11th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2007, Hammamet, Tunisia, 05-09 September, 2007.

THE INFLUENCE OF THE NUMBER OF TEETH INGRAINED BETWEEN THE BELT AND PULLEY ON THE TEETH LOAD OF TRANSMITTERS WITH JAGGED BELTS

Dr.sc.Azem Kyçyku
Dr.sc.Nijazi Ibrahimi
Dr.sc.Heset Cakolli
Dr.sc. Avdi Salihu
University of Pristina, Mechanical Engineering Faculty
Prishtina
Kosova

ABSTRACT
During the work of transmitter with jagged belt, where the belt is ingrained with the pulleys, the power transmits from the driving pulley to driven pulley through two kinds of forces (the force between the ingrained teeth in pulling layer of belt and the force the acts aside the ingrained teeth). This paper discusses the dispersion of the load during ingraining of the belt with the pulley, depending on the number of ingrained teeth.
Keywords: Force, trapezoid belts, ingrained teeth.

1. ITNRODUCTION
Transmitters with jagged belts are greatly applied in all branches of the industry, such as: motor vehicles, in precise mechanics and information technology. The main advantage of these transmitters, respectively belts, is the constant ratio of transmission. The way power is transmitted in these transmitters differs distinctly from transmitters with trapezoid belts. This paper presents a dynamic analysis of ingrained zone, because that is where the transmission of power is transmitted through pulling layer and ingrained teeth.

2. LOAD DISTRIBUTION IN INGRAINED TEETH
In general, belt carries the power through pulling layer, whereas in ingrained zone power is carried in a combined form - through pulling layer and teeth. It is of great practical importance to define the mathematical model of power distribution that acts on the pulling branch in ingrained teeth and in the pulling layer between them. A simple transmitter is taken as a sample to analyze this problem, presented in Fig. 2.1.

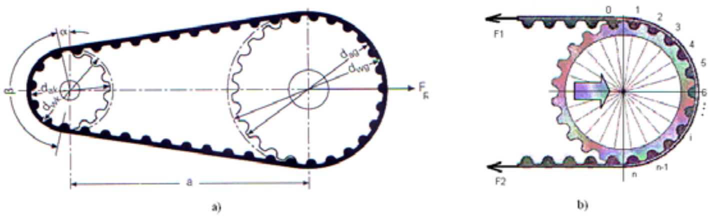

Figure 2.1. Simple transmitter with jagged belt

To analyze the distribution of force F_1, which acts in pulling branch among ingrained teeth and on the ingrained teeth, from the transmitter presented in fig 2.1 a), is analyzed the driving pulley and the belt with indicated teeth, as depicted in Fig. 2.1 b).

The first tooth in full ingraining is noted with 1, and the last one with n. To make a detailed dynamic analysis of forces that act on where the belt is ingrained with the pulley, serves Fig. 2.2.

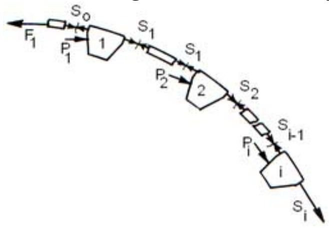

Figure 2.2 Distribution of forces in the ingrained part.

On the first tooth in full ingraining acts the force P_1, on the second P_2, between them S_1 and so on to the last tooth. Of a practical importance is to find the mathematical model that determines the dependence between force S_i and F_1, respectively between P_1 and F_1.

3. DYNAMIC ANALYSIS OF FORCES IN THE INGRAINED PART OF THE BELT

If k_0 represents the non-dimensional constant of the belt stiffness, then the differential equation of forces on one segment of belt in the ingrained part will be:

$$\frac{d^2 S_i}{di^2} = k_0 \cdot S_i, ...0 \le i \le n \qquad ...(1)$$

After the limitation conditions: $S_0=F_1$ and $S_n=F_2$, we get a unique solution of equation 1:

$$\frac{S_i}{F_1} = \frac{\sin\left[h \cdot \sqrt{k_0} \cdot (n-i)\right] + \frac{F_2}{F_1} \cdot \sin\left(h \cdot \sqrt{k_0} \cdot i\right)}{\sin\left(h \cdot \sqrt{k_0} \cdot n\right)} \qquad ...(2)$$

$$1 \le i \le n$$

Where:

- k_0 [-] - non-dimensional constant of belt stiffness represents the quotient between the constant of tooth stiffness and constant of stiffness of the pulling layer of the belt.
- h [mm] - the distance from acting-point of force P_i to neutral axis of pulling layer threads.
- N [-] - number on belt teeth in ingraining.
- i [-] - number on analyzed tooth.
- F_1[N] - the force on belt pulling area.
- F_2[N] - the force on belt free area.
- P_1[N] - the force on the first full ingrained tooth.
- S_i [N] - the force on belt pulling layer between ingrained teeth.
- $S_{ib}(i)$ [N] - the force on the belt pulling layer among ingrained teeth when the friction is considered.
- λ_1, λ_2 – the friction factors which depend on friction coefficient between the belt and the pulley, the k_0 constant and the ingraining angle.

Expression 2, can calculate the force ratio of the pulling layer S_i in any part of ingraining area against the force in pulling branch. Based on this expression, for the profile HTD-3M and data: F_1=400; F_2=100; ko=0,005; k_{o1}=0.01; k_{o2}=0.02; h=0.6; we get the results presented in figure 3.1

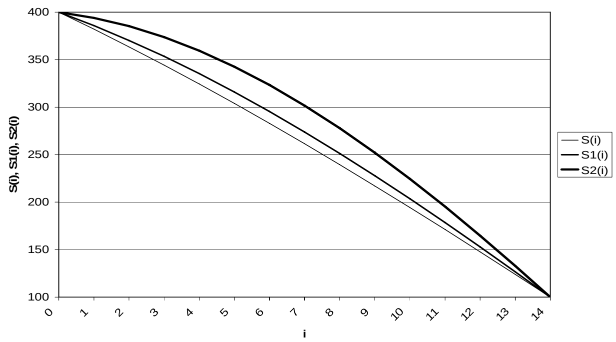

Figure 3.1. The force between ingrained teeth in pulling layer

Based on expression 3, for F_1=5250; F_1=750; λ_1=1.097; λ_2=0.948; μ=0.20; we got results are presented in figure 3.2.

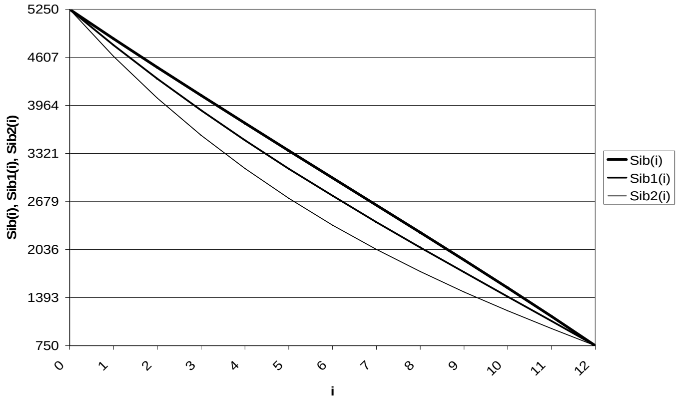

Figure 3.2. The force between teeth in pulling layer when the friction is considered

Another important segment of dynamic analysis for the ingrained area of belt is finding the mathematical expression for the variance of the load on the first tooth in full ingraining, depending on partaking number of teeth in ingraining and other parameters of dynamic condition. If the angle between two adjoining forces S_{i-1} and S_i is not considered, then the equilibrium condition of tooth i is:

$$P_i = S_{i-1} - S_i \ldots\ldots\ldots\ldots 1 \le i \le n \qquad \ldots(4)$$

The first tooth which is in full ingraining handles the bigger load and this is calculated by the expressionion:

$$\frac{P_1}{F_1} = 1 - \frac{\sin\left[h \cdot \sqrt{k_0} \cdot (n-1)\right] + \frac{F_2}{F_1} \cdot \sin\left(h \cdot \sqrt{k_0}\right)}{\sin\left(h \cdot \sqrt{k_0} \cdot n\right)} \qquad \ldots(5)$$

It is hard to clearly see the influence of the number of teeth in ingraining from the force value that acts on the side of first tooth in full ingraining. This influence is more clearly depicted in figure 3.3.

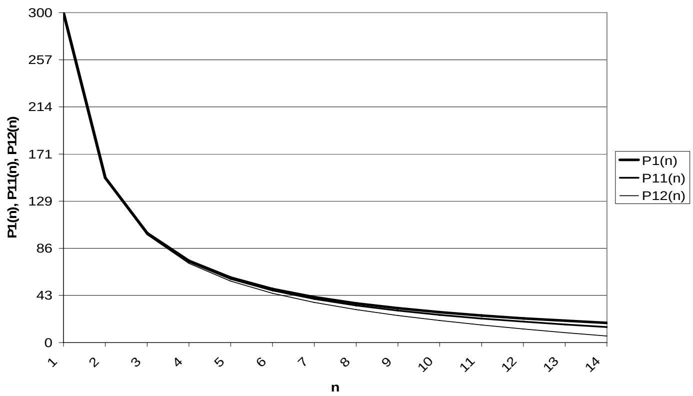

Figure 3.3. The influence of number of teeth in mesh on the first tooth load

4. DEMARCATION OF FORCE IN PULLING LAYER EXPERIMENTALLY

The force on the pulling layer of belt experimentally is assigned in respective device which measures the belt deformation optically and through the installed on the computer which is linked to the device and it gives the force variance graph. Measures are done for all segments of the belt. By the standard, the length of a belt segment must be equal to the pitch between teeth. Figure 4.1 depicts the diagram of the variance of force on the pulling layer between teeth.

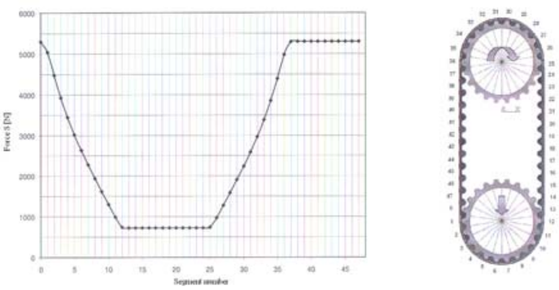

Figure 4.1. The force on belt pulling layer

According to the diagram depicted in figure 3.4., it can be said that the force on the pulling layer of belt of pulling branch S is equal to force F_1. In the ingrained area of driving pulley the force S decreases and in the last segment has the value of force in the idle branch F_2. In the idle branch, the force S equalizes with force F_2. In the first segment of ingrained zone with driven pulley, the force S begins to increase and in the last segment of this zone it equalizes with the force F_1.
If we compare the MathCAD results with the ones deduced from lab work, a satisfying match between them can be concluded.

5. EXPERIMENTAL DEMARCATION OF LAOD DISTRIBUTION ON TEETH SIDES

Distribution force that acts on pulling branch of belt across the ingrained teeth is researched for the both pulleys of transmitter. The researched machine's transmitter has a transmission ratio u=1. During the experiment the deformation of teeth in tangential direction is measured, whereas the software installed on the computer of the machine researched gives the values of corresponding forces in ingrained teeth. In figure 5.1 depicts the ingrained teeth distribution load of gearing teeth for the diving pulley.

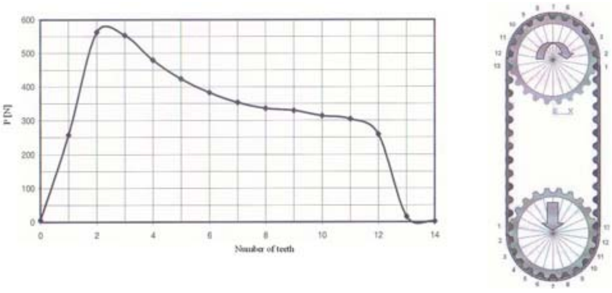

Figure 5.1 Load of ingrained teeth for the driving pulley.

It can be seen by the diagram that maximal load acts on tooth 2, respectively in the first full gearing tooth. This conclusion proves the gained results through MathCAD software.

6. CONCLUSION

Based on the results presented in this paper, by MathCAD software from lab work, we can conclude that:

- at the transmitters with jagged belts, the transmitting of force is done in a combined way through the pulling layer and ingrained teeth
- The force between ingrained teeth into pulling layer decreases as the number of teeth increases,
- The increase of the number of ingrained teeth significantly decreases the load on the first fully ingrained tooth.

7. REFERENCES

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