Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 96 (2014) 39 – 43

Procedia Engineering

www.elsevier.com/locate/procedia

Modelling of Mechanical and Mechatronic Systems MMaMS 2014

Timing belt gear design for mechatronics system

Grzegorz Domek[a], Marian Dudziak[b,c], Andrzej Kołodziej[c]*

[a]*Kazimierz Wielki University in Bydgoszcz,Chodkiewicza 30, 85-064 Bydgoszcz, Poland*
[b]*Poznzn University of Technology, Pl. Marii Skłodowskiej-Curie 5, 60-965 Poznan Poland*
[c]*Higher Vocacion State School in Kalisz, Nowy Świat 4, 62-800Kalisz*

Abstract

The development of measurement techniques allows for a new approach to the design of machines. One can use 3D scanning systems and multi-axis computer numerical control (CNC) machines as coordinate measuring machines (CMM). The obtained cloud of measuring points allows to enter more variables into the geometrical product specification (GPS) and hence it allows to get a new method for assessing the tolerances. These situtation refers to axisymmetric elements that have an impact on operation of number of mechanisms. The application of coordinate measuring machines allowed for a new approach to the quality of belt pulley mounitng. Conditions of the contact surface area and allowable manufacturing errors, the actual position of the rotation axis of shaft hole and many other parameters can be defined during the manufacturing stage.

Keywords: *axially symmetric, taper bushings, mechanical gears.*

Keywords: Type your keywords here, separated by semicolons ;

1. Introduction

Belt transmissions have been applied to transfer the torque on long distances for many years - without any special requirements for their manufacturing accuracy. We can connect the shafts in different planes and also can change the direction of motion by twisting the belt. Toothed belts are used in precise drives for control and adjustment units. The quality of shaped-frictional contact between the toothed belt and pulley was always observed. Information on incorrect mounting of belt pulleys was presented in many instructions and elaborations. However, there is a lack of analysis of the influence of incorrect mounting of the belt pulley on the coupling character between the pulley and the belt. The authors made an attempt to implement this above mentioned problem into the coupling model. Mounting errors of belt pulleys caused by very popular mounting systems were also analysed.

2. Pulleys manufacturing problems

The most common manufacturing defect of the timing belt gear is the manufacturing error of running flanges. This element has not been standardized so far. Poor mounting of flanges on the pulley causes the flanges to drop off. It may cause the damage of the belt's edges, and its cord can damage the machine. The manufacturing errors of the toothed ring are the defects that are more difficult to reveal. The technological level of the equipment for production of timing pulleys is diversified due to the different financial levels of pulleys manufacturers [8]. Gear measurements have indicated the diameter errors and these errors mean that the shape of belt teeth is improperly manufactured. The defects result from using one type of cutter for production of the whole diameter ranges of pulleys. The toothed ring errors are often time-varying - after a short time of operation we can

doi:10.1016/j.proeng.2014.12.095

observe some volumetric wear of the belt [9]. A picture of the wear is very helpful to identify the toothed ring error of the pulley. The examples of the toothed ring errors are the following: roundness errors (Fig. 1), low-grade manufacturing of the groove for cooperation in case of belts with a driving taper and a low quality of teeth surfaces. Some manufacturers make some modifications of the belt construction so as to make the replacement of the belt manufactured by other producer impossible. This is an unfair market activity and fortunately it happens very rarely.

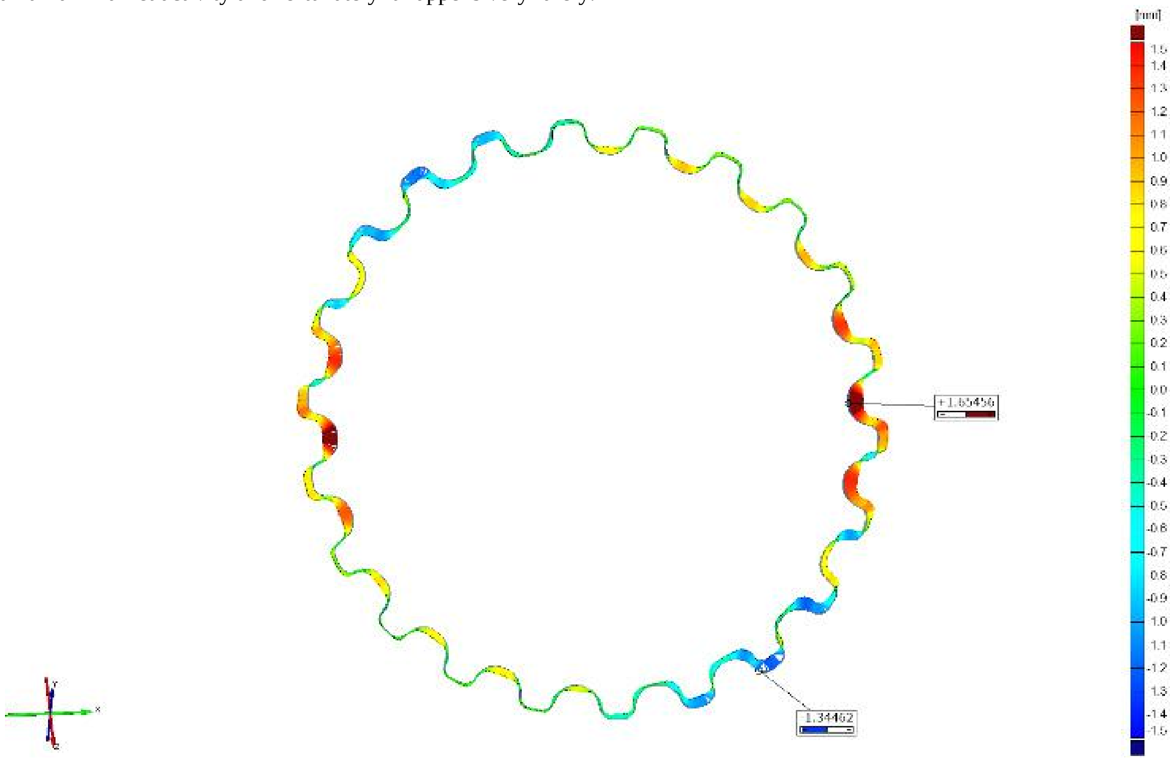
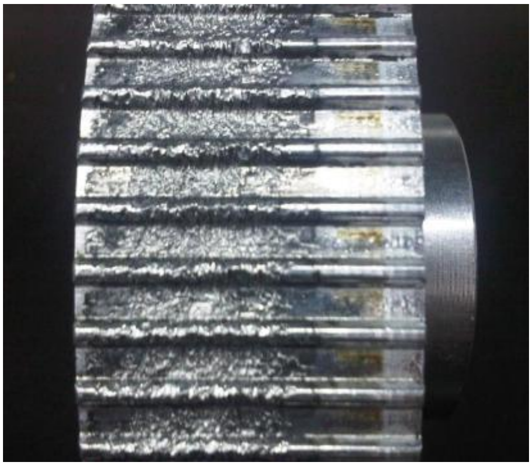


Fig. 1. Non-circular pulley from valve timing of the combustion engine.

During designing one should be aware of the design life of the product, i.e. operation and disposal. During the timing belt gear design the designers forget about the recommendations for cooperation between the pulley and belt. The users are not aware of the essence of the pulley quality and they often exceed the service life for the pulley (Fig. 2) [5].



A much more important issue is a proper seating of gear wheels. Many seating solutions for gear units are well known. Different types of mountings significantly affect the kinematics of gear and thus the durability of the belt.

3. Problems of the belt pulley mounting on the shaft

During the design of belt drive systems and control systems two common mounting solutions and a variety of specialized solutions are applied (Fig. 3). Basic methods of mounting the pulleys on the shaft are the following: Taper-lock and Taper-bushes. Both mounting systems cause the errors associated with mounting the bush on the shaft and fixing the bush in the pulley [6].

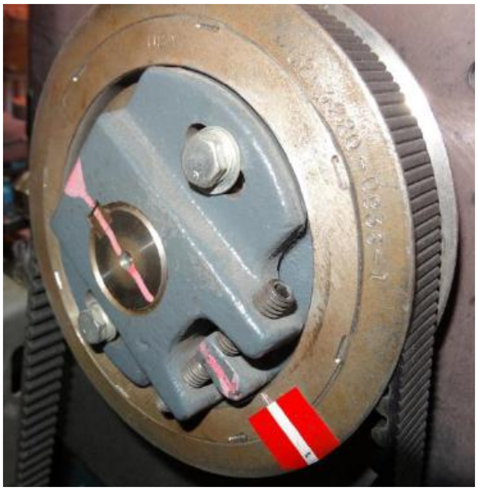


Fig. 3. Taper bushing.

Modern measurement systems allow to observe and identify these errors. This situation permits to obtain the best operating parameters which will provide a direct mounting of the gear wheel on the shaft.

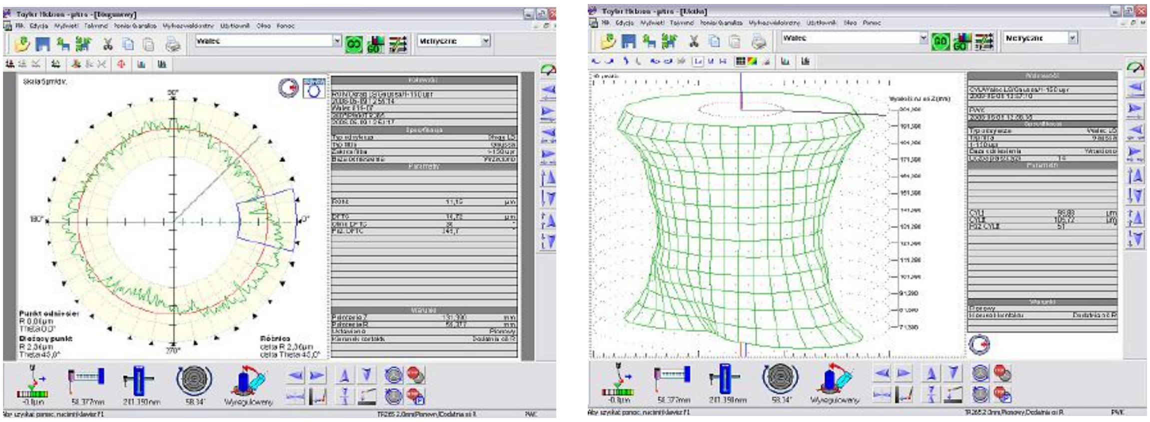


Fig. 4. Hole measurement.

The measurement results of a hole show the manufacturing errors of the hole such as roundness and cylindricity errors (Fig. 4). The measurements show also the inaccuracy which cannot be expressed in the form of classical form errors. This error is important for the contact stresses between the connected areas and for the final position of the gear wheels in a transmission. Drilling technology allows to slightly improve the hole quality. It can be done when we use the specialized and expensive processing. A majority of attention is focused on the manufacturing of the shaft where the gear wheel is mounted.

The whole process of mating the shaft with the hole is directed to the concentricity of the axes. A lack of alignment or angular position of the shaft and gear wheel will cause swinging of the gear wheel. The meshing process will run uniformly. The coupling process between the belt and pulley can have some errors associated with the period of rotation of the pulley. The increase of inaccuracy, displacement error, velocity and ratio make the transmission to be unusable for mechatronic systems.

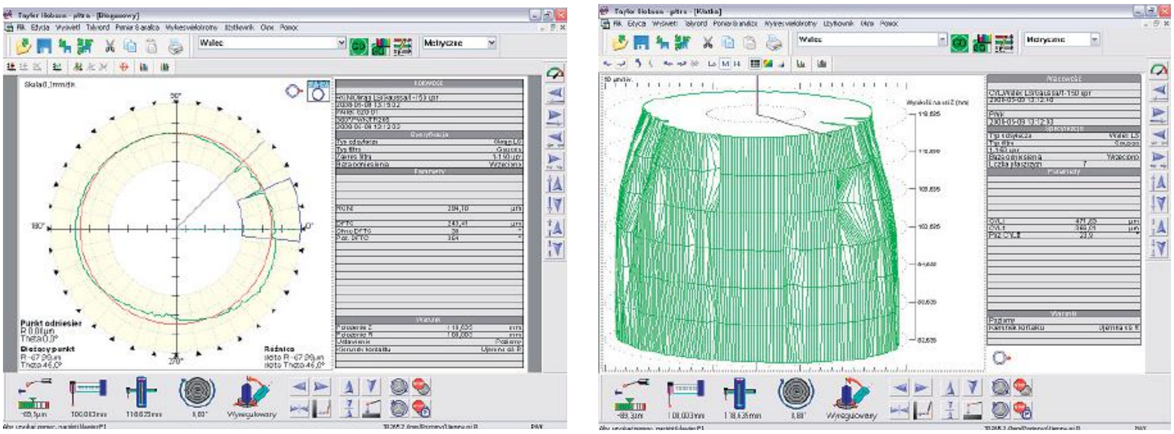


Fig. 5. Shaft measurement.

The measurements of the geometrical form of the shaft, e.g. roundness errors, clearly indicate the entire length of the measuring section (Fig. 5). Form errors have different values and the presented results show the error in the diameter - probably due to the technological process. Summarizing the measurement results we can observe that there is a misalignment between the belt pulley and the shaft. The occurring eccentricity should be taken into account in the coupling model.

4. Coupling model with mounting error

Detailed analyses of problems associated with the construction of timing belts have not been conducted yet. New arrangement of teeth on the belt width solves the problem of smoothness of belt operation and noise emission. Unfortunately, this type of belts operates worse in power transmissions with high torque and control units [2, 3]. Coupling of the belt drive *P* can be interpreted as a function of the ratio of tension stresses in the cord between the active S_1 and passive S_2 strand. The total deformation of the teeth on the arc of contact also depends on geometric properties of the belt such as the pitch utilization factor. The more comprehensive coupling model can be expressed in a form of the following formula:

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

where: K_W - belt pitch utilization factor, σ_k - cord deformation (extension and torsion), 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 a cord, belt material and additional materials, Y - ratio between the toothed belt pitch and toothed pulley pitch, $Z= Z_v+ Z_e$ (belt and pulley volumetric Z_v and energetic Z_e wear).

(2)

The coupling relation should take into account an error resulting from the identified problems of pulley fitting which for sleeve snap should be doubled.

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

5. CONCLUSIONS

Timing belts are finding new applications in mechatronic systems, robotics and automation (Fig. 6). Geometrical tolerances are limited only by geometrical deviations of an actual object from its nominal counterpart. This is why they are included in the group of simple geometrical tolerances. In machine industry, actual objects like rollers or balls of bearings rarely have elementary shape e.g. of a cylinder or a sphere. Geometrical shape of machine parts is usually more complex, e.g. a stepped shaft consists of several cylindrical surfaces, a wheel-case is a solid with several holes, etc. In such cases, apart from the necessity of meeting dimensional and geometrical requirements, it is also necessary to ensure a proper orientation and location of individual components. For example, surfaces of a double-stepped shaft should be coaxial cylinders, whereas axes of holes in a wheel-case should be parallel. It is not easy to achieve these requirements due to technological reasons.

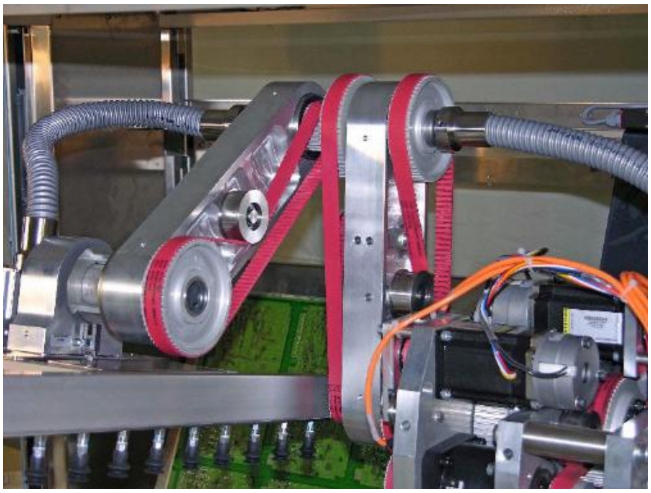


Fig.6. Timing belts in robotics [12]

Described problems should be aware of reduced efficiency and inaccuracies of power transmission. Phenomena associated with the contact between the toothed belt and the pulley can be divided into a few categories. The first category includes phenomena occurring inside the belt and is associated with the load transfer from the belt material to the cord as well as effects occurring between the respective belt and pulley surfaces. In some experiments synchronous gear worked in parallel with standard belt gear in order to improve the power transmission by friction. Analysis of these effects constitutes the fundamentals for individual attitudes to design and operation of toothed belt transmission gears. Timing belt gears are successfully applied in control and regulation systems and there still exists a wide field of their new applications. Understanding the structural design allows to distinguish the belts and wheels for driving and control applications. Like other mechanical transmissions used in the control units, as well in this case the gear is selected with a limited backlash or it is "backlash free". The most popular method of the analysis of functionality and reliability of axisymmetric joints is determining the minimum and maximum value of the analysed parameter. However, due to manufacturing deviations of the elements of axisymmetric joints, it is necessary to apply more complex methods. Actual operation of these joints is associated with: reduction of the contact area, variation of the defined function (negative allowance, play), assembly stresses, stress concentration and spread of friction factor values which reduces the ability of load transfer. The assessment of actual functionality of axisymmetric joints depends on appropriate selection of the fit, shape and geometric structure of the joint components.

References

[1] G.Domek, Leistungverluste in Zahnriemengetrieben, Antriebstechnik 12/2006, s. 30-31.

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

[3] G. Domek, Meshing in gear with timing belts, International Journal of Engineering and Technology (IJET), T307 in the February 2011

[4] G. Domek, M. Dudziak, A. Kołodziej, Problems related to functionality and unreliability of axisymmetric joint in the mechanical engineering, "WISNIK" Lviv University of Technology, N651, Lviv2009, s. 28-34.

[5] G. Domek, M. Dudziak, Energy dissipation in timing belts made from composite materials, Journal of Advanced Materials Research, Vols. 189-193(2011) pp 4414-4418.

[6] G. Domek, P. Krawiec, Methods of Designing of Timing Belts Pulley, University Reviev, Vol 1, No.3 /2007, Aleksander Dubcek University of Trencin, Izhevsk State Technical University s. 15-20.

[7] G. Domek, I. Malujda., Modeling of timing belt construction, Wiley Inter Science PAMM Volume 7, Issue 1, Date: December 2007, Pages: 4070045-4070046

[8] M. Dudziak, G. Domek, Change of belt's tooth shape caused by bending and pressure on the pulley, TRANSACTIONS of VŠB – Technical University of Ostrava, Metallurgical Series, Issue 1 / 2008, Vol. LI

[9] M. Dudziak, G. Domek, New quality expectaction in design of drives, Studium Vilnense.A vol. 5, Vilnius 2009, s. 60-62.

[10] J. Vollbarth, Anforderungen an Zugtraeger fur Zahnriemen und deren Eigenschaften im Vergleich, Tagungsband zur 14. Internationalen Fachtagung Zahnriemengetriebe, Dresden 20/30.09.2010, p.57-63.

[11] W. Terschuren, Neue Glasfasern mit innovativen Beschichtungen fur Riemenanwendungen, Tagungsband zur 14. Internationalen Fachtagung Zahnriemengetriebe, Dresden 20/30.09.2010, p.64-78.

[12] MULCO training materials.