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MULTISCALE MODELING OF CHAIN-GUIDE CONTACT BY USING TESTS AND FEM

MIHAI T. LATES*, RADU G. VELICU* AND RADU PAPUC*

* Department of Product Design, Mechatronics and Environment
Transilvania University of Brasov, Romania
e-mail: latesmt@unitbv.ro, www.unitbv.ro

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Summary. The paper presents the modelling of the contact area between a link of the toothed chain and its guide, by using the multiscale methods.

1 INTRODUCTION

Chains used in cars distribution transmissions are equipped with tensioning guides in order to assure a tensioning force, needed to reduce the vertical oscillation of the chain. The vertical oscillations of the chain are influencing the dynamic behaviour of it (there are introducing shocks and vibrations which can affect the cars transmissions). In time, due to the wear, there are appearing clearances in the chains components and, due to this, higher tensioning forces are needed. Conclusions regarding the increase of the clearances are given in [1] – 1.21 times after 200 h. According to the references, the chain's length can have an increase of 3% due to the wear [2]. Also, due to the friction high temperatures are achieved in the contact areas between the guide and the links which make chain lubricants start to thin and become weak above 70°C [3].

In the case of the chain-guide subsystem, according to the hardness, the guide (made from polyamide type materials) is the weak element; its functioning life time is limited by the wear. In the last years the ttensioning rail and the guide rail are made from low-cost polyamides PA66 and PA46 which are characterized also by high durability [4].

The contact calculus of the chain-guide contact area is necessary to be fulfilled in order to obtain information about the characteristics of the contact area and its maximum contact pressures. The modelling of the chain-guide contact requests some input parameters as the material characteristics (the polyamide type used to design the guide is unknown) and the loading conditions. The contact's properties are identified by using the multiscale method (using information from different sources).

The guide studied in this paper is a component of a Citroen car's distribution transmission and the link is from a toothed chain transmission. The material characteristics – the Young's modulus, the hardness and the friction coefficients are determined by using the information from the tests (indentation and tribological tests, respectively).

The contact pressures are obtained by modelling with the finite element method (with

Ansys 14.0), according to the loading forces values.

2 THE INDENTATION TESTS

The indentation tests are achieved on an indentation module of a tribometer (Figure 1). This module is used generally to perform scratch, indentation and Vickers and Rockwell hardness tests. The device is equipped with a capacitor sensor (Figure 2) and can fulfil tests with a maximum indentation force of 1000 N.

In the case of the guide's material (polyamide - PA) is achieved a Vickers indentation test which offer the values of the Young's modulus and of the Vickers hardness. The Vickers indenter (with an angle of 136^{o} for the diamond's peak on the top) is presented also in the Figure 2.

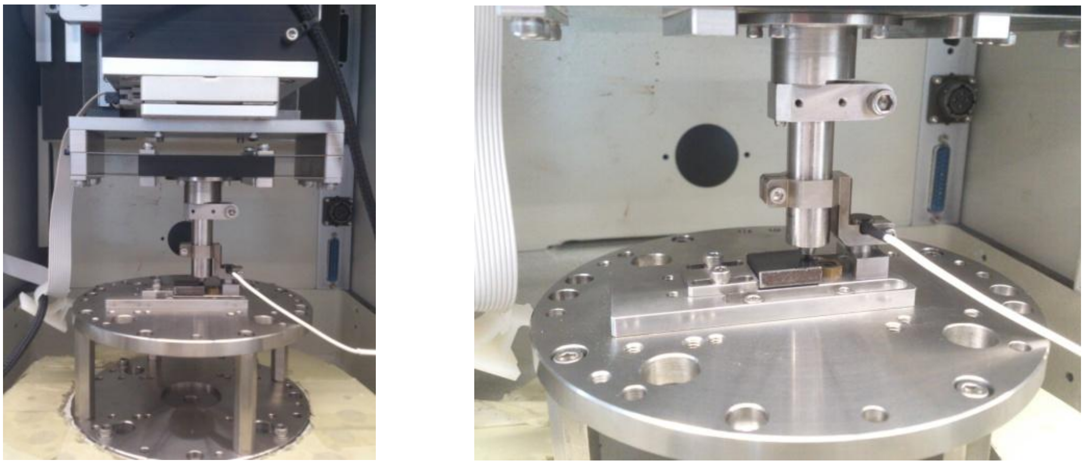

Figure 1: The indentation module

The indentation is performed by using a F=10 N indentation force which is acting on a part from a guide used in the Citroen car distribution transmission.

Figure 2: The capacitor sensor and the Vickers indenter

The tests are offering as results the values of the hardness and of the Young's modulus of the guide's material. The Vickers hardness of the tested polyamide is 3.2 (3 HRV) – 4 HRV according to the references [6, 7] and the Young's modulus is 2.8 GPa – 3.3 GPa according to the references [6, 7]; the references [6, 7] are indicating these values for the PA66 polyamide which has better values for the friction coefficient than the PA46 polyamide and is more frequently used in guide's construction than the PA46 polyamide [5]. So, the material's characteristics of the studied guide are much closer to the PA66 polyamide.

3 THE TRIBOLOGICAL TESTS

The friction in chain drives reduces the efficiency of them, produces wear and occurs mainly between the links and the sprockets and between the guide and the links [8]. The tribological tests are performed in order to obtain the values of the friction coefficient for the guide – link contact.

The static and dynamic friction coefficients are determined on a tribometer by using a rotary device as it is presented in the Figure 3. One link from the chain drive is mounted in a holder which is pushing with a normal force on a disk plate made by the guide's material.

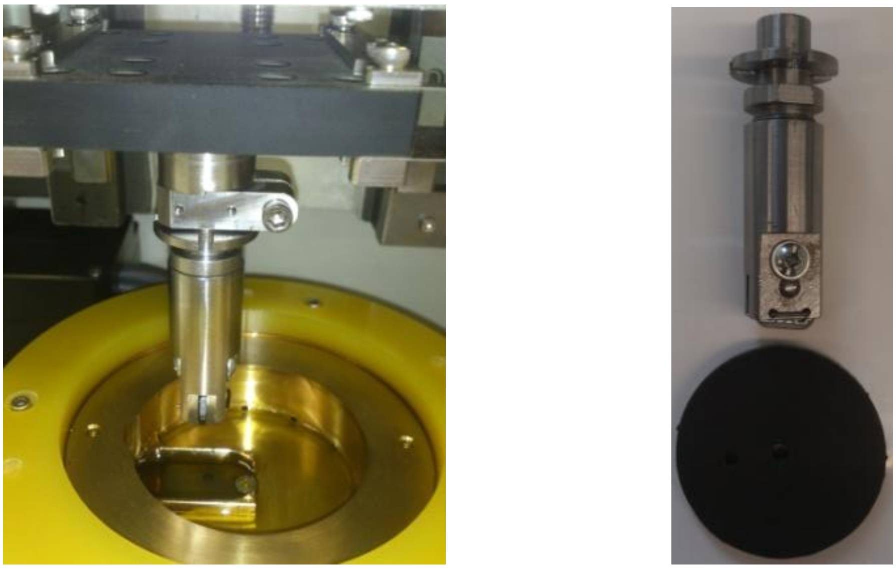

Figure 3: The test equipment

Figure 4 presents the variation of the friction coefficient COF in the case of a 2 way constant rotational speed of the disk plate V2= 500 rpm and a normal force of 5 N, established from the condition of the fluid friction. The values of the static friction coefficient (0.12 - determined when the rotational speed is 0) and of the dynamic friction coefficient (0.11 - determined when the rotational speed is constant but not 0) are comparable with the values from the references.

There are made also Stribeck type tests; in this case is presented the variation of the friction coefficient with the rotational speed which has values in the interval of 0 and 3000 rpm (Figure 5); the normal force is set up to 5 N. The values of the dynamic friction coefficient are decreasing with the rotational speed due to the fluid friction which is achieved at high rotational speeds.

References present that polyamide type materials are characterised by low friction coefficients (0.1 ... 0.13) [5]. The values of the friction coefficients obtained by testing the guide's material are close to the values for a PA66 polyamide type.

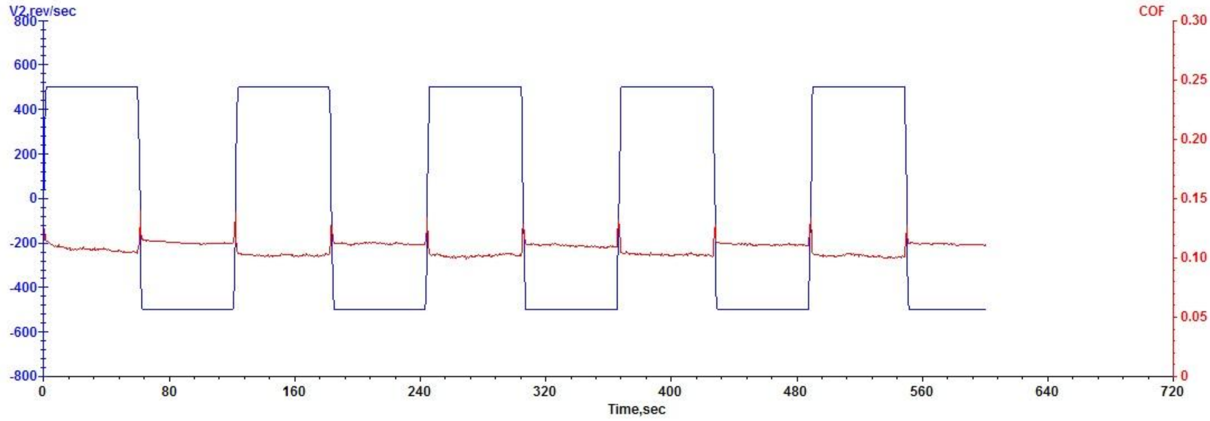

Figure 4: The friction coefficient

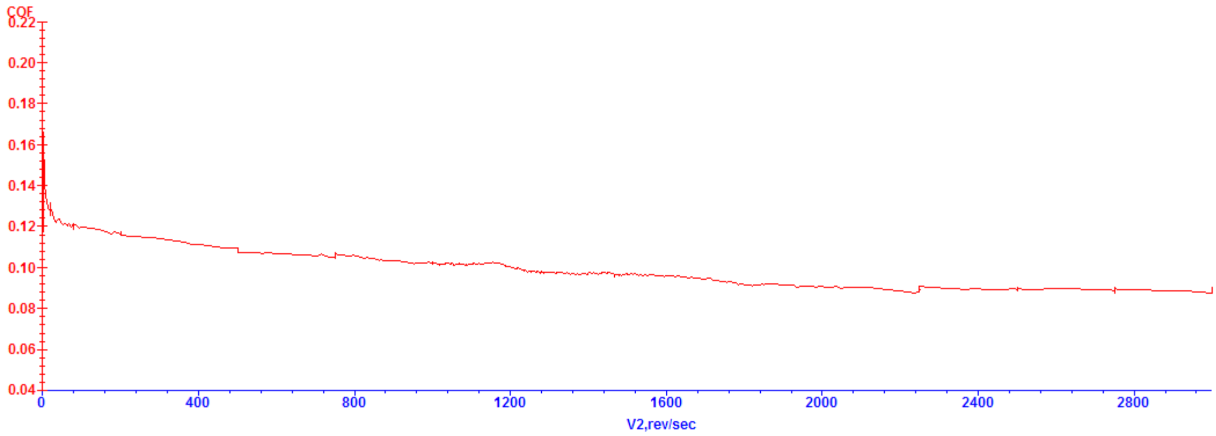

Figure 5: The friction coefficient in the Stribeck test

4 THE FINITE ELEMENT MODELING

The aim of the finite element modelling (FEM) is to find out the maximum contact pressure which occurs in the contact area between the link and the disk made by the guide's material [9].

The geometrical model is achieved by using the Catia v5R20 software; the two components are modelled as different parts and then, by considering contact geometrical constraints between the link and the disk, the final assembly is obtained. This assembly is imported as geometry in the Ansys 14.0 software in order to perform the FEM [10].

The modelling of the material is obtained by defining a new isotropic material due to the reason that the polyamide (PA type) can be considered as an isotropic material in the case of small forces [11]; there are defined the Poisson's coefficient and the Young's modulus obtained from the indentation test. All the other material parameters are calculated automatically by the software.

The external load is represented by a normal force, equal with 5 N (same as the force used in the tribological tests) and is acting on the link; the value of the force is determined by considering the condition of fluid friction between the link and the disk at 500 rpm as in the test was.

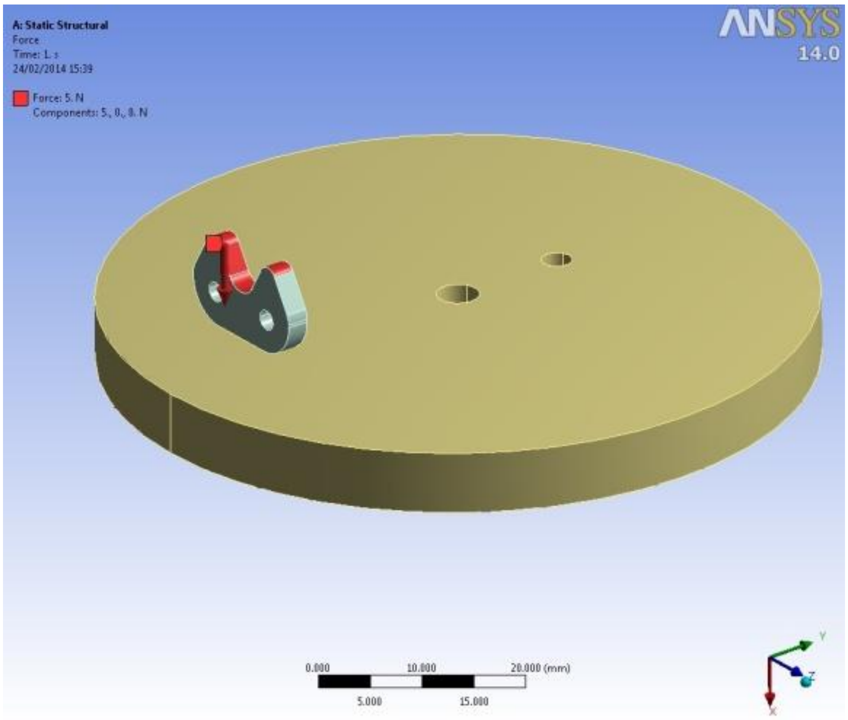

Figure 6: The finite element model

The constraints are represented by the fixed bottom surface of the disk and a frictional contact between the link and the disk; the value of the friction coefficient is 0.11, corresponding to the dynamic friction coefficient. The final model is presented in the Figure 6.

After solving the model, the values and distributions of the contact pressure, sliding and frictional stress are studied.

The distribution of the contact pressure is presented in the Figure 7. The value of maximum contact pressure 0.77 MPa is smaller than the allowable pressure for the lubricant (3 ... 5 MPa), so the fluid friction is achieved.

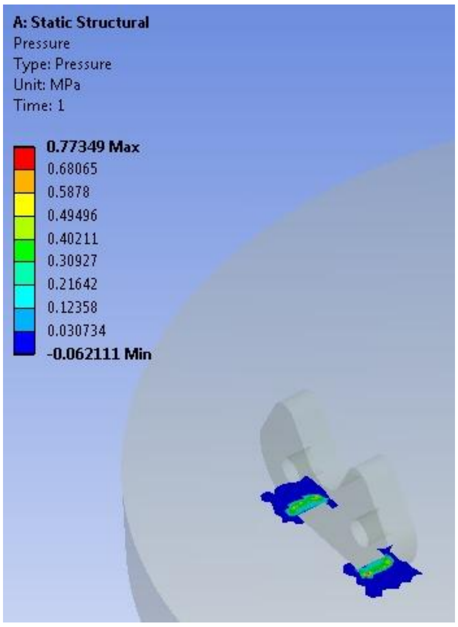

Figure 7: The maximum contact pressure

The frictional stress occurs due to the friction between the link and the disk. Small values of the normal force are producing small values for the frictional stress (the maximum frictional stress is 0.05MPa) – Figure 8; actually, these small values are due to the fluid friction.

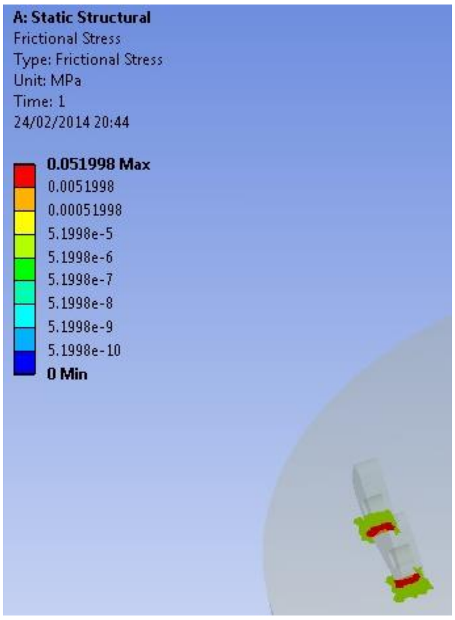

Figure 8: The frictional stress

The sliding phenomenon appears due to the tendencies of the link to slide on the disk. Even it is a fluid friction, with small values for the friction coefficient, due to the small forces, the sliding distance is small (Figure 9) – 0.00010613 mm.

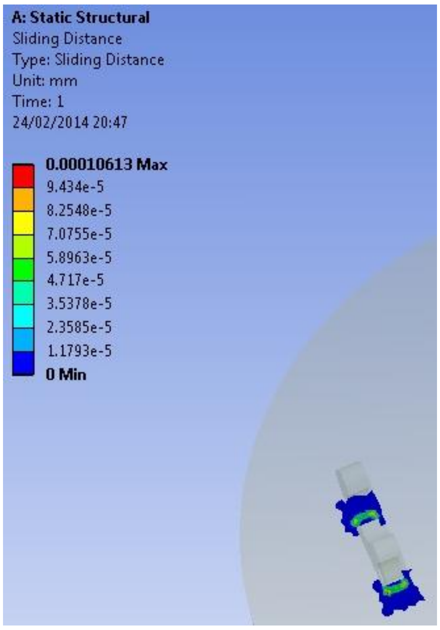

Figure 9: The sliding distance

5 CONCLUSIONS

- The test procedure and the finite element modelling presented in the paper can be applied in the case of any chain/guide type contacts with unknown material characteristics of the guide's material (Young modulus and friction coefficients) in order to establish the contact pressures between the guide and the link.
- The results can be used to optimize the guide/link contact area by using different profiles for the links or/and different materials for the guides.
- The numerical values from the tests (the hardness, the Young's modulus, the friction coefficients) are validated by the references.

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