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STRESSES IN SKATE/CHAIN CONTACTS v2

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***Abstract*—**The chain drives are used in agricultural machines, one person transport vehicles and the distributions mechanisms of the cars. Due to the wear, tensions systems are used; in the case of fast transmissions are used skate tensioning systems. The paper presents the analysis of the mechanical phenomena in the contact area between the chain and the skate; first is presented the contact calculus and then, is presented the FEM analysis by using *ANSYS* in order to identify all the mechanical variables. There are presented the main design parameters and their influence on the stresses in the contact area.

Keywords*—ANSYS*, chain transmission, contact stress, finite element modelling, skate.

I. INTRODUCTION

THE skate tensioning systems are used for chain drive transmissions which are functioning with abundant lubrication [1]. The lubrication is needed in order to decrease the friction between the chain and the sprockets and between the chain and the tensioning system. High contact pressures in the contact area between the chain and the tensioning element produce the expulsion of the lubricant from the contact zone and the consequence is a high friction.

The main solutions which are used as tensioning systems are the systems with clogs and the systems with skates.

Fig. 1 presents a tensioning solution for a chain drive which uses a skate as tensioning system.

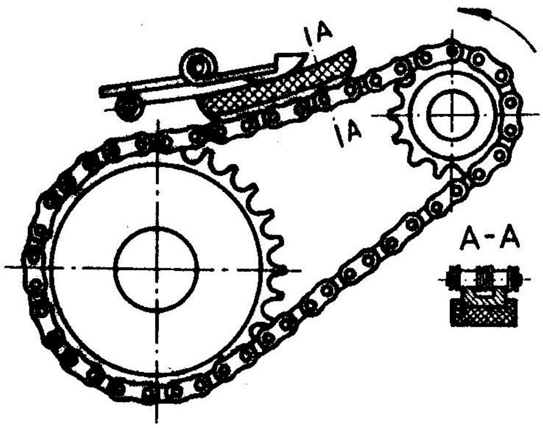

Fig. 1. Tensioning system with skate [2]

Fig. 2 shows a solution where a clog is used to tension the chain drive.

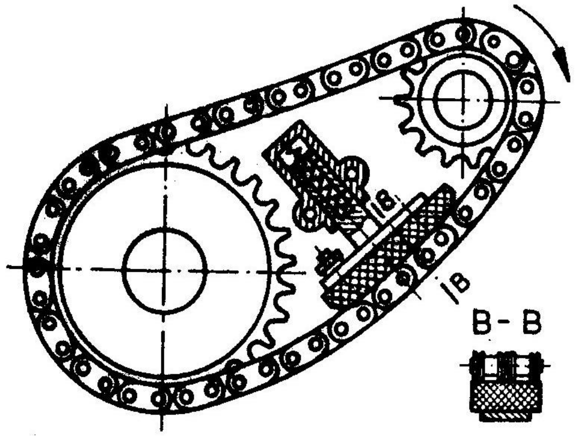

Fig. 2. Tensioning system with skate [2]

In the first part, the paper presents the analytical modelling of the contact calculus in order to find out the values of the contact stresses. The modelling is achieved by considering sets of values for the constructive parameters (the dimensions of the link and of the skate) and for the tensioning forces which assure small variations of the contact stresses.

The second part of the paper presents the finite element modelling by using *ANSYS 14.0*; the aim of the modelling is to validate the contact stresses values obtained from the analytical modelling and to identify the other supplementary from the contact area: the physical phenomena, the sliding stress, the mechanical penetration of the materials.

II. THE ANALYTICAL MODELLING

The contact model of the skate/bush chain is presented in the Fig. 3; F represents the tensioning force, R_1 is the radius of the skate and R_2 is the radius of the chain link.

In the case of automotives, the tensioning force which is acting on one side of a link is between $F \in [5, 13]$ (N), the radius of the skate $R_1 \in [120, 250]$ (mm) and the radius of the link $R_2 \in [7, 18]$ (mm) [2]; all the numerical calculus are achieved by varying the radius R_1 and the radius R_2 in the mentioned intervals in order to obtain a small variation of the contact stress.

According to the contact model and to the contact theory [3, 4, 5] the contact zone has a rectangular shape with the length equal with the width of the link and the width equal with *b*.

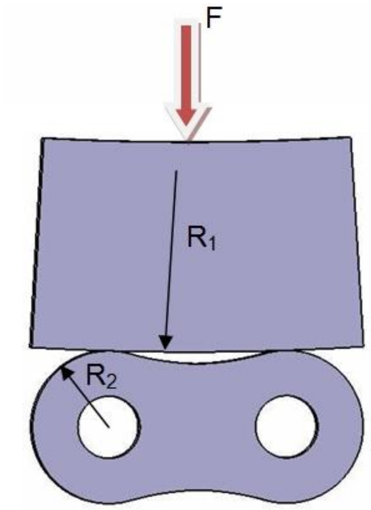

Fig. 3. The skate/chain contact model

The reduced curvature, according to Fig. 3, is

$$\frac{1}{\rho}=\frac{1}{R_1}+\frac{1}{R_2}\,. \tag{1}$$

The variation of the reduced curvature, by considering the radius of the skate $R_1 \in [120, 250]$ (mm) and the radius of the link $R_2 \in [7, 18]$ (mm) [2], is presented in the Fig. 4.

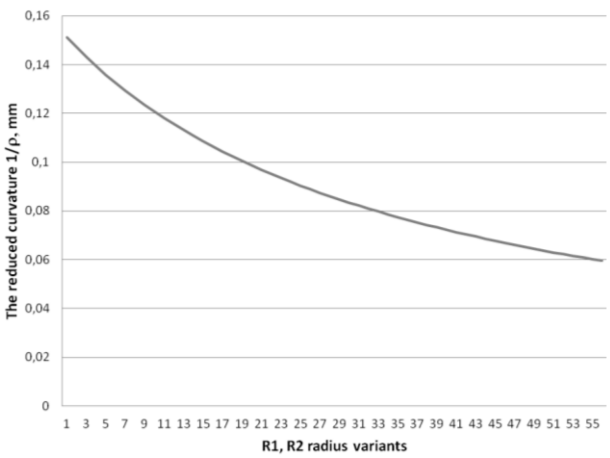

Fig. 4. The variation of the radiuses

The half width of the contact area, is defined as [5]

$$b=\sqrt{\frac{8\rho F}{\pi l E}}\,, \tag{2}$$

where, *l* represents the width of the link and according to [5], *E* is

$$\frac{2}{E}=\frac{1-\nu_1^2}{E_1}+\frac{1-\nu_2^2}{E_2}\,, \tag{3}$$

where E_1, E_2 represent the *Young*'s modulus for the skate and the link and ν_1, ν_2 represent the *Poisson*'s coefficient of the two materials (for steel – the link, $E_1=2\cdot 10^5$ (MPa), $\nu_1=0.266$; for plastic – the skate, $E_2=2.2\cdot 10^3$ (MPa), $\nu_2=0.38$ [5]).

According to the numerical values, Fig. 5 shows the variation of the half width.

The maximum contact stress is established with [5] and its variation is presented in the Fig. 6.

$$p_0=\frac{2F}{\pi b l}\,. \tag{4}$$

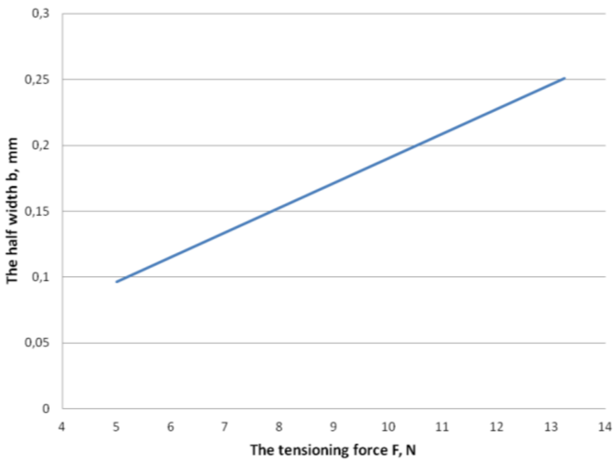

Fig. 5. The variation of the half width

The distribution of the contact stress is established with

$$p=p_0\sqrt{1-\frac{x^2}{b^2}}\,. \tag{5}$$

where *x* is the dimension $x \in [-b, b]$.

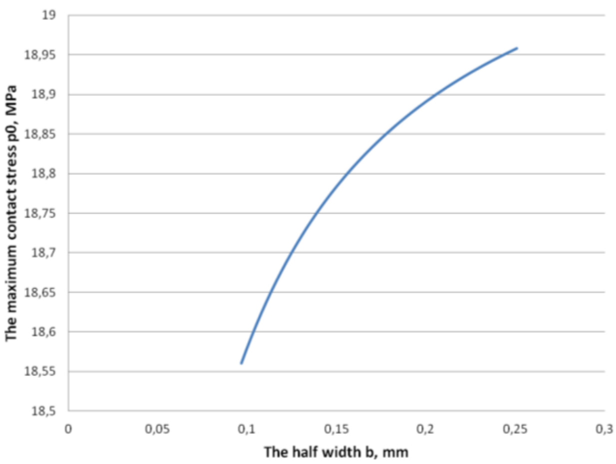

Fig. 6. The variation of the maximum contact stress

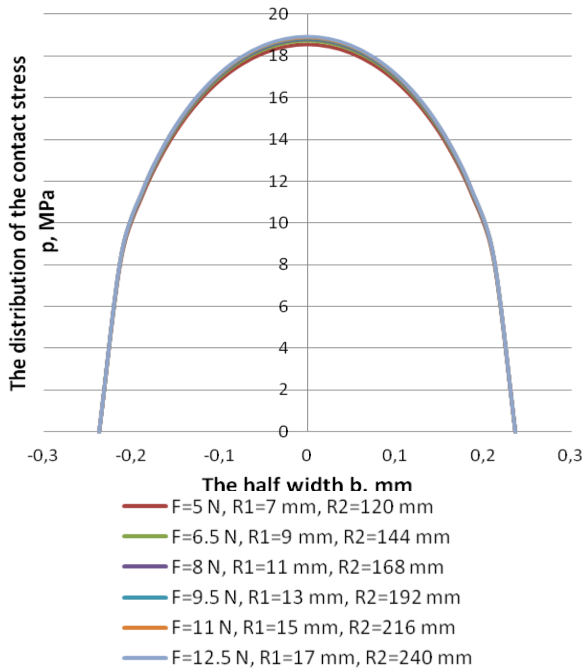

Fig. 7. The variation of the contact stress

The variation of the contact stress with the contact width, for different pairs of contact radiuses, which are corresponding to the tensioning forces, is presented in Fig. 7; as it was mentioned at the beginning, the variation of the radius R_1 and the radius R_2 in the mentioned intervals assures a small variation of the contact stress.

III. THE FINITE ELEMENT MODELLING

The finite element modelling is achieved by the case of a 200 mm radius for the skate and the corresponding dimension for the link (see the previous point) with the pitch of 12.7 (mm); the acting load has the value of 12.5 (N).

The geometrical model (see Fig. 3) is made by *CATIA V5R20* software and is imported in *ANSYS 14.0* by considering the materials properties for the link and the skate, as they were used at the point before.

In the finite element model, to achieve the convergence, there are used 102927 hexahedral type finite elements with 454619 nodes. As modelling parameters, for the finite elements, is used a proximity accuracy of 0.5 mm, a maximum size of 0.2 mm and a number of 10 cells across the gap [6].

The boundary conditions are represented by the contact type finite element between the skate and the link and the clamped inner surfaces of the link.

After the solving process, the physical phenomenon is analyzed; as it is presented in Fig. 8, a sliding phenomenon is present, between the skate and the link, on the border regions of the contact area. The analysis is a static one but, due to the deformation of the skate, and due to the position of the resultant force which is acting on the skate, the skate has a bending and it slides on the link.

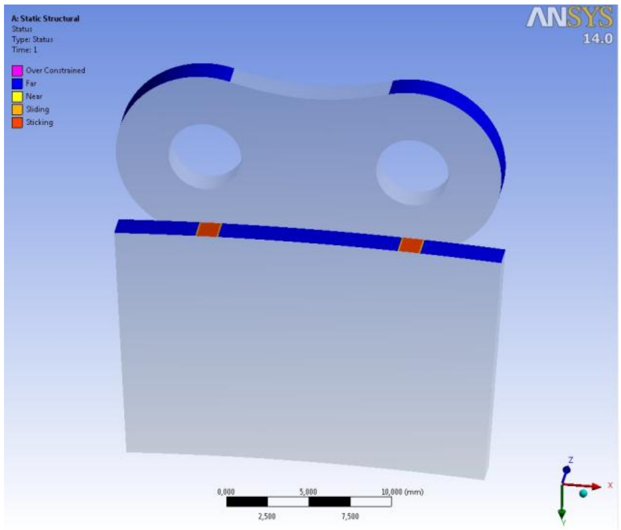

Fig. 8. The physical phenomenon in the contact area

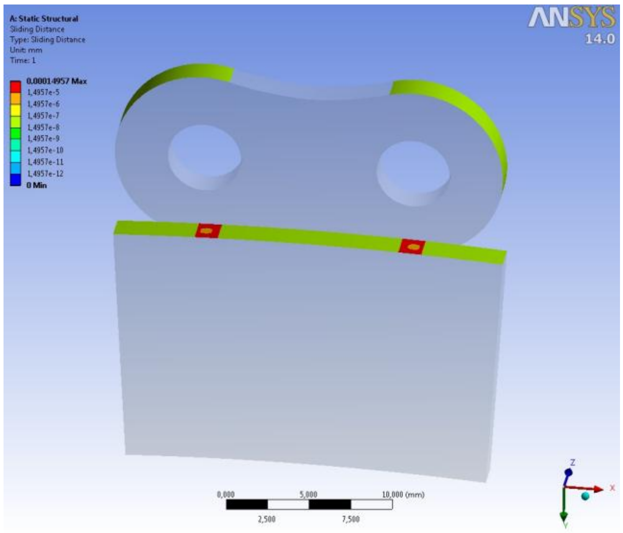

Fig. 9. The sliding distance

The sliding phenomenon's consequence is the sliding distance presented in Fig. 9.

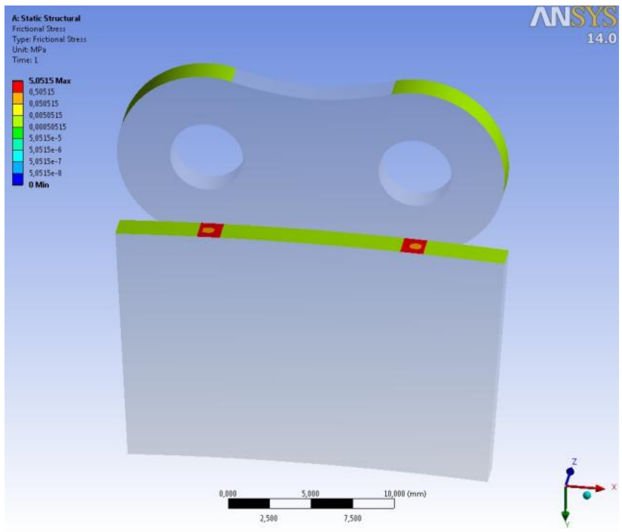

Fig. 10. The friction stress

The maximum value of the sliding distances are in the border area of the contact zone and the value of it is small – 0.00014957 (mm) – so, practically the sliding is almost zero. This is possible due to the friction between the link (made by steel) and the skate (made by plastic); the friction produces a friction stress and its maximum value is 5.05 (MPa). This maximum value is placed at the border region of the contact area (Fig. 10), the area which "intends" to slide.

The distribution of the von Mises stresses is presented in Fig.11; the maximum value of it is in the contact area and is equal with 17.71 MPa. The difference between the analytical modelling and the finite element modelling (by considering the maximum value of the contact stress – analytical is 18.87 (MPa) and the finite element model is 17.71 (MPa)) represents a deviation of 6.14% which validates the results.

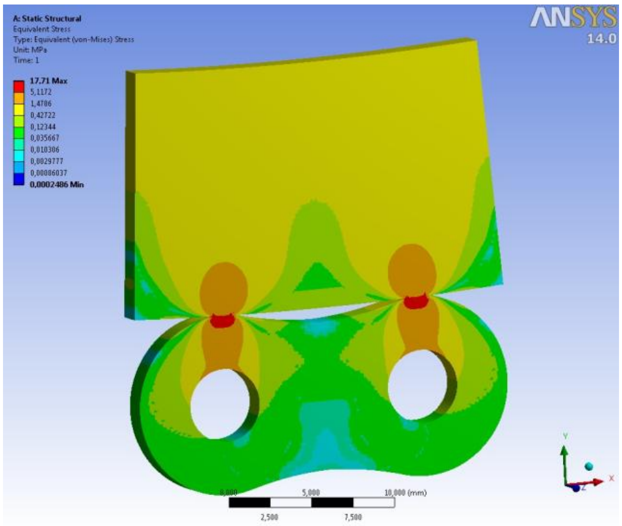

Fig. 11. The von Mises stress

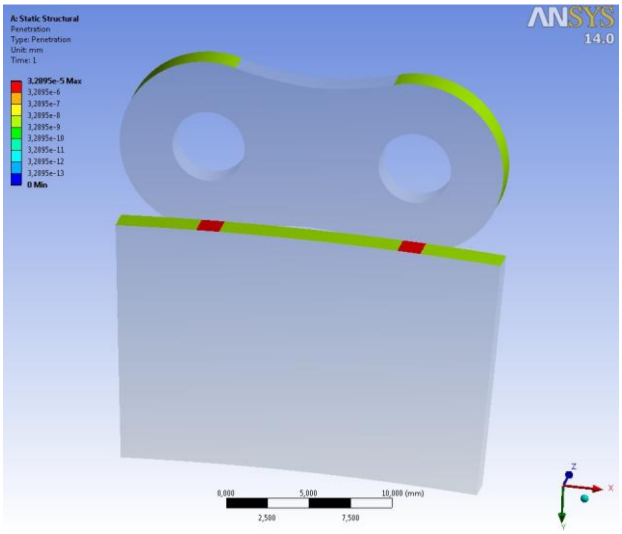

Fig. 12. The penetration of the link in the skate

The contact stress produces a penetration of the harder material (the steel) in the lighter material and its maximum value is equal with 0.000032895 (mm) and is situated in the region where the contact stress is maximum – Fig.12.

IV. Conclusion

In order to reduce the wear, the contact zone between the skate and the link is lubricated.

The contact calculus of the skate/link assembly is important in order to find out the pressures which are produced in the contact area. The value of these pressures can be compared with the allowable pressure of the lubricant from the contact zone.

The paper presents the modelling of the chain/skate mechanical contact. The modelling (the analytical and the finite element) is achieved for the bush chains and is reliable to be applied also for other type of chains.

The chosen sets of the constructive parameters (the dimensions of the link and of the skate) and for the tensioning forces assure small variations of the contact stresses.

The finite element modelling by using *ANSYS 14.0* validates (due to the difference of 6.14% between the analytical and the finite element modelling) the results of the analytical calculus. Also, due to the finite element modelling, a sliding phenomenon (with a very small maximum value – 0.00014957 (mm)) is identified in the contact area.

By using the analytical methods for the contact calculus, this sliding phenomenon and all its consequences (the sliding distance, the friction stress) cannot be identified; so, in order to identify the entire physical phenomenon and to obtain all the values of the physical parameters, the finite element modelling is required.

Acknowledgment

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