Device for the study of the friction coefficient in the bolt-chain link joint

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Abstract. The friction which appears in chain drives has an important influence on their dynamic behaviour, wear and lifetime. The most significant friction and also wear is given by the bolt and chain link joint; in most of the cases this led to changes of the chain geometry and failures. Due to this, the study of the friction in the chain joints is required, but also difficult because of some particularities, as bolt and chain link reduced dimension, the oscillate motion in joint, chain link load. The paper presents a device for the friction coefficient study in the chain link-bolt joint, according to the mentioned requirements. First, the device ensemble 3D model is presented; the geometrical and kinematical restrictions between the parts are also defined. Then, the finite element analysis on this model is realized and is achieved for different initial conditions. In the paper final part, the analysis results and conclusions are presented.

1. Introduction

Mechanical products virtual modelling using computer performing software saves time in product developing, reduces the number of physical prototypes and experiments, reduces the prices of product and also, increases the quality of product [1, 2]. The paper presents aspects regarding the virtual modelling, and FEM analysis related to a testing device, to be used for tribological tests for small pieces, as bolt used at chain links.

Generally, the tribometers are used to study the friction between two surfaces in contact [3-5], which belong to real pieces adjusted to be a mechanical structure. For testing various pieces, the tribometer has its own devices, to fit the parts together. There are situations when the pieces to be tested are in particular shape, so cannot be fitted in the apparatus device without some cutting, trimming or polishing operations. Usually, for small pieces, as bolt or chain links, this could lead to the part destruction. In the paper, to avoid this, is presented an adequate special device, to be used to fix small bolt and chain links for the friction coefficient study in the bolt-chain link joint. Also, the device needs to allow the settings of the load force and movement.

The required device has, as main parts (as presented in figure 1):

- the rotational main part, which has to fit in tribometer apparatus; also, needs to keep the related part – the bolt holder;
- the bolt holder, which properly keep the bolt and needs to fit in the rotational main part;
- the chain link pusher needs also to fit in apparatus and has to keep the link pressed on rotating bolt with various loads.
2. The virtual model
For the device virtual modeling, the CATIA software is used [1, 6, 7]. After the sketching of the device parts, it follows the each part’s virtual model computing, using the Part Design module. The main dimension of the proposed device are corresponding to the tribometer dimensional requirements. The standard parts, can be chosen from the software virtual library and are not represented in figures. The device parts models are presented in figure 2.

![Figure 2. The device main parts.](image)

The subjected parts to be tested are the chain link and the bolt. For these components, the models are presented in figure 3.

![Figure 3. The chain link and bolt.](image)

Then, using the Assembly Design module, the device assembly is computed, following the corresponding constraints. The assembled device model, with the bolt and chain link, is presented in figure 4. If necessary, the testing device further technical documentation can be computed in the Drafting module [2].
3. Finite element analysis, simulation and results

For the analysis, the ANSYS software is used. The analysis objective is to determine the chain link and bolt ensemble behaviour under the load. For the analysis, the simplified version of the virtual model is used, without rotational main part, as is presented in figure 4(b). The material properties, as Young modulus, Poisson coefficient, Tensile Yield Strength, Ultimate Strength should be defined [8, 9]. The load consist in a force, applied along z axis, on chain link pusher, as is presented in figure 5. Different values of force will be applied: 25 N, 50 N, 75 N respectively 100 N.

![Figure 4. Assembled testing device.](image)

![Figure 5. The force applied on model.](image)

The results present the variation of the total displacement, equivalent stress and the reaction moment for the considered force values. Figure 6 presents the total displacement for an applied force equal with 25 N. The maximum value appears at the top end of the chain link pusher. In figure 7 is presented the equivalent stress for the applied force equal with 25 N. It can be observed that the maximum value appears at the contact portion between the chain bolt and the bolt holder. In the same position also appears the chain bolt bending which led to the reaction moment along x axis, as is presented in figure 8.
Figure 6. The total displacement for $F=25$ N.

Figure 7. The equivalent stress for $F=25$ N.

Figure 8. The reaction moment for $F=25$ N.
For the applied force equal with 50 N, in figure 9 the total displacement is presented. Also here, the maximum value appears at the top end of the chain link pusher. In figure 10 is presented the equivalent stress for the applied force, equal with 50 N. The maximum value appears in the same contact portion between the chain bolt and the bolt holder. Figure 11 presents an increased value of the reaction moment along x axis, for the considered force value at 50 N, due to the increased chain bolt bending.

Figure. 9. The total displacement for \( F = 50 \) N.

Figure. 10. The equivalent stress for \( F = 50 \) N.

Figure. 11. The reaction moment for \( F = 50 \) N.
Increasing the applied force to 75 N, in figure 12 the total displacement is presented, with the maximum value on the top end of the chain link pusher. In figure 13 is presented the equivalent stress for the same applied force, equal with 75 N. The maximum value can be observed in the same contact portion, between the chain bolt and the bolt holder. Figure 14 presents the value of the reaction moment along x axis, for the considered force value at 75 N.

![Figure 12. The total displacement for F=75 N.](image1)

![Figure 13. The equivalent stress for F=75 N.](image2)

![Figure 14. The reaction moment for F=75 N.](image3)
The maximum applied force is 100 N. In figure 15 the total displacement is presented, with the maximum value on the top end of the chain link pusher. In figure 16 is presented the equivalent stress for the same applied force. Also in this load case, the maximum value can be observed in the same contact portion between the chain bolt and the bolt holder. The reaction moment along x axis, for the considered force value at 100 N is also presented in figure 17.

Figure. 15. The total displacement for $F=100$ N.

Figure. 16. The equivalent stress for $F=100$ N.

Figure. 17. The reaction moment for $F=100$ N.
The values for the total displacement, equivalent stress and the reaction moment for the considered forces are presented in Table 1. It can be observed that, the total displacement increases with the increasing applied force, from 25 to 100 N. Due to the bolt deformation, on x axis appears an increasing reaction moment and the contact area between bolt and chain link is changed. Also, the equivalent stress increases with the applied force increasing; the maximum value result for the applied force value at 100 N.

Table 1. The total displacement, equivalent stress and the reaction moment for the considered forces.

| Applied force $F$, N | The total displacement $s$, mm | The equivalent stress, MPa | The reaction moment on x axis $M_x$, Nmm |
|----------------------|--------------------------------|---------------------------|----------------------------------------|
| 25                   | 0.013099                       | 47.203                    | 160.51                                 |
| 50                   | 0.026199                       | 92.405                    | 321.02                                 |
| 75                   | 0.039298                       | 138.61                    | 481.52                                 |
| 100                  | 0.052398                       | 184.81                    | 642.03                                 |

4. Conclusions
The total displacement increases with the applied force increasing and also with the bolt deformation. Also, appears a reaction moment on x axis, which increases with the applied force increasing. The total displacement maximum value should be lower than the clearance between the chain link and bolt (recommended by the chain producer). The equivalent stress increases with the applied force increasing. For extreme increased force values, the equivalent stress value may exceed the recommended bending limit stress for the chain bolt material (recommended by the chain producer) and the properly tribological test with a rotation bolt into the chain link hole could not be possible. Testing device damages could also appear in this case.

The proposed device can be used for a different type of chain links and bolts. For different dimension, as chain pitch or bolt diameter, the bolt holder should be changed.

5. References
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