioned conditions contributed to the new interpretation of phenomena taking place during combined form-fitting and friction coupling as well as to the directions of the toothed belt structure development (Figs.3,4,5).

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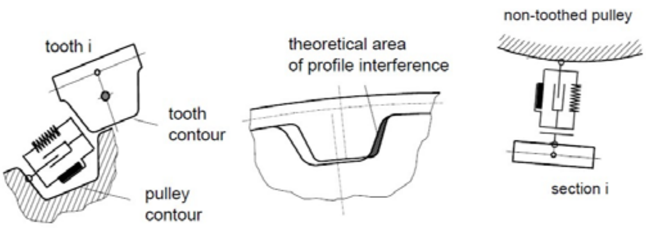

Fig2. Contact approach for timing belt[12]

The main method for designing toothed belts is to select appropriate belt and cord materials. The cord extension value on the arc of contact is determined by the angle of the arc of contact over which the belt teeth are deformed. The number of deformed teeth depends also on the value of the pitch [8]. To develop a qualitative model of the geometric coupling between the toothed belt and pulleys, it is necessary to consider deformation and the number of coupled belt teeth.

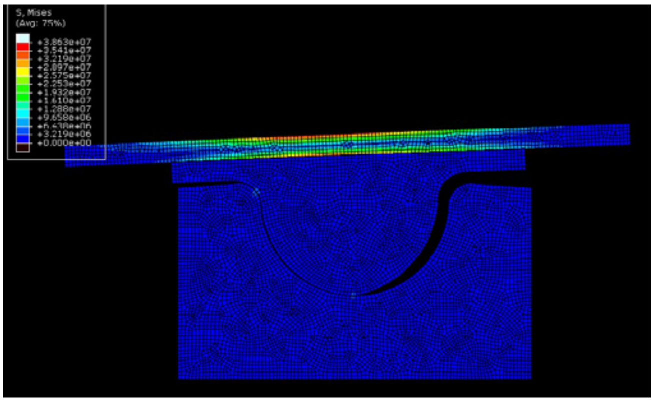

Fig. 3. Belt starting cooperation with pulley

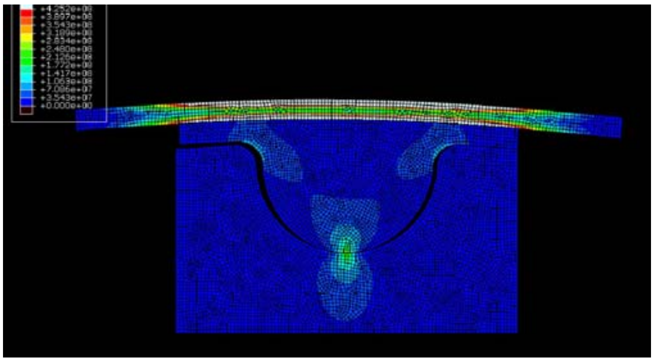

Fig. 4. Belt pressure on pulley under pretension force

The belt coupling model takes into account deformation of all coupled teeth. The model considers different phenomena occurring in the driving and in the driven wheel. Teeth deformation depends on the belt material as well as on both volumetric and energetic wear of teeth [2].

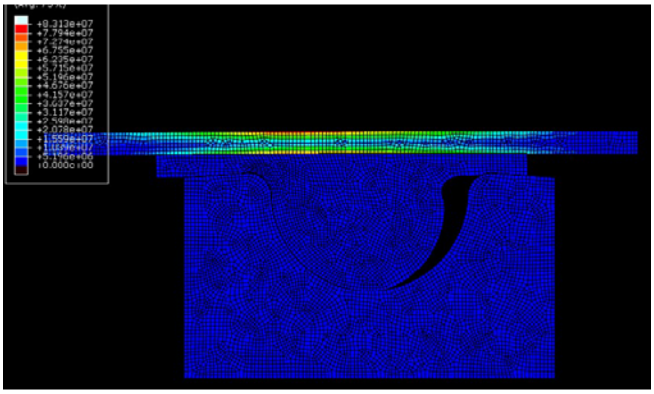

Fig. 5. Tooth deformation under radial force

III. COUPLING IN GEAR WITH TOOTHED BELTS

The total deformation of teeth on the arc of contact depends also on geometric properties of the belt, such as the pitch utilization factor. The more comprehensive coupling model can be expressed in form of the following formula:

$$\frac{S_1}{S_2} = f(\sigma_{\mathrm{k}}, \sigma_{\mathrm{p}}, K_{\mathrm{W}}, A_{\mathrm{kp}}, Y, Z) \qquad (1)$$

where: K_W belt pitch utilization factor, σ_k cord deformation (extension and twist), σ_p belt material deformation causing belt tooth height change σ_{ph} and the width change σ_{pb} as well as shape change σ_{pA}, A_{kp} adhesion factor for cord, belt material and additional materials, Y the toothed belt pitch to toothed pulley pitch ratio, Z – belt and pulley wear of volumetric Z_v and energetic Z_e type.

$$\sigma_{\mathrm{p}} = \{\sigma_{\mathrm{ph};}\sigma_{\mathrm{pb};}\sigma_{\mathrm{pA}}\} \qquad (2)$$

$$Z = Z_{\mathrm{v}} + Z_{\mathrm{e}} \qquad (3)$$

Use of toothed belts of the same pitch value and different cord types allows to satisfy the need for internal friction reduction (by reducing the tooth height and the height below the neutral axis) with simultaneous increase of flexibility and making use of flat belt advantages.

Using the cord typical for belts with 16–20 mm pitch in belts with 8–10 mm pitch will make it impossible for those belts to work together with pulleys of small diameter. However, those belts shall transmit similar torque value when working with pulleys of diameters similar to minimum pulley diameters for large pitches. The larger the belt pitch the more irregular the transmission gear due to reduced belt teeth overlap factor for pulley X and due the polygon effect. The belt material is also more prone to deformation due to increased belt pitch [9,10].

$$X = \frac{\sqrt{2D_{\mathrm{p}}h_{\mathrm{l}} - 4h^2 - h_l^2}}{2P} \qquad (4)$$

where: X the belt teeth overlap factor, D_p root diameter of the toothed belt, h_l tooth height up to the cord axis, h the belt tooth depth.

When the coupling is expressed in form of the relationship of temporary stress values, it takes the form:

$$\frac{\mathrm{d}S_1}{\mathrm{d}S_2} = f(\mu_{\mathrm{pk}}, X_{\mathrm{c}}, X_{\mathrm{B}}, K_{\mathrm{w}}, K_z, F_N, \varepsilon^N, d_u, \mathrm{d}z_{\mathrm{co}}, \mathrm{d}z_{\mathrm{bo}}) \quad (5)$$

The temporary number of teeth on the arcs of contact of the driving pulley $\mathrm{d}z_{\mathrm{co}}$ and the driving pulley $\mathrm{d}z_{\mathrm{bo}}$ respectively, significantly influences the change of coupling, particularly for transmission gears, where the value of X, determined from the formula (4) does not exceed the unity. Belt material properties specified by the formula (1), indicating to the influence of deformations on the change of material properties are also important. The pre-tensioning force F_N, influences the coupling character by influence on matching the belt and the pulley pitches as well as on the angle – α_0, the value of which depends on the mechanical properties of the load-carrying layer [4].

IV. CONCLUSIONS

Phenomena associated with the contact between the toothed belt and the pulley can be divided into categories. The first category includes phenomena occurring inside the belt and is associated with load transfer from the belt material to the cord as well as effects occurring between respective belt and pulley surfaces. In some experiments synchronous gear worked parallel with standard belt gear in order to improve power transmission trough friction [11]. Analysis of those effects constitutes the grounds for individual attitudes to design and operation of toothed belt transmission gears.

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