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Friction phenomenon study for chain link – guide contact in translational oscillatory motions

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Abstract. The fuel consumptions of the automobiles are hardly influenced by the friction between the components of their mechanical transmissions being in relative motion. One of the main parts of the automobiles mechanical transmissions is represented by the chain drive transmission. The frictions inside the chain drive transmissions could be split in: the friction inside the chain, between its components (links, bolts); the friction between the chain links and the sprockets; the friction between the chain links and the active part of the tensioning guide. The aim of the paper is to investigate the friction phenomenon in the chain link – guide contact for a set of normal forces, velocities and temperatures. The tests are achieved for sets of motions frequencies, normal loads and oil bath temperatures; according to these, there are determined the dynamic friction coefficients (during the motions) and the static friction coefficients (at the end parts of the strokes). The results show graphically the variations of the static and dynamic friction coefficients with the motions frequencies, the normal loading forces and the oil bath temperatures. The conclusions are useful in order to identify the functioning cases where the frictional losses are small.

1. Introduction

According to the literature, [1-5], the chain link – guide friction represents the main contribution in the global friction phenomenon which appears in the chain transmission. In order to reduce the friction between the chain links and the guide, the active part of the tensioning guide is made by polyamide type materials; these materials are characterized by small friction coefficients in combinations with steel mechanical parts, reduced wear and high stability with the temperature. The friction is developed between a steel material used to the manufacturing of the link and a polyamide material used to design the active part of the tensioning guide; these two components are in a relative translational motion under different loadings and temperatures of the lubrication oil.

Polyamides are used in the fabrication of the mechanical spare parts due to their special properties as good frictional behaviour, reduced wear, high endurance and good mechanical properties in the case of high temperatures, [1-5]. In the case of the tensioning guides used in the chain drive transmissions, the active part of the guide is made by polyamide and is highly loaded, due to the action of the tensioning force. The studies show that these polyamides have small deformations in the case of the high loadings, [2, 3].

The polyamides are used widely in the automotive industry, mechanical transmissions and food industry due to their good frictional properties in the case of a wide range of speeds, loadings and temperatures. The tests performed in [6-8] are achieved for temperatures up to 160°C, pressures up to 5MPa and rotational speeds up to 4000rpm; in all the cases, the tested polyamides demonstrate small



frictions and small wear. Also, at very high temperatures (up to 210°C) the polyamides keep their crystalline structure, [9, 10]. According to their frictional behaviour, the results of the tests show that the polyamide type materials may be used in functioning conditions with temperatures up to 180°C, [11-14].

2. The friction tests

The tests are achieved on a test rig which has as components a tribometer and a computer used for the acquisition of the measured data, [15], figure 1. On the upper part of the tribometer a holder is mounted on a force sensor which allows measurements for forces about two directions in a range of $F=0.1 \dots 1000\text{N}$ and the resolution $R_f=50\text{mN}$. The vertical motion of the upper holder is up to $d=150\text{mm}$ with the speed of $v_v=0.001 \dots 10\text{m/s}$; the lateral motion of the holder is up to $l=75\text{mm}$ with the speed of $v_l=0.01 \dots 10\text{m/s}$. The motion resolution is $R_r=2\mu\text{m}$.

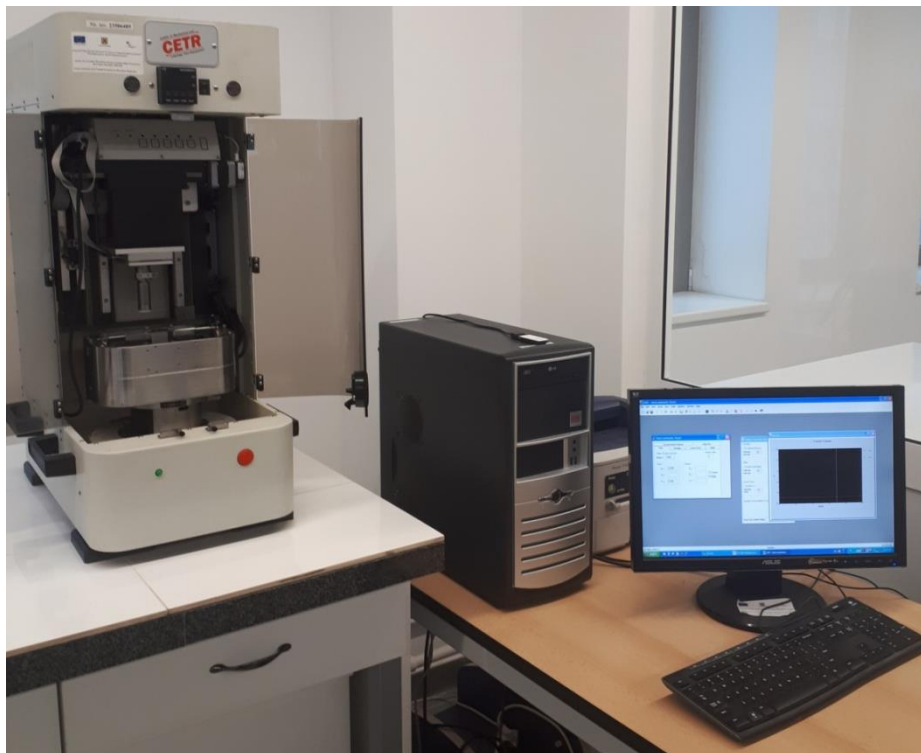


Figure 1. The test rig.

In the lower part of the tribometer is mounted the unit which allows the reciprocating motion – figure 2. The unit is equipped with a one direction force sensor which allows measurements up to $F=1000\text{N}$ with a resolution of $R_r=1\mu\text{N}$. The frequency of the motions is between $\nu=0.1 - 60\text{Hz}$ and the stroke is $s=0.05 - 25\text{mm}$ [15].

Inside the reciprocating motion unit is mounted an oil bath where is placed a chain link – figure 3. The temperature can be controlled in the oil bath up to $t=150^\circ\text{C}$ [15]. On the chain link is acting a holder which has mounted on it a polyamide type disk (figure 3). The polyamide disk is made by a polyamide material used in the fabrication of the active part of a tensioning guide.

The tests are performed with the following input parameters: the motion frequency $\nu \in \{1, 10, 20\}\text{Hz}$; the normal force $F \in \{5, 10, 20\}\text{N}$; the temperature of the oil bath $t \in \{90, 120\}^\circ\text{C}$. Depending on the stroke of the oscillatory motion and depending on the dimensions of the polyamide cylinder and the chain link, table 1 presents the equivalence between frequencies and speeds and between normal forces and normal pressures.

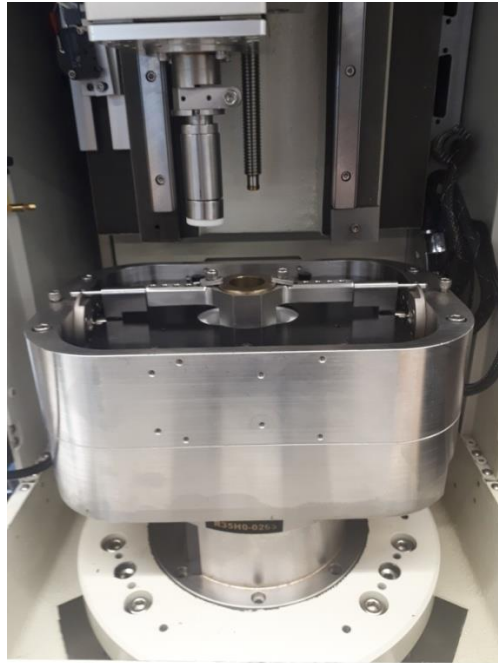


Figure 2. The reciprocating unit.



Figure 3. The holder with polyamide disk on chain link.

Before the tests, during 2 hours, it is performed a running-in process with a normal force of 10N, at a motion frequency equal with 10Hz and a temperature of the oil bath equal with 90°C.

Table 1. The equivalence between frequencies and speeds and between normal forces and normal pressures.

Frequency ν , Hz	Speed v , mm/s	Normal force F , N	Normal pressure p , MPa
1	4.66	5	0.125
10	46.6	10	0.25
20	93.2	20	0.50

3. Results

The results present the variation of the friction coefficient with the test parameters: the frequency of the motion, the normal force and the temperature of the oil bath.

Figure 4 presents the evolution of the wear during the running-in process; the value of the wear is stabilised after approximately 75 minutes at a value around 0.08mm.

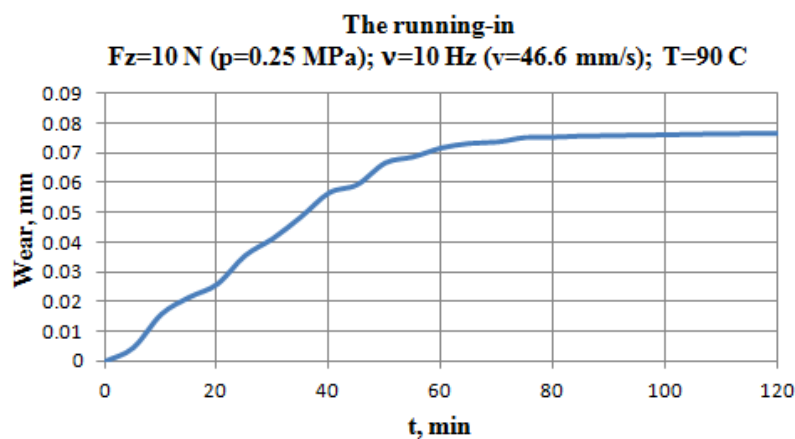


Figure 4. The evolution of the wear during the running-in process.

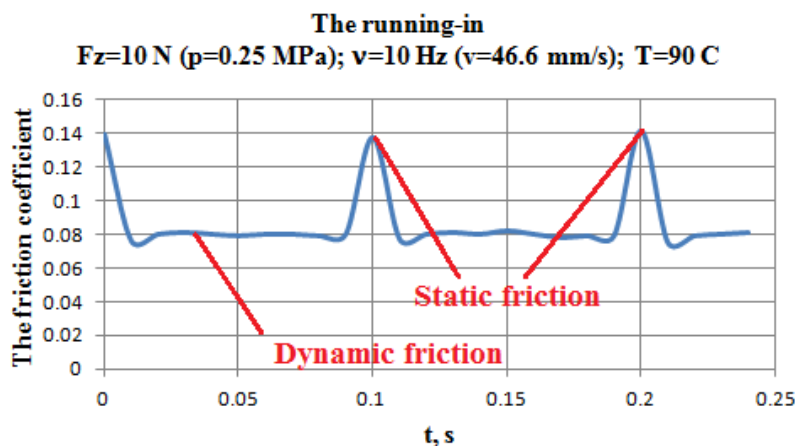


Figure 5. The friction coefficient during the oscillatory motion.

During the oscillatory motions, the contact between the chain link and the polyamide part is characterised by two types of friction coefficients: the static friction coefficient (at the end of the stroke when the motion changes the direction) and the dynamic friction coefficient (during the motion) – figure 5.

The variation of the dynamic friction coefficient, during the running-in process, is presented in figure 6; after 40 minutes of tests, its value is stabilised at a value of 0.08. The evolution of the static friction coefficient is observed in figure 7; this one is stabilised after 20 minutes at a value of 0.14 (this shorter time for the stabilised value happens due to the change of the direction of friction forces at the ends of the stroke).

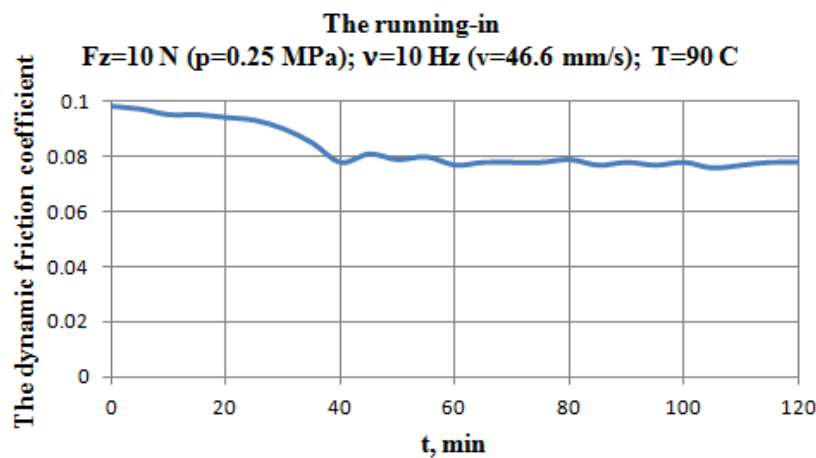


Figure 6. The dynamic friction coefficient.

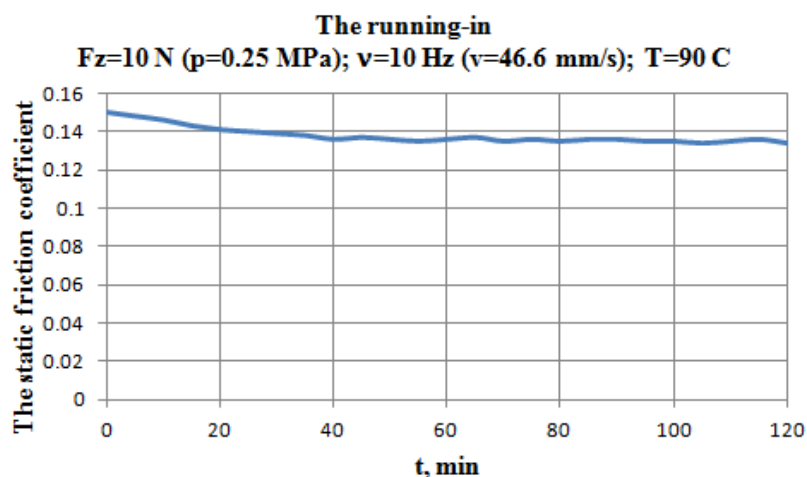


Figure 7. The static friction coefficient.

Figure 8 and figure 9 present the values of the dynamic friction coefficient and the static friction coefficient, respectively, for a normal force equal with 10N. The tests are performed for frequencies equal with 1Hz, 10Hz and 20Hz; the temperature is set up for two values: 90°C and 120°C (these values correspond to the real functioning temperature values of the lubricant in the case of the automotives). The friction coefficients have a decrease with the increasing of the motions frequencies. The value of the friction coefficients increases with the increasing of the temperature.

Figure 10 and figure 11 present the values of the dynamic friction coefficient and the static friction coefficient, respectively, for a value of the motion frequency equal with 10Hz. The tests are performed for normal forces equal with 5N, 10N and 20N; the temperature is set up for two values: 90°C and 120°C. The friction coefficients have a decrease with the increasing of the normal forces. The value of the friction coefficients increases with the increasing of the temperature.

In conclusion, the static and dynamic friction coefficients are influenced by the variation of the normal force, the motion speed and the environment's temperature.

The static friction coefficient in the guide/chain link contact appears in real functioning conditions in the start/stop moments of the car. The dynamic friction coefficient in the guide/chain link contact appears in real functioning conditions during the functioning of the car's engine.

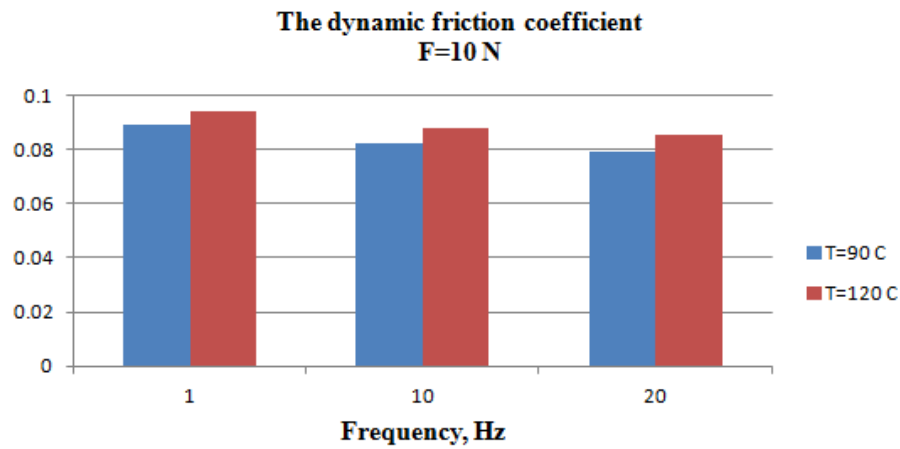


Figure 8. The dynamic friction coefficient.

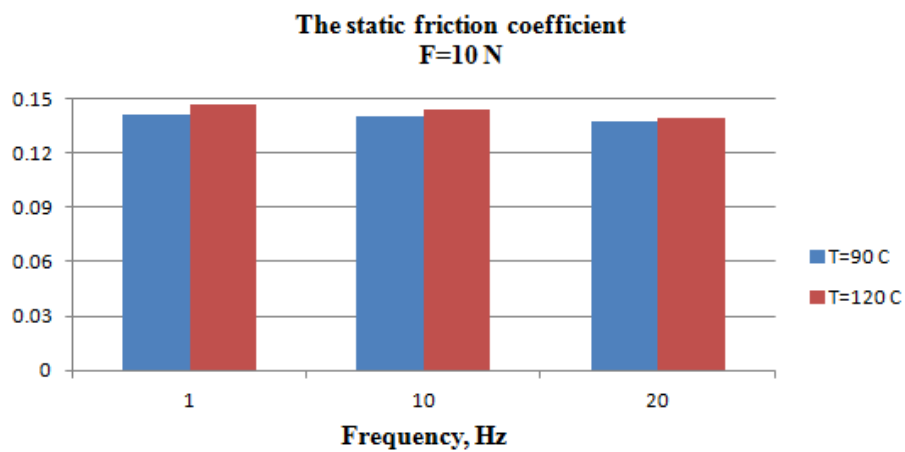


Figure 9. The static friction coefficient.

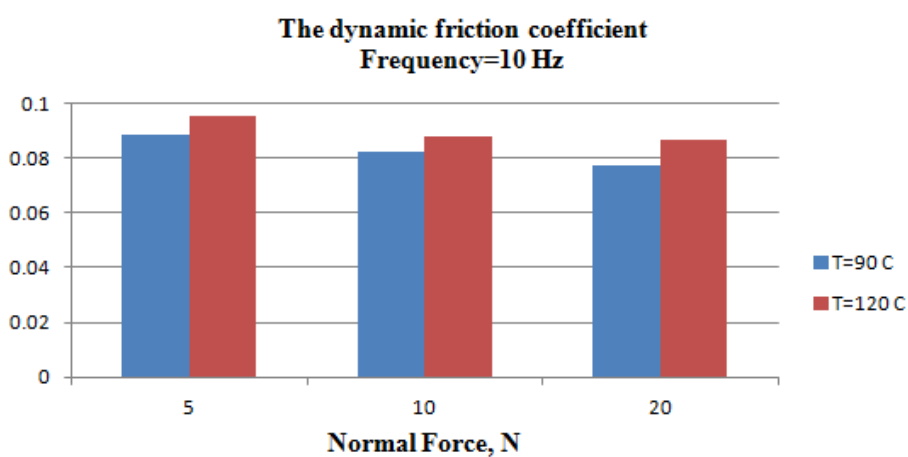


Figure 10. The dynamic friction coefficient.

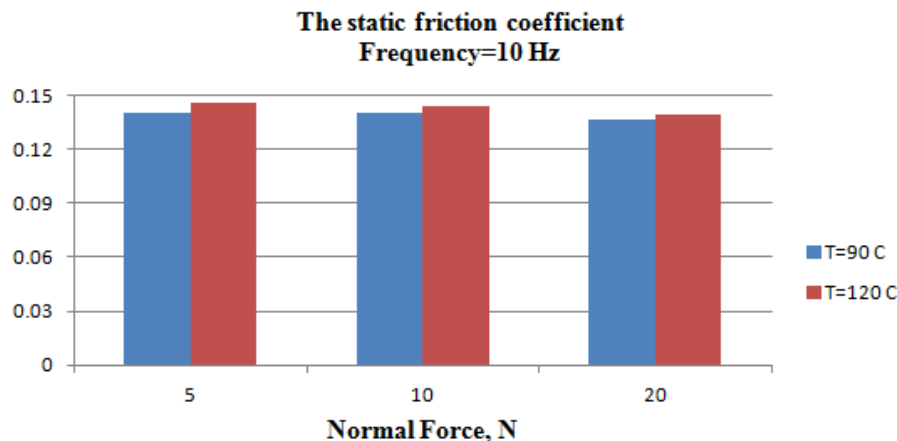


Figure 11. The static friction coefficient.

4. Conclusions

In conclusion, the static and dynamic friction coefficients are influenced by the variation of the normal force, the motion speed and the environment's temperature.

The static friction coefficient in the guide/chain link contact appears in real functioning conditions in the start/stop moments of the car. The dynamic friction coefficient in the guide/chain link contact appears in real functioning conditions during the functioning of the car's engine.

The static and the dynamic friction coefficients values are decreasing with the increasing of the normal force and of the motion's frequency and are increasing with the increasing of the temperature. The decrease of the friction coefficients with the normal force and the motions frequencies happens due to a better contact between the chain link and the polyamide type material. The increase of the friction coefficient with the temperature happens due to the decrease of the lubricant viscosity.

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