Serbian Tribology Society

SERBIATRIB '13

13th International Conference on Tribology

Faculty of Engineering in Kragujevac

Kragujevac, Serbia, 15 – 17 May 2013

EXPERIMENTAL ANALYSIS OF TOOTH HEIGHT CHANGING AT TIMING BELTS

Blaža Stojanović[1], Lozica Ivanović[1], Andreja Ilić, Ivan Miletić[1]
[1]Faculty of Engineering, University of Kragujevac, Serbia, blaza@kg.ac.rs, lozica@kg.ac.rs, imiletic@kg.ac.rs

Abstract: *Timing belt drives present relatively new power transmitters that transmit power by friction and form contact. Load at timing belts is under direct influence of active surface of timing belt tooth. During exploitation, the height of tooth at timing belt decrease and, by that, reduction of active surface is provoked, load increases and working life decreases. Besides of tooth height, changing of tooth width at timing belt, also presents very important factor. The tribomechanical system at pulley teeth - timing belt teeth with height changing during exploitation is analyzed in this paper. Experimental testing of tribological characteristics was done at custom design and made testing device at Center for power transmission at Faculty of Engineering in Kragujevac.*

Keywords: *timing belt, tribomechanical system, timing belt teeth, friction, testing.*

1. INTRODUCTION

Working life and reliability of timing belt transmitters are highly influenced by timing belt geometrical dimensions that means timing belt pitch, its tooth height and width. Timing belts are made of polymer materials reinforced by metallic materials and their dimensions vary during exploitation. Highest variation of geometrical dimensions occurred during running-in period of new belt. During this period, changing of timing belt pitch is highest, primarily influenced by plastic deformations of side surfaces of its tooth. After running-in period, changings of geometrical characteristics are linear with same trend for considered values [1-4].

The contacts of timing belt and pulley cause changing of geometrical properties. On the basis of kinematic analysis of pulley and belt contact in details, following three tribomechanical systems can be identificated [5, 6]:

1. belt teeth – pulley teeth
2. side surface of belt – pulley rim
3. inter teeth belt space – head of teeth pulley

Friction force in tribomechanical system belt teeth – pulley teeth is dominant factor in case of tooth height changing analyses.

2. TRIBOMECHANICAL SYSTEM BELT TEETH – PULLEY TEETH

During mashing of belt teeth with pulley teeth contact between side surfaces is done. The contact is at line, for the beginning, when belt teeth come in mash with pulley teeth. The mashing starts with impact of belt teeth and pulley teeth. The belt teeth deform, due to its elastic properties and, by that, enlargement of contact surface is done. After enlargement of contact surface, and rotations of belt and pulley, belt teeth slide on side surface of pulley, when rolling with sliding type of friction is happened.

The value of friction force decreases with length of sliding path, so its maximal value is at the base of belt teeth (Fig. 1). Simultaneously, acting point of resulting component of normal force moves from head to base of the teeth. Normal force varies with parabolic dependence:

$$N_i = -\frac{N_{\max}}{l_t^2}\cdot\left(l-l_t\right)^2 + N_{\max}, \qquad (1)$$

where is:

$N_{\max}$ - maximal value of normal force,
l - length of tooth profile and
l_t - length of sliding path.

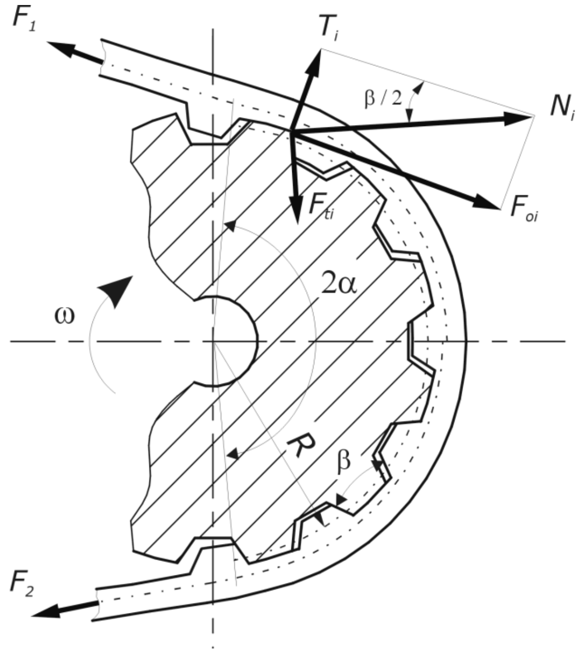

Figure 1. Friction force on side surface of belt teeth

Friction force on side surface of belt teeth can be determined by following relation:

$$F_{ti} = N_i \cdot \mu = \frac{F_{oi} \cdot \mu}{\cos(\beta/2)} \quad (2)$$

where is:

N_i - normal force on belt teeth,

μ - friction coefficient,

F_{oi} - peripheral force that act on belt teeth and

β - belt profile angle.

3. TESTING OF TIMING BELT

Experimental testing of tribological characteristics was done at custom design and made testing device with open power loop at Center for power transmissions at Faculty of Engineering in Kragujevac [7-9]. Basic elements of testing device are (Fig. 2):

1. driving unit,
2. Cardan transmitter,
3. input shaft with measuring devices,
4. sensor for input shaft number of rotation,
5. torque sensor on input shaft,
6. considered power transmitter (timing belt-pulley),
7. output shaft,
8. mechanical brake,
9. tension mechanism and
10. signal amplifier.

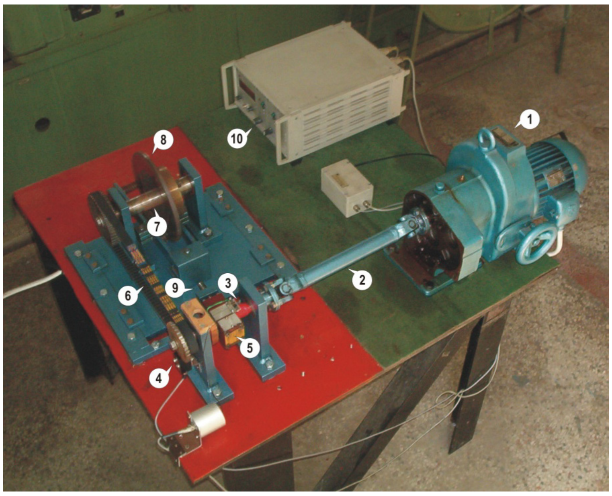

Figure 2. Device for timing belt testing.

Driving unit, type KR-11/2C (37-180 rpm^{-1}), consists of electromotor (1) type ZKT90S-4 (totally enclosed single phase asynchronous motor with cage rotor with thermal protection, size 90L, 4-pole type), friction power transmitter, and gear reductor. Design solution provides automatic regulation of pressure between friction discs and compensation of axial gap due to wear. Changing of number of rotations per minute is done manually, by rotation of wheel that by coupling of gear and bar, radially (vertically) move electromotor with conical friction disc from friction wheel. Driving unit (1) and input shaft (3) are connected by Cardan transmitter (2).

Input shaft (3) is design in the way to be elastically deformed under maximal torque load. Inductive sensor of number of rotations per minute (4), type MA1 is placed on input shaft, so as torque transducer (5) that is formed of strain gauges and signal transmitter MT2555A that is mounted by special adapter with battery compartment BK2801A.

Input and output shafts (7) are connected by considered power transmitter (6), means timing belt - pulley system. Tension of timing belt is done by the tension mechanism (9) with external threaded spindle. By spindle rotations the movements of plate with output shaft and mechanical brake are done.

Mechanical brake is specially designed for open power loop (Fig. 3). Breaking is done by acting of breaking pads on both sides of the disc. Regulation of force and torque is done manually by the means of spring and screw.

Mechanical brake obtain certain braking torque, means load torque on output shaft of timing belt – pulley power transmitter. Value of torque is presented on digital display of the signal amplifier that gets signal from measuring device on shaft by signal transmitter EV2510A. The number of rotations per minute of input shaft is also displayed on amplifier gain that gets signal from inductive sensor and impulse receiver DV2556.

Working regime of input shaft at power transmitter is measured and regulated in presented way.

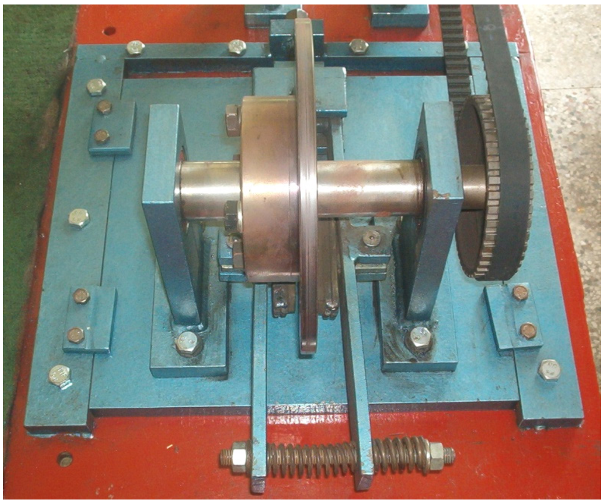

Figure 3. Mechanical Brake

By adaptations of joining elements with driving unit from one side and output shaft equipped with measuring devices testing of various types of power transmitters can be done on presented equipment with limitations in dimensions and load.

4. TESTING RESULTS

Measuring of geometrical dimensions is done at Zastava tool factory, Department of quality. In order to provide relevant analysis measuring of the following values are done at eight teeth of timing belt (Fig. 4):

- pitch (h),
- belt width (b),
- distance between belt teeth (t_1) and
- belt height (t).

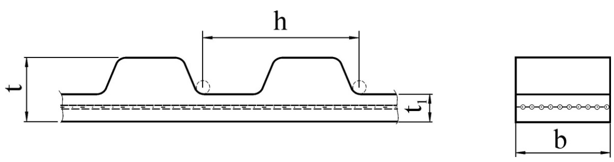

Figure 4. Basic geometrical properties of timing belt

Change of timing belt height is considered in this paper. Belt height is distance between head of belt tooth and backing surface. Measuring was done by DIGIMAR measuring device (Fig. 5). Changing of belt height (Δt) during testing can be calculated by following relation:

$$\Delta t = t_o - t,$$

where is:

t - measured value of belt height and

t_o - starting height of the belt.

Figure 5. Measuring device –DIGIMAR

Results of measuring of the belt height changing during exploitation at eight considered tooth are presented at Tab. 1 by values and at Fig. 6 by diagrams.

Table 1. Change of timing belt height $\Delta t = t_o - t$ [μm]

Exploitation period [h]	Δt							
	Belt teeth							
	1	2	3	4	5	6	7	8
5	52	75	34	23	17	3	32	13
10	53	77	38	30	23	15	39	15
20	62	83	46	41	36	17	42	30
50	65	96	49	52	57	26	53	51
100	65	98	50	53	57	33	53	53
150	67	101	54	53	57	35	57	53
200	68	105	58	61	57	55	74	55
250	69	109	58	65	67	63	82	63
300	76	125	63	67	67	66	84	63

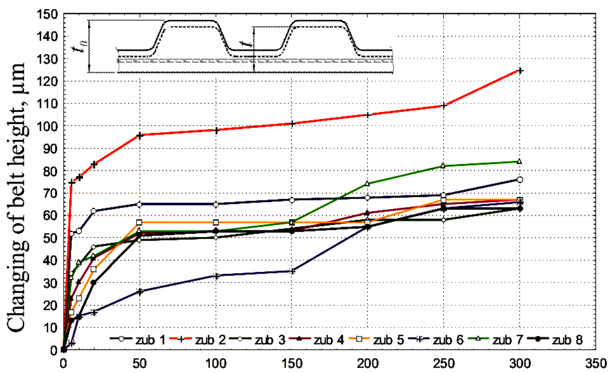

Figure 6. Changing of tooth timing belt height in exploitation

Evaluations of the obtained results implicate that belt height decreases monotonely during exploitation. During running-in period, that lasts for approximately 20 hours, this changing is very significant and it is happening on all of considered eight belt tooth. The changing during running-in period is caused by deformations of the belt, its pitch and width decrease. During period of exploitation due to normal wear belt height decreases. During period of 20 hours to 50 hours of exploitation this changing is significant. After 50 hours of exploitation till 200 hours of exploitation, the very fast changing occurred at most of the tooth. Plastic deformation occurred during running-in period. Due to the fact that those deformations are small during period of normal wear, cylindrical wear of tooth head are not significant, so height changings are small. After 200 hours of exploitation changing of tooth heights are significant.

On the basis of the further analyses, conclusion that changings of all values are subjected to same decrease function is implicated. But, on the basis of the analysis in details it is implicated that changing of belt height is bigger than changing of inter tooth space width. This fact leads to decrease of active tooth heights that are in contact with tooth of the pulley. If the reduction of belt width after 150 hours is taken into consideration, it is implicated that value of nominal surface side of timing belt tooth also decrease. As timing belt - pulley transmitters transmit power by form contact and friction, increase of timing belt pitch and decrease of nominal active surface of tooth all together cause failures in exploitation of those transmitters.

5. CONCLUSION

The basic tribomechanical systems at timing belt – pulley transmitter are: timing belt teeth – pulley teeth, belt side – rim of the pulley, inter space of timing belt tooth – head of pulley tooth. Friction forces are highest at side surfaces of timing belt tooth and pulley tooth. Directions and values of those forces are under direct influence of meshing kinematics of timing belt transmitters.

As the consequence of friction at side and head surface of tooth, the reduction of belt height is caused. Decrease of belt width and reduction of its height cause decrease of active contact surface, that further cause increase of loads at tooth and simultaneous decrease of transmitter coefficient of efficiency. Average changing of timing belt tooth height relatively to starting value is 3.14 %.

Considered changing of geometrical properties of timing belt causes significant influence to reliability and working life of timing belt transmitters.

REFERENCES

[1] R. Perneder, I. Osborne: *Handbook Timing Belts: Princilpes, Calculations, Applications*, Springer-Verlag Berlin Heidelberg, 2012.

[2] S. Tanasijević: *Mechanical drives: chain drives, timing belt drives, cardanic drives* (in Serbian), Yugoslav tribological society, Faculty of engineering from Kragujevac, 1994.

[3] B. Stojanović, S. Tanasijević, N. Marjanović, L. Ivanović, M. Blagojević: *Wear as the Criterion of Mechanical Transmitters Working Life*, J Balk Tribol Assoc 17, pp. 215-222, 2011.

[4] B. Stojanović, M. Babić, N. Marjanović, L. Ivanović, A. Ilić: *Tribomechanical Systems in Mechanical Power Transmitters,* J Balk Tribol Assoc 18, pp. 497-506, 2012.

[5] B. Stojanović, S. Tanasijević, N. Miloradović: *Tribomechanical Systems in Timing Belt Drives*, J Balk Tribol Assoc 15, pp. 465-473, 2009.

[6] B. Stojanović, N. Miloradović, N. Marjanović, M. Blagojević, A. Marinković: *Wear of Timing Belt Drives*, J Balk Tribol Assoc 17, pp. 206-214, 2011.

[7] B. Stojanović, N. Miloradović, N. Marjanović, M. Blagojević, L. Ivanović: *Length Variation of Toothed Belt During Exploitation*, Strojniški vestnik, Vol. 57, No. 9, pp. 648-654, 2011.

[8] B. Stojanović, L. Ivanović, M. Blagojević: *Friction and Wear in Timing Belt Drives,* Tribology in Industry 32, pp. 33-40, 2010.

[9] B. Stojanović, L. Ivanović, N. Miloradović: *Testing of Timing Belt Drives,* IMK-14 37, pp. 77-80, 2010.