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MODELING THE PRESSURE DISTRIBUTION IN THE CONTACT BETWEEN GUIDE AND CHAIN

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Abstract: *This paper has as purpose the study of tensions and contact pressures between the stretching guide and geared links of a transmission chain used in internal combustion engines. In the first step there will be presented some notions regarding the chain transmisson. The first step highlights a geometrical model regarding the stretching guide and defining the contacts between geared links of a transmission chain, then being analyzed through finite elements method. At the end of the chapter there will be presented the conclusions regarding the geometrical modeling of the guide - chain contact.*

Key words: *Transmission, chain, guide.*

1. Introduction

The chain transmissions are a part of indirect mechanical transmissions and serve to convey the motion and the torque moment between two or more pparallel shafts. The chain transmissions are placed so that the chain will function in vertical plane, regardless the relative position of the wheels. The optimum positionins is the horizontal one or the one inclined at 45 degrees [1].

The vertical positioned transmissions need a thourough and mandatory chain tensioning, because the developed arrow tends to take out the links from the geared connection with the inferior toothed chain sprockets [2].

The simplest solution is adjusting the tensioning by moving one of the chain sprockets. When the adjustment is done with geared or smooth sprockets, these are usually mounted on the geared branch closer to the bigger wheel. Positioning the sprockets close to the smaller wheel is recommended only when their mounting is possible outside the transmission, fact that leads to increasing the wrapping angle on the smaller wheel. In the case of fast transmissions and of low power, which function with an abundant lubrication, there are used tensioning guides or wheels [3].

Basically, a chain transmission is made acording with Figure 1:
- 1 the chain;
- 2 tensioning guide;
- 3 leaf spring;
- 4 output chain sprocket;
- 5 guide fixed;
- 6 input chain sprocket

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As it can be seen in Figure 1, the chain is made from articulated plates, which ensure its flexibility needed for wrapping around the wheels. The essential difference between the transmission chains (chains with bushings, pins, rollers) and the ones with toothed plates is that the last can take over and forward the force based on direct contact between the wheels teeth and the chain plates. This constructive - functional principle ensures a better dynamic than the case of chains with cylindrical contact elements. Because of this, the chains with toothed plates are also named silent chains.

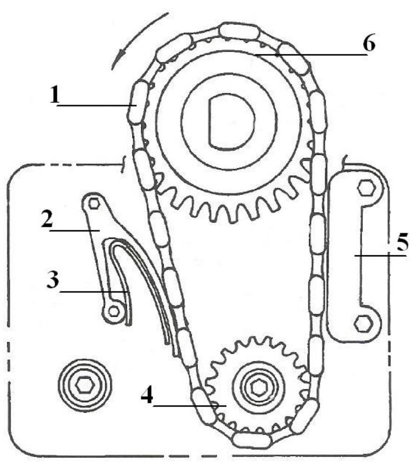

Fig. 1. *The chain wrapped on the wheels[4]*

2. Finite Element Modelling

Finite element method is a numerical method used in solving partial derivatives equations which model the systems with an infinite number of freedom degrees. After applying this method, the equations are reduced to systems of algebrical equations, meaning a discrete system with a finite number of freedom degrees [5].

To achieve a higher efficiency in FEA (finite element analysis) there is used a general and simpler structure concept than usual . Usually in FEA through structure (resistance) it is understood an assembly of bars, plates, layers and volumes (solids) [6].

The finite element method has applicability in various engineering domains where there are physical phenomena described by partial derivatives equations. Amongst the main domains where this method is used there are: structural analysis, fluids analysis, magnetical analysis and electrical analysis In order to perform a FEA analysis on a structure, the first step is *to* develop the calculus model of that structure. The FEA models are approximative mathematical models of the structure that will be analyzed. In order to pass from the real structure to the calculus model there are no algorithms and general methods which ensure the development of an unic model, that can approximate with a predefined known error this structure. In general it is possible to develop several models for one structure, all of them correct but with different performances. The structure resistance model is made based on intuition and previous experience of the person that performs the modeling. The model has to efficiently synthesize all the available information regarding the analyzed structure [7].

Generally, FEA defines all the unknows (displacements or efforts) in the model`s points and computes their correponding values. In these conditions, ensues that meshing has to be made so that it will define a large enough number of points in the areas of interest, in order that the approximation of the structure`s geometry, the support and load conditions is satisfying to FEA purpose [8].

As it was mentiond at the begining of this paper, it will be designed a geometrical model of the tensioning guide which will later be assembled on a transmission chain, following to be analyzed through finite element method. The software used for designing was Catia.

In the Figure 2 is presented the guide model, highlighting the areas of interest.

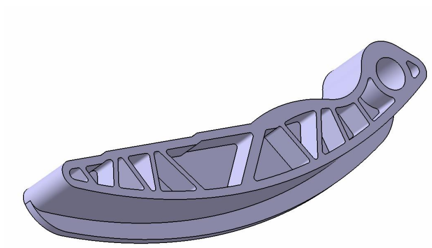

Fig. 2. *Guide*

Figure 3 shows the guide chain assembly, highlighting in detail the elements which will be studied in this chapter.

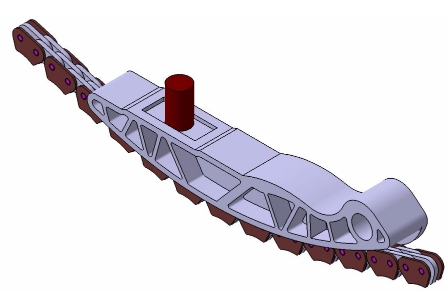

Fig. 3. *Guide chain assembly*

The numerical evaluation will be made on this concept of guide mounted on a toothed chain. It will be followed the deformation status determination and the distribution of tensions between the interest components in contact, respectively the plates and tensioning guide. Therefore, after these static analyzes which assume identifying the displacements fields and tensions, it is observed the pressures variation in the areas found in contact.

The concept was the meshing with finite elements the hexahedron and/or second order tetrahedron deformable solids with integration node, and for the rigid defined components the software used in meshing special rigid elements. Defining some components as being infinite rigid has the advantage of reducing the number of finite elements by their idealization through the use of special rigid elements, 2D, and the software does not compute the values for their deformations and tensions. Using this simulation methods, which do not significantly change the results values, helps reducing the overall computation time necessary to solve the equations resulted from the modeling with finite elements.

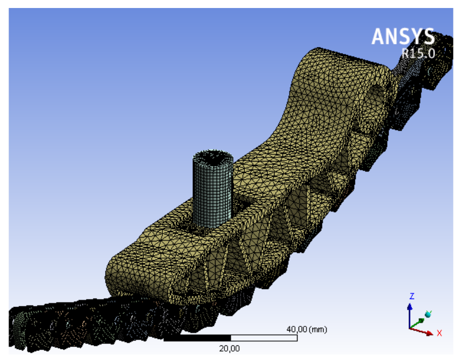

Fig. 4. *Finite elements model*

In figure 4 there are presented the active components of the concepts, respectively the toothed plates of the chain, the guide and tensioning element (cylinder)

As it was mentioned before, to each element of the guide - chain assembly was assigned certain materials (for the guide it was used polyamide PAx, and for the plates it was used steel). For the basic components on which this study is based, there were assigned materials used in series manufacturing. As main interest are the materials used for tensioning guide and chain plates because of the friction coefficient studied between these components.

Next, there will be presented the results obtained through finite element method.

3. The Study of Tensions, Displacements and Contact Pressures

This concept briefly shown in Figure 3, was imported in the analysis software Ansys Workbench R15.

It must be mentionned that for this case it will be apply two forces. Also it must be mentionned that the material used for construction of the tooth links is the steel with the following propreties [9], [10]:

- E = 230000 MPa;
- з = 0.3;
- TYS ů02 = 248 MPa;

Concerning the guide, the material used was polyamide PAx with the following properties:

- E = 3200 MPa;
- з = 0.42;
- TYS ů02 = 37.2 MPa;

For the first case the force F_1 is 900 N.

The model`s load pattern and imposed limit conditions are shown in Figure 5, where the force F was applied normally to the element`s surface, the chain was fixed at both ends after all freedom degrees, and for the guide there were restricted five freedom degrees, allowing translation. Because the force transmission from the applying point to the chain is made only thought the contacts between components, in Figure 5 there are also shown the contact zones defined in Ansys.

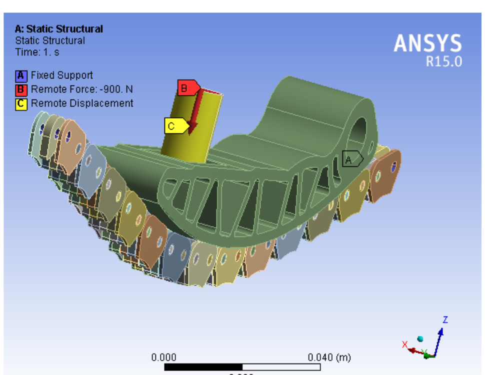

Fig. 5. *The model`s load*

On the components found in contact it was performed a finer meshing, with more layers of finite elements and nodes, in order to have a better de convergence of the results and contacts in that area, meaning between the contact surface between the guide and plates of the geared chain. After meshing there were obtained 293648 finite elements and 981036 nodes. The input data of this concept are presented as follows:

- the guide radius R = 160 mm;
- the guide material PAx,
- F = 900 N;
- Friction coefficient ε=0.2.

By applying the normal force of 900 N, it was obtained an uniform theoretical distribution of deformations, with the maximum value of 0,3266 mm in the guide pressing area, Figure 6.

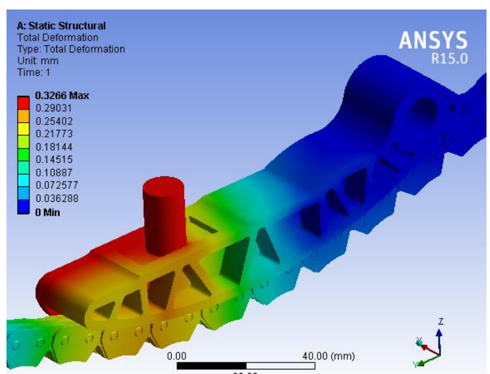

Fig. 6. *The displacement distribution*

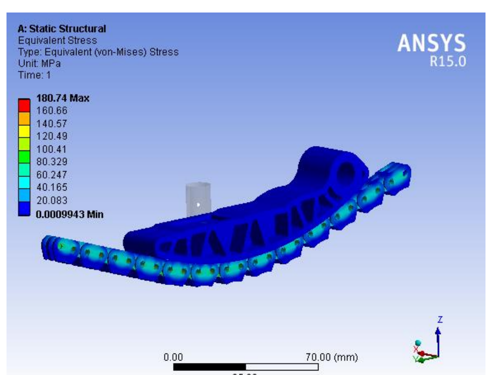

Fig. 7. *The tensions distribution*

In Figure 7 it is shown the von Mises equivalent tensions distribution for the considered model. It is observed that these tensions are distributed in the articulated areas of the chain. Also, the maximum tension in this case is placed in the contact area between the bolt and toothed plate.

The contact pressure distribution between guide and chain plates is presented in Figure 8. It is observed that the maximum pressure (20.769 MPa) is found in the action area of the normal force applied on the guide.

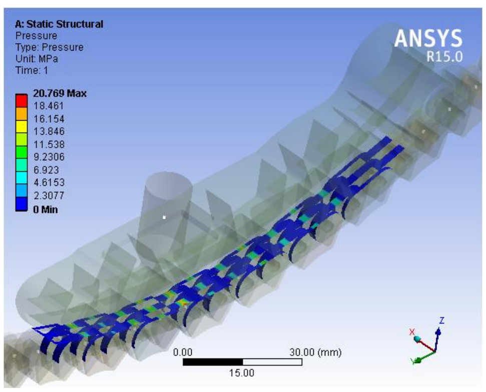

Fig. 8. *Contact pressure distribution*

For the seconde case the force F_2 is 1350 N.

The limit conditions imposed on the modelôs load patern are presented in the Figure 9.

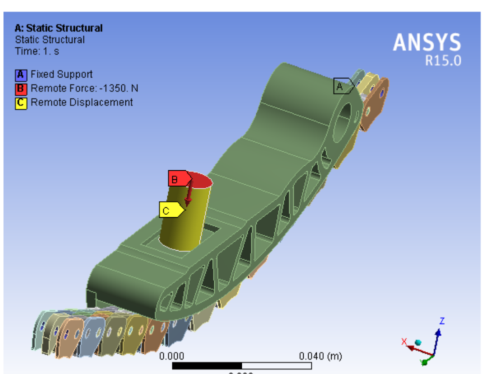

Fig. 9. *The model's load pattern*

After it was applied the normal force of 1350 N it was obtained an uniform theoretical distribution of deformations, with the maximum value of 0,46982 mm in the guide pressing area, Figure 10.

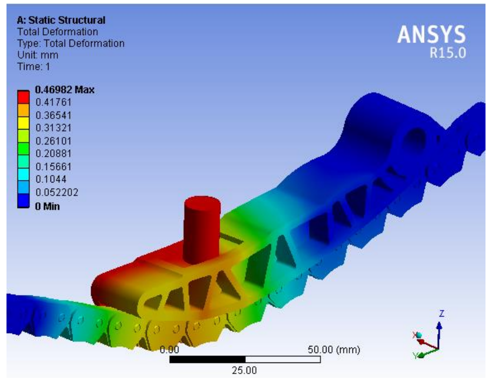

Fig. 10. *The displacement distribution*

The von Mises equivalent tensions distribution for the considered model is presented below, Figure 11.

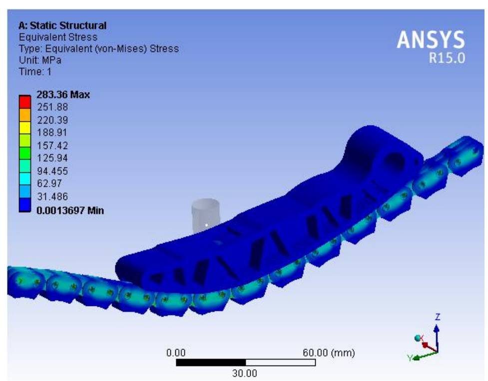

Fig. 11. *The tension distribution*

In the Figure 12 is presented the contact pressure distribution between guide and chain plates.

For a contact with low pressures betwen the guide and the chain it is necessary to maximize the number of the links that are in contact with the guide.

The links number depends of the assembling arrow and also of the radius guide.

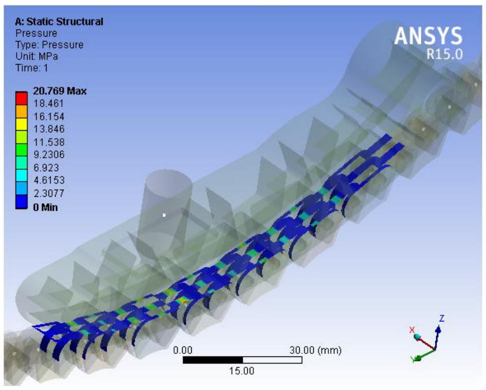

Fig. 12. *Contact pressure distribution*

4. Conclusions

The model elaborated through finite element method and presented in the previous figures allows a deeper analysis on the distribution of von Mises tensions, deformations and contact pressures between chain plates and tensioning guide.

After the analyzes and results interpretation regarding the theoretical displacements distribution it can be concluded that the maximum loads can be found in the area of where the normal force is applied on the pressing guide element.

The von Mises tensions spikes are placed, mainly, in the articulated areas of the toothed chain, also the maximum values are obtained in the end articulated chain areas.

In order to determine the specific pressures there were read their obtained values on each plate found in contact with the tensioning guide.

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