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Comparative study of the friction phenomenon in the contact between the guide and the bush and silent chain links

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Abstract. The optimisation process of the chain drives includes the development of new chain links in order to reduce the noises, the vibrations and the non-linearity of the motions. One solution is the development of the silent chains in order to replace the bush chains. According to the literature, the silent chains have a better dynamic behaviour instead of bush chains but there are only few studies regarding their frictional behaviour. As part of the global friction in a chain drive transmission, the paper presents an experimental comparative study of the friction between a PA46 polyamide material (used to manufacture the active part of the tensioning guide) and the bush chain and silent chains respectively. The tests are performed on a tribometer by considering different rotational speeds, local pressures and temperatures. The results are presented as variations of the dynamic and static friction coefficients depending on the test parameters. Finally there are offered conclusions regarding the practical applications of the results.

1. Introduction

Chain drive transmissions are widely used in the case of mechanical systems which should transmit high power with application in: automotives, machine tools, naval engineering etc [1, 2]. The main disadvantages of the chain drive transmissions are referring on: the non-linearity of the transmitted motion (due to the gearing and due to their construction, there are shocks and are developed noises during their functioning), the necessity to use the tensioning guides, the wear influence on the chain's stiffness; the friction which influence the transmission's efficiency [1, 2].

In order to improve their dynamic behaviour there are developed new types of chains with different geometries of their links. For instance, the silent chains have a better dynamic behaviour than the bush chains due to the reason that the toothed links have a better gearing process with the sprockets, instead of the links from the bush chains [1, 2]. According to these, in the case of the silent chains, there are smaller shocks, smaller noises during their functioning period than in the case of the bush chains.

The frictional loses are characterising both the silent chains and the bush chains. Generally, the friction in a chain drive transmission can be split in the friction inside the chain links (between the links and pins or between the links and the bushes), the friction between the chain links and the sprockets [3] and between the chain links and the tensioning guides [4].

The literature [5, 6] provides measuring methods and test results in order to study the friction of the chain drive transmissions; one of the basic references used to develop measuring methods to determine the friction between the chain links and the polyamide-made guides is represented by [7]. Polyamides are widely used in the construction of the active part of the tensioning guides due to their good frictional behaviour and internal structure stability with the variation of the temperature [8, 9, 10, 11].

The aim of the present paper is to make a comparative study of the friction between a PA46 polyamide type material used in the design of the active part of a tensioning guide and the bush chain and silent chain links, respectively.

2. The tests

The measuring and acquisition system used for the tests is presented in figure 1. The tribometer is equipped with a force sensor which allows measurements of forces about the vertical direction and about a horizontal direction in the interval of 0.1 ... 1000 N with the resolution of 50 mN; the friction coefficient is determined by calculating the ratio between the measured horizontal force and the normal force [12]. The sensor force is mounted on two sliders which allow vertical motions with a stroke equal with 150 mm and with a speed between 0.001 ... 10 m/s and lateral motions with a stroke equal with 150 mm and with a speed between 0.001 ... 10 m/s.

On the force sensor is mounted a suspension in order to damp the oscillations. On the base plate of the force sensor is mounted a holder which allows the mounting of different pieces as ball, pins, plates. The vertical stroke is equal with 75 mm and it can be reached with a speed situated in an interval of 0.01 ... 10 m/s [12].

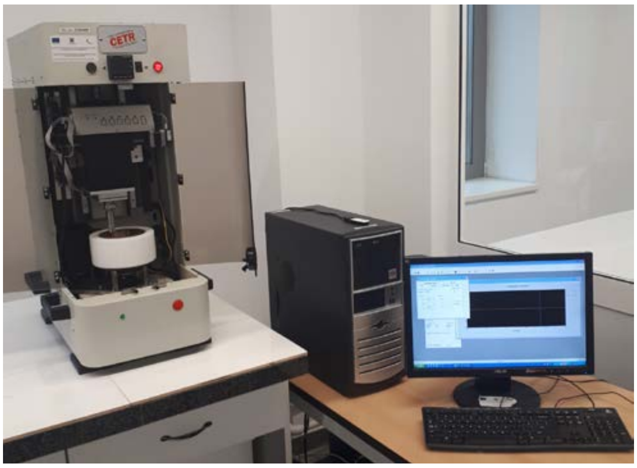

Figure 1. The test rig.

In the tribometer is mounted a rotary unit which allows rotational motions with a rotational speed in the interval of 0.001 ... 5000 rpm and a resolution equal with 1 µm [12]. The rotary unit is equipped with and oil bath connected to a heater which allows a heating up to 150 ^{o}C [12].

The tests are performed in two situations: a bush chain link in contact with a PA46 polyamide disk and a bush silent link in contact with a PA46 polyamide disk – figure 2. The polyamide disk is made from a PA46 material which is used in the manufacturing of the active part of the tensioning guides used in chain drive transmissions from the car distribution transmission. The chain links have the same pitch – 8 mm.

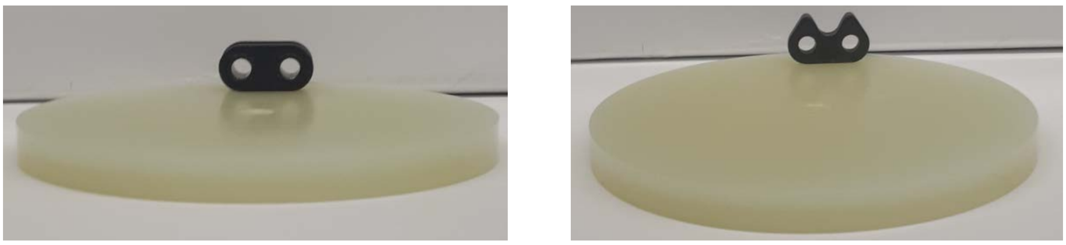

Figure 2. The chain links in contact with the disk.

The chain links are mounted inside a holder – figure 3. The links are mounted inside the solder with a clip which allows small relative motions – as in real functioning conditions of the chain drive transmission

Figure 3. The chain link mounted in the holder.

The disk is mounted inside an oil bath of the rotary unit of the tribometer and the holder with the chain link is mounted on the upper slider as it can be observed in figure 4. The contact between the chain link and the disk is accomplished by moving the sliders about the vertical and the lateral directions.

The tests are performed by using two disks, made by the same materials, with the same geometry, used – one for the bush chain link and the other for the silent chain link tests. At the beginning a running-in procedure is tested during 2 hours for a pressure of 5 MPa, a rotational speed of 500 rpm about two directions in every 10 minutes and an environmental temperature of 22 ^{o}C. The tests continue with a set of rotary speeds of 50, 100, 500, 1000, 2000 rpm about two directions at every 5 minutes, at local pressures between 5 ... 10 MPa and at the temperatures of the oil bath equals with 90 ^{o}C and 120 ^{o}C.

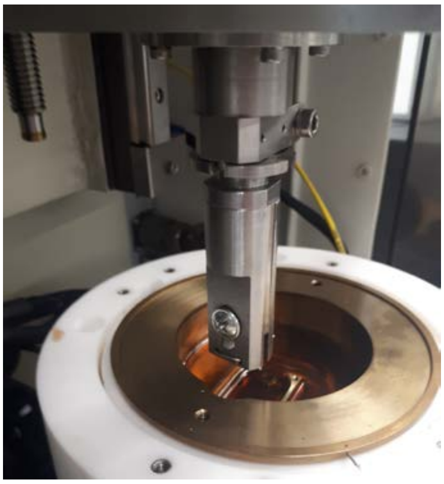

Figure 4. The holder mounted on the tribometer.

3. Results

The results present the evolution of the wear and of the friction coefficient during the running-in process and the variation of the friction coefficient during the tests, depending on the local pressure, the rotational speeds and the temperature of the oil bath.

Figure 5 presents the evolution of the wear during the running-in process. The wear evolution is slightly the same for the tested chain links; the value of the wear is stabilised after approximately 25 minute at a value around 0.12 mm.

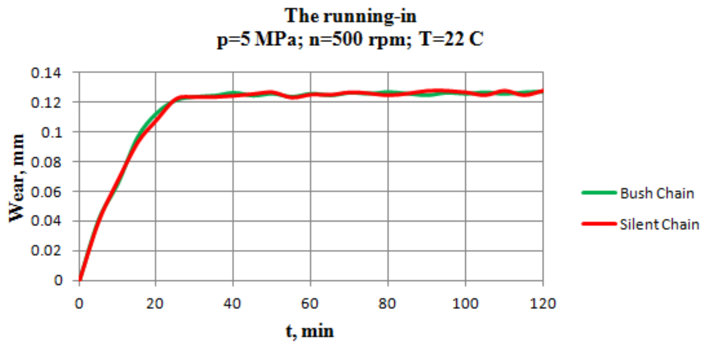

Figure 5. The evolution of the wear during the running-in process.

During the running-in period and during the tests, due to the rotations about two directions, there are identified and measured two types of friction coefficients: the dynamic friction coefficient (during the motion) and the static friction coefficient (when the motion changes the direction) – figure 6. Due to inertial reasons, when the motion slows down in order to change the direction, it is a small decrease of the friction coefficients value; from the same reason, the value of the static friction coefficient in the case of the silent chain link is smaller than the value of the static friction coefficient in the case of the bush chain link. The values of the dynamic friction coefficients are mainly the same.

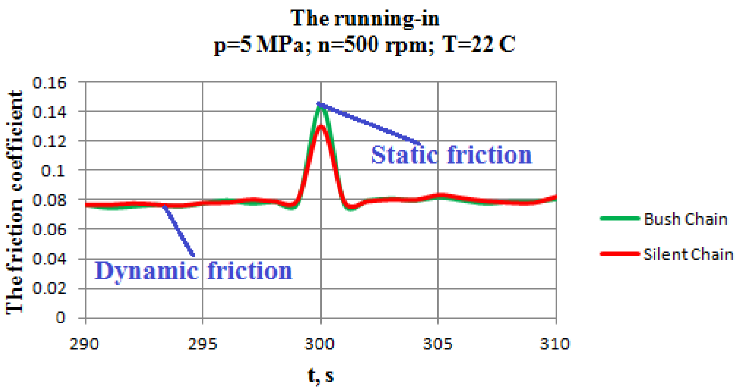

Figure 6. The friction coefficient during the change of the motion direction.

The evolution of the dynamic and of the static friction coefficient during the running-in process is presented in figure 7 and figure 8, respectively. The dynamic friction coefficient has the same variation for both chain links: it is stabilised after 15 minutes at a value around 0.08. The static friction coefficient has smaller values for the silent chain link thank the bush chain links; an explanation of this is based on the different inertias of the links, due to their shapes. The value of the static friction coefficient is stabilised after 60 minutes at around 0.135 for the bush chain and at around 0.125 for the silent chain.

Figure 9 and figure 10 present the values of the dynamic friction coefficient and the static friction coefficient, respectively, for a local pressure of 5 MPa; the values of the dynamic friction coefficients are almost identically for the bush chain and for the silent chain. The dynamic friction coefficient decreases with the increasing of the rotational speed and increases with the increasing of the temperature.

According to figure 10, the value of the static friction coefficients decreases with the increasing of the rotational speed and increases with the increasing of the temperature. The static friction coefficient has smaller values for the silent chain link than the static friction coefficient for the bush chain link; the difference between these two parameters decreases with the increasing of the temperature.

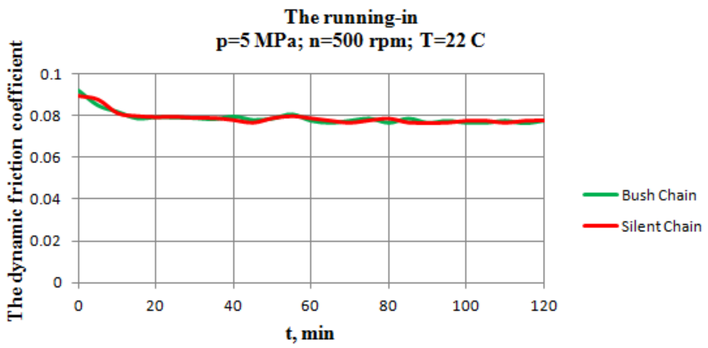

Figure 7. The dynamic friction coefficient.

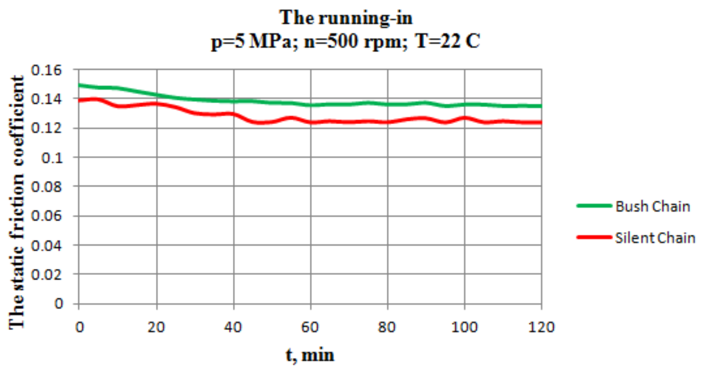

Figure 8. The static friction coefficient.

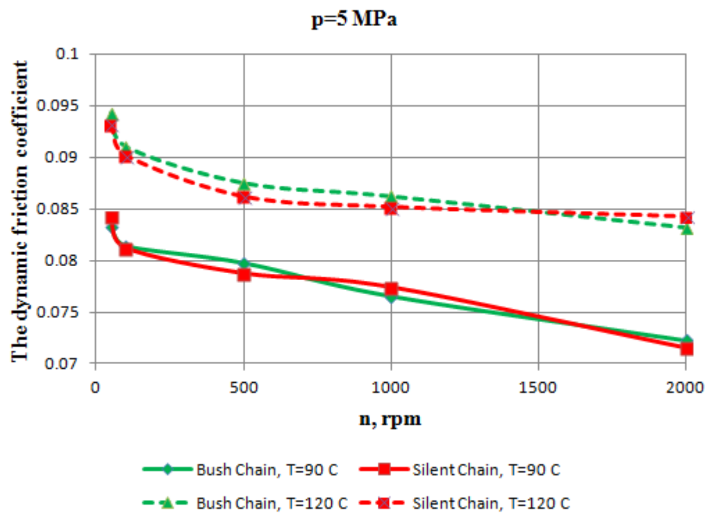

Figure 9. The dynamic friction coefficient.

4. Conclusions

As a general conclusion the values of all the measured friction coefficients decrease with the increasing of the local pressure and of the rotational speed; the values of the friction coefficients increase with the increasing of the temperature.

Regarding the comparative study of the friction coefficients for the bush chain link and the friction coefficients for the silent chain links, it can be concluded that the values of the dynamic friction coefficients are similar. In the case of the static friction coefficients, their values are smaller for the silent chain link than the values for the bush chain link. This can be explained by taking into account to the different inertias of the chain links. Practically, these conclusions shows that, in the case of start/stop situations of the car's engine, it is a smaller frictional lose if the silent chains are used in the distribution transmission of the car.

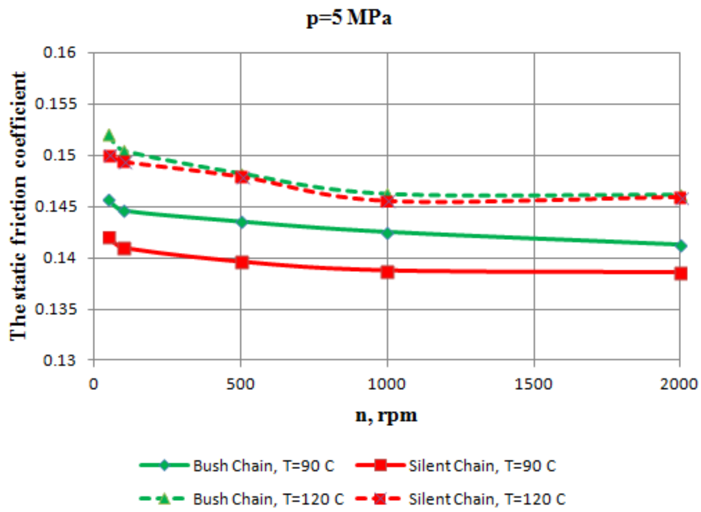

Figure 10. The static friction coefficient.

5. References

[1] Heisler H 2005 Advanced vehicle technology *The bath press*

[2] Vlasrnik J 2009 Chain drive computional model as virtual engine module *Ph.D. Thesis. Brno University of Technology* pp 7-87

[3] Pedersen S L 2005 Model of contact between rollers and sprockets in chain-drive *systems Arch. Appl. Mech.* **74** pp 489-508

[4] War X and Dwyer-Joyce R S Model experiments on automotive chain drive systems *Els. Sci.* **39** pp 851-861

[5] Fink T and Bodestein H 2011 Friction reduction potentials in chain drives *MTZ Worldwide Edition* **72** pp 46-51

[6] Hyakutake T, Inagaki M, Matduda M, Hakamada N and Teramaki Y 2001 Measuring of friction in timing chain *Soc. Autom. Eng. Jap.* **22** pp 343-347

[7] J. van Ruiten van J, Proost R and Meuwissen M 2012 How the choise of the polyamide type in timing chains tensioning systems affects the CO_2 emission and fuel economy of internal combustion engines *Presentation at VDI Vertiltrieb un Zylinderkopf*

[8] Buccella M, Dorigato A, Pasqualini E, Caldara M and Fambri L 2012 Thermo-mechanical properties of Polyamide 6 chemically modified by chain extension with Polyamide/Polycarbonate blend *J. Polym. Res.* **19** pp 9935-9944

[9] Gordon D H and Kukureka S N 2009 The wear and friction of polyamide 46 and polyamide 46/aramid-fibre composites in sliding–rolling contact *Wear* pp 669-678

[10] Chiu F-C and Kao G-F 2012 Polyamide 46/multi-walled carbon nanotube nanocomposites with enhanced thermal, electrical and mechanical properties *J. Comp.* **43** pp 208-218

[11] Hsiao S, Wang H, Chou J, Guo W and Tsai T 2012 Synthesis and characterisation of novel organosoluble and thermally stable polyamides bearing triptycene in their backbones *J. Polym. Res.* **19** pp 9902-9911

[12] *** 2009 UMT Multi-Specimen Test System. Hardware Installation & Application Manual. Center for Tribology, Dell Ave, Campbell, USA