International Conference
6th Workshop on European Scientific and Industrial Collaboration
on promoting Advanced Technologies in Manufacturing
WESIC'08

Bucharest, 25-26 September 2008

Noise and Deformation Analyze During Wheel and Belt Contact

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ABSTRACT

It is presented in this paper the results of image processing of the belt's behavior recorded on the video-tape and the results of noise level processing. This system allows establishing the influence of the functional parameters of the belts on the deformations between belt and the motor and receptor wheels and also the correlation between the magnitude of deformations and the noise levels in the same points. It is presented the influences of different parameters like: speed, tension, shape and moment on the belt and wheel, like images recording with a high speed video-camera and image processing software in the same time with the noise level of the contact point.

INTRODUCTION

The power transmission by synchrony tooth belt represent a research field not so very deep studied and which allow now the approaches of the research variants like: the effort distribution on the teeth, life time, noise/dynamic regime, static deformations etc.

All the studies on the tooth belts establish only the understanding of the functionality and less of them the optimization analysis. By this study it is accomplish the analyze on the belt deformations on the contact of the belt tooth with the wheel tooth, starting with the numerical modeling and the verifications by speckle interferometer and establish then a calculation model of the deformations into static and dynamic regime in correlation with the noise level from the same area. From the point of view constructive there are two profile types of the synchrony tooth belt: **the trapezoidal profile** and **curve profile (HTD = High Transmission Drive),** and from the point of view materials used: the belt with **poliuretan teeth and the Kevlar center**; the belt with **policloropren teeth and the nylon center**. Because the HTD profile of the synchrony tooth belt is the most efficient from the point of view power transmission we were using in this analyze this builded profile.

TEORETICAL ASPECTS

The most important aspect into the synchrony teeth belt function is the correct establishing of the gearing step. The position of the belt is linear between the wheel teeth and it surrounds on the superior part of the wheel teeth. This behavior can define the gearing step measured on the median line of the belt. The gearing step it is **p'** and it is establish by the next relation:

$$p' = AE = AB + BC + CD + DE \tag{1}$$

It can observe that the gearing step it is different from the wheel step $\mathbf{p_r}$ this one being measured on the medium diameter of the wheel. So the gearing step giving by the relation (2):

$$p' = 2(R_w - r_w)\sin\phi + 2(r_w + c)\phi + 2(R_w + c)\beta \quad (2)$$

depends of the follow parameters: the angle ϕ and β, the radius $\mathbf{r_w}$ and $\mathbf{R_w}$ of the wheel and the distance **c** from the median line.

The most important problem in the case of using dental belt into power transmissions it is to define and to estimate the *play* between the belt tooth and the wheel tooth. It is defining two types of such *play* for the teeth finding totally into gearing contact: the longitudinal *play* between the teeth - LP; the radial *plays* on the bottom of the dental system – RP. It is possible to observe, in the fig.1, that for the HTD profile, the contact is made on the radius $\mathbf{r_c}$ (the radius for the belt) and on the radius $\mathbf{r_{rr}}$ (the radius for the center with the wheel tooth). The angles $\boldsymbol{\alpha_r}$ and $\boldsymbol{\alpha_c}$ are not identical, so the longitudinal *play* it is not constant and the radial *play* has positive values.

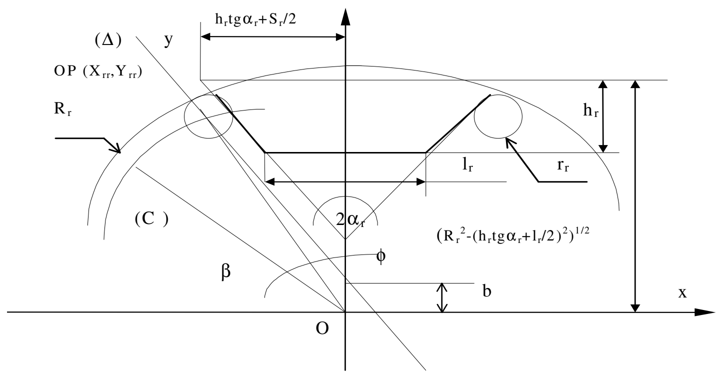


Figure 1.

For determine the behavior of the dental belt on the contact with the teeth of the wheel, for different functional states it musts calculate the medium longitudinal *play* starting with the high $\mathbf{h_r/2}$ (h_r = the wheel tooth high).

Then we can have the values **K** and **C** given by the follow relations:

$$K = \sqrt{R_r^2 - \left(h_r tg\alpha_r + \frac{l_d}{2}\right)^2} - \frac{h_r}{2} \quad (3)$$

$$C = \sqrt{R_r^2 - \left(h_r tg\alpha_r + \frac{l_d}{2}\right)^2} - h_r = K - \frac{h_r}{2} \quad (4)$$

The point coordinates **A** and **B** are determined from the next equations systems:

$$\begin{cases}(X_B - X_{or})^2 + (Y_B - Y_{or})^2 = r_{rr}^2 \\ Y_B = K\end{cases} \qquad \begin{cases}(X_A - X_{oc})^2 + (Y_A - Y_{oc})^2 = r_c^2 \\ Y_A = K\end{cases} \quad (5)$$

With the values:

$$X_B = \sqrt{r_{rr}^2 - (K - Y_{or})^2} + X_{or}$$
$$X_A = \sqrt{r_c^2 - (K - Y_{oc})^2} + X_{oc} \quad (6)$$

can determine the medium *play* value like:

$$LP = 2(X_B - X_A) \quad (8)$$

Because the belt is in the gear with the wheel, there is not a step coincidence; this step difference creates the initial *plays* named **base interference**. It is can possible that the *plays* **C(I)** and **B(I)** can take also the negative values, in this case, the teeth of the belt are already charge with the initial tension from assembly operation, so there is a pre-charge with an initial force.

For the static behavior analyze of the contact between the wheel teeth and the belt teeth, it can consider, by the operation of discretization, only a belt step on which it was establish the action force directions and orientations. The connection between the central field and the tooth on the belt it was assuming by a pivot connection, neglecting the rigidity of the central part of the belt. It was necessary to introduce four unknowns: **T(I), T'(I)** - the tension into the central part; **S(I), S'(I)** – the forces into the central part. The contact between the belt tooth and the wheel tooth it is modeling by an articulation without friction and **Q(I)** represents the reaction given by the wheel tooth on the belt tooth.

To establish the equilibrium of the belt tooth it is necessary to define a supplementary action, with is noted **C(I)** and which represents a torsion couple due by the forces activated in points **A** and **B** by the wheel. The action mode of the **Q(I)** force it was establishing by the tooth equilibrium in **I** tangent point between the circles $\mathbf{C_c}$ and $\mathbf{C_r}$ and then the projection of it on the three axes.

EXPERIMENTAL SETUP

It was accomplishing the video recordings, successive, of the behavior of the gearing, in the static regime and also in the dynamic regime to view the phenomena's, which were developing in the contact zone of the synchrony belt tooth with the motor, or receiving wheel tooth.

Also, for the visualization of the noise phenomena's, it was recording the noise levels for each tip of studied parameters.

For the static regime records it was using a system with a video cam with video sensor CCD, in normal light, with image conversion system and acquisition card on the IBM-PC computer PII, with 128 MB in RAM, 8,0 GB and a 750 MHz frequency, having the possibility to display the images with 1024x1024 resolution.

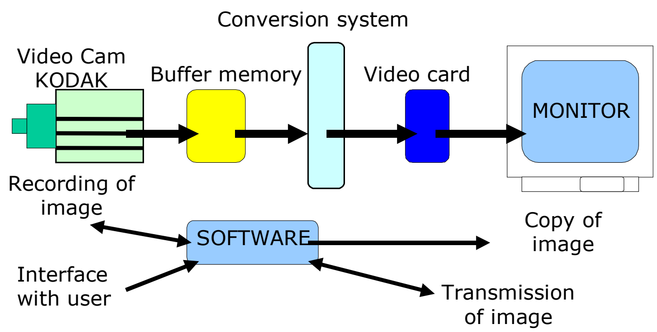
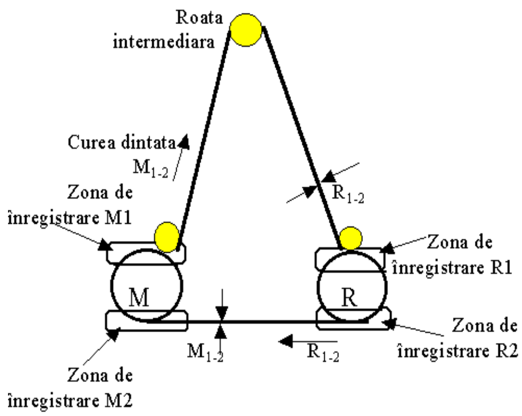


Figure 2

The experimental setup for the dynamic regime recordings is more complex and it is equipped with a high-speed video cam, using an electronic shutter which allow to record an image into an interval of time to 1/5000 from a second and with a maximum speed of 500 frames/sec, a buffer memory for a 2048 images and a transfer system on video-recorder on standard speeds or much reduced (1, 2, 5, 10 frames/sec.).



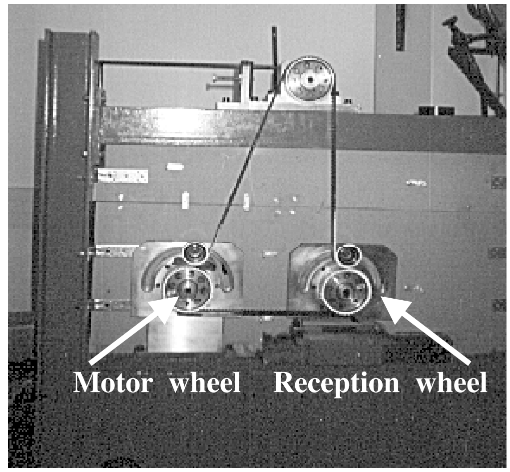


Figure 3

The selection of the recorded images it was realizing in function of the determination type, these ones being processed by the image - processing model to obtain the specifics attributes.

For these analyzes of the contact between the belt tooth and the wheel tooth we were introducing the variations of the follow functional parameters: pre-tension initial into the belt, with the values: **50, 150, 300 N**; initial couple, with the values: **0, 4, 8, 10 Nm**; functional speed, with the values: **4, 10, 14 rot/s.**

RESULTS AND CONCLUSIONS

In the next images it is showing some frames recorded with high-speed video cam MOTIONSCOPE 250/500, selected from buffer memory and processed by specialized soft to obtain the contour and the contact edges between the tooth of the wheel and of the belt.

From these processed images we can study the contact, in the moving direction, from the surface on the teeth of the belt the contact, which is different in dimension, volume and place of manifestation, due the gearing conditions.

The gearing conditions were the same (pre-tension initial, initial couple, rotation speed of the motor wheel).

The formation of the space between the wheel tooth and the belt tooth it was visualizing and determining that it was generating starting from the third tooth being in the gearing state. This space grow once with the proportional modification of the functional parameters (initial couple, rotation and initial pre-tension) and also it can to modify itself the initial place of generation from the successive contacts between the wheels and the belt.

To examine the correlation between the noise level and the shape and size of deformation it was necessary to record and to process the noise in the gearing zone, in the same initial conditions. From these processed values of the noise level it can observe a phenomena's, which appears at the very high-speed values and a big difference between the minimum and maximum values of the noise, in the same recording.

From the noise level study in correlation with the size of deformations it was establish these phenomena's that perform a non-uniform friction and use of the belt.

So at the different function regime, after a not big number of hours appear a type of noise and a tooth jump, which make the belt to advance with a tooth, without that this tooth being in the contact with the wheel.

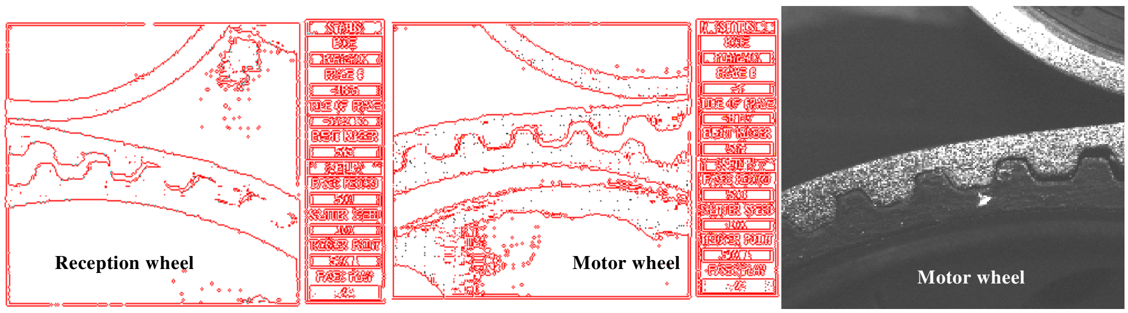


Figure 4

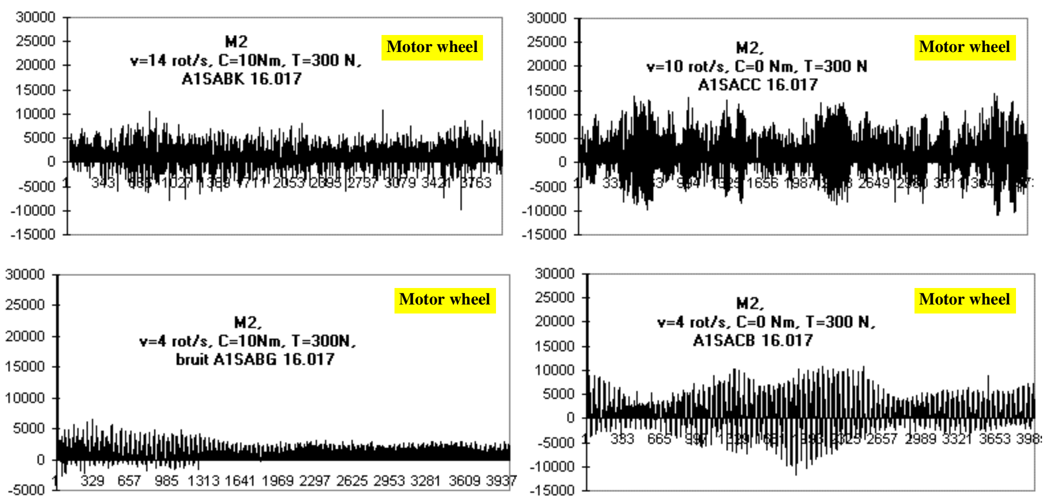


Figure 5

Analyzed and processed all the information's of the noise level which were acting in the contact zone of the wheel tooth with the belt tooth and make the correlation between the size of deformations with them, in same field and in the same conditions, it can extract the follow conclusions: *the noise level* is direct proportional with the rotation sped of the motor wheel, couple, and initial pre-tension of the belt; for the receiving wheel the deformation (the air cavity between the belt and wheel) grows, respectively diminishes once with the growing, respectively diminishing of the initial couple, in concordance with the growing of the noise level (the other parameters remain constant); in the case of receiving wheel the contact zone *it is moving* from the left side to the right side of the same tooth of the belt and the air cavity it is bigger when the initial tension in the belt it is diminishing to the minimum limits; in the case of motor wheel the phenomena's are different in manifestation mode at the same parameters (the air cavity it is forming on four teeth before the out of gear), for that it can observe evident a noise level much reduce at the motor wheel compare with the noise level at the receiving wheel; in the case of reducing of the initial tension at the minimum values, it is showing a cyclic phenomena's of noise jump, uninformed, which determines the shocks in belt material structure, respectively wheel; in the situation in which it was using the medium parameters it can observe an uniform noise level on the function duration, but a growing of the air cavity between the belt and the wheel, respectively of the belt deformation, being necessary to place an intermediate wheel, closer with the wheel-belt contact zone.

The results of this behavior analyze of the deformations and noise level, by image processing and data treatment for the HTD belt confirm and they are in concordance with the numerical simulations presented in [4], but bringing a new aspects and information's about the local behavior of the contact zone between belt tooth and wheel tooth in static and dynamic regime.

ACKNOWLEDGMENTS

Researches are part of inter-laboratories cooperation between INSA Lyon France – University TRANSILVANIA Brasov and also of Grants A1058 with CNCSIS Romania 2008.

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