

Oil temperature influence on friction losses in silent chains

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Abstract. Evaluation of friction in chain drives is the first step in the process of reducing the friction. This paper presents the experiments on the analyses of temperature influence on friction in silent chains. A rig dedicated for friction measurements on parallel axes transmissions is used. Friction is measured as friction torque with possibility to control and measure the input rotational speed, chain tensioning, pressure and temperature of the oil for chain lubrication, pressure and temperature of the oil for bearings lubrication. Temperature depending viscosity of chain lubrication oil is measured separately. The functioning conditions of the bearings are maintained constant during the testing and only the temperature of chain oil lubrication is increased and then decreased in the range of functioning temperature of a timing chain. Oil temperature influence on friction from silent chains joints gives an image on the type of lubrication. The reduction of silent chain friction by reducing the functioning temperature may be a very simple solution and this paper shows how much power may be saved. Friction torque is measured for three distinct rotational speeds in the same tensioning parameters. Conclusions on the influence of rotational speed on friction losses with temperature are finally drawn.

1. Introduction

The importance of reducing friction in automobiles transmission is as high as possible in the context of the regulations imposed by the 20/20/20 goals from the Directive for Energy Efficiency of the European Union (2012/27/UE), imposing targets for year 2020, like: 20% reduction of CO₂ emissions compared to 1990 levels and 20% reduction of final energy consumptions.

In the same directions have been moved the goals of automotive industry for year 2020. Targets in fuel consumptions and also in the equivalent CO₂ emissions have been drawn. American standards CAFE (Corporate Average Fuel Economy) impose, for 2020, a one third reduction of fuel consumption, relative to year 2008. European Commission set a goal for 2021 of average CO₂ emissions of 95 grams CO₂ / km for the whole fleet produced in 2020.

Bush chains are used in the timing system of combustion engines, where tensioning and speed reach some of the extreme values of the field of use. Reducing friction in timing chains is an important goal since, according to [1, 2], the part of the fuel energy dedicated to overcome friction in the engine system is 7–18% of total losses. This is why, it is of high importance to evaluate influences on chain friction in order to take the right measures for reducing it.

Results on measuring losses in the timing chain and the loss in the guides of an engine, using equipment consisting in a full engine are presented in [2]. The rig allows a good replica of the real engine conditions. The contribution of chain friction and guide friction on the global timing system friction are only presented for one value of oil temperature.



Friction in chain drives friction is subject of several papers referring to friction coefficients [3], friction contribution [4] or theoretical approaches [5].

Research on friction in chain drives, mainly used for the timing system of combustion engines, has been developed with the finance of Schaeffler Group, at the Tribology Centre of Transylvania University of Brasov. For a basic chain drive with identical sprockets, the procedure for measuring chain friction is presented in [6]. The chain rig used for these experiments is presented in figure 1. Friction losses are measured as global friction torque depending on speed, tensioning and oil temperature, based on the diagram from figure 1, a.

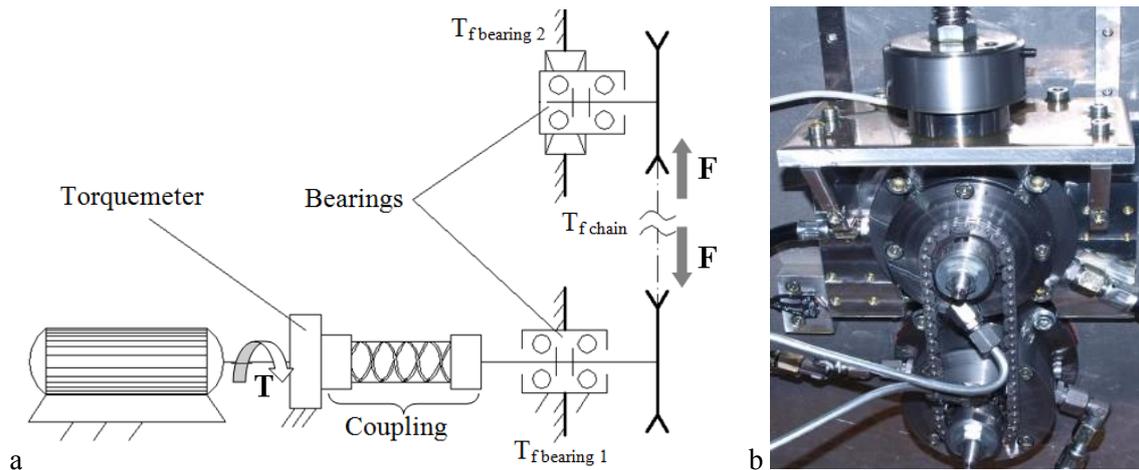


Figure 1. Chain friction rig: a – functioning diagram, b – front picture of the chain drive [6].

The aim of the paper is to experimentally determine the influence of oil temperature on the friction in the chain, without considering bearing friction. Influence of speed is also investigated.

2. Experimental on temperature influence on bush chain friction

The tests have been developed on the chain rig described in [6], based on the procedures presented in the same reference.

The subject of the test is a silent chain with 8 mm pitch, 64 links, with identical 23 teeth sprockets. Tensioning is created by enlarging the centre distance. For all the tests, the tensioning is automatic, ensuring a constant tensioning force F of 1 kN. The transmission is a vertical basic transmission with transmission ratio equal to one.

Lubrication of the chain is made with two jets of oil oriented to the points of chain entering the two sprockets (see figure 1, b). Lubrication of the bearings is made with a lower pressure flow of oil inside the bearing boxes. The rig has two separated circuits for lubrication of chain and bearings. Temperature and pressure in each circuit are measured with a precision of ± 0.1 °C. The temperature of oil in each circuit is controlled with a maximum deviation of ± 2 °C. The oil used for tests is fresh 5W30 Castrol Edge synthetic oil. Figure 2 presents the measured dynamic viscosity η of the oil depending on temperature. The same oil is used for chain and bearing lubrication.

Global friction torque (including friction resistance in chain and bearings) is measured for constant speed and tensioning, automatically keeping constant the temperature of the bearing oil and only changing the temperature of the oil for chain lubrication. Since the conditions of working of the bearings are kept constant, the change in friction is only coming from temperature influence on chain friction.

With a software controlled interface, the averaged values of the measurements (time, friction torque, chain oil temperature and pressure, bearing oil temperature and pressure, tensioning, rotational speed) are saved at each 5 seconds. The database is accessed as an .xls file.

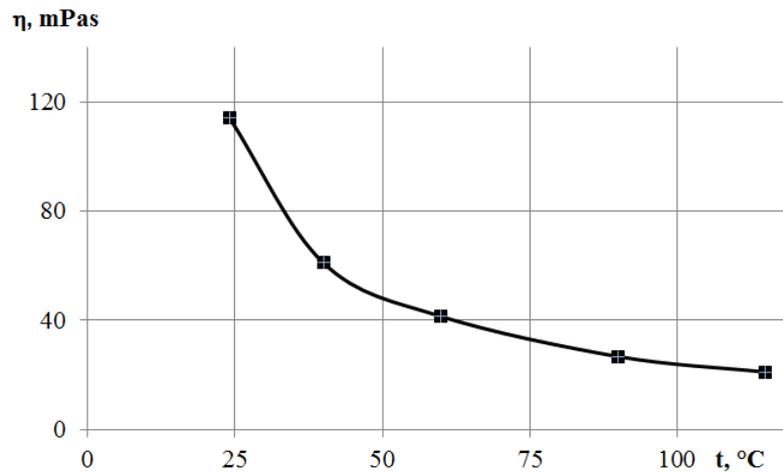


Figure 2. 5W30 Castrol Edge oil dynamic viscosity vs. temperature.

The tested chain has been previously subject of running in for 50 hours, at constant tensioning of 1 kN, 2000 rpm rotational speed and 50 °C chain oil temperature.

Tests have been developed for constant bearing oil temperature of 60 °C, constant tensioning of 1 kN. The chain oil is heated from 70 °C to 100 °C and then cooled back to 70 °C. The tests have been repeated 3 times separately for three values of rotational speed, 1000, 2000 and 4000 rpm.

Figure 3 presents time depending chain and bearings oil temperature for constant 2000 rpm rotational speed.

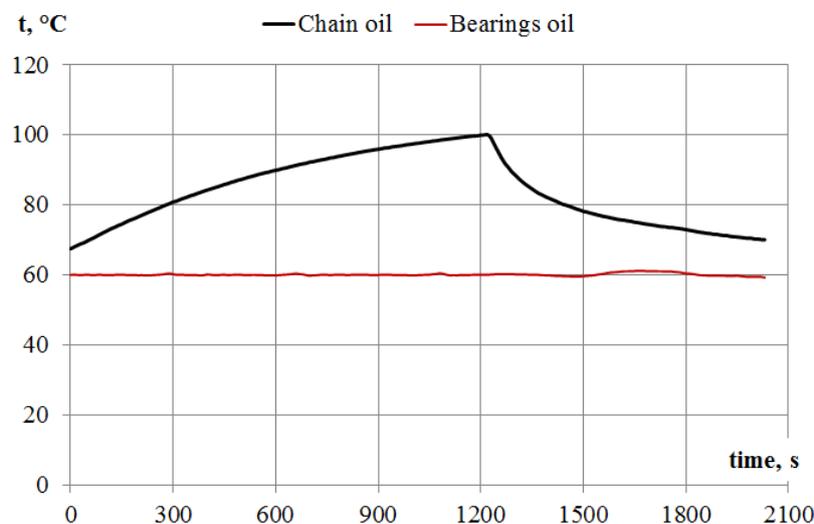


Figure 3. Time depending chain and bearings oil temperature during a test.

Figure 4 presents, for the same test, time depending chain and bearings oil pressure.

The analyses of the results presented in figures 3 and 4 allow us to draw few conclusions:

- Chain oil temperature is increasing slower and faster decreasing, especially at the beginning of cooling;
- Chain oil pressure decreases with increasing temperature and increases back during cooling; we tested this influence on friction and it is not important.

Figure 5 presents the measured global friction torque depending on chain oil temperature, for the two stages of increasing temperature and decreasing temperature.

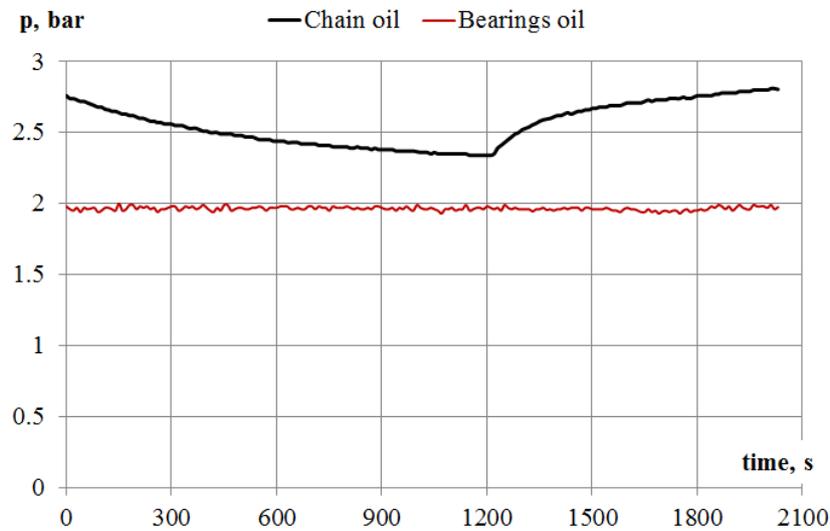


Figure 4. Time depending chain and bearings oil pressure during a test.

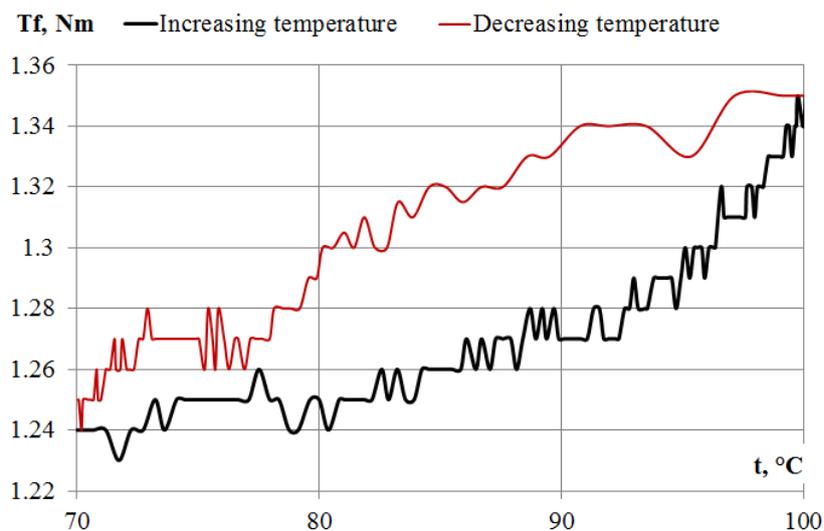


Figure 5. Global friction depending on chain oil temperature.

The change of global friction comes from the change in chain friction since the bearing friction conditions are about the same. This means that chain friction increases with increasing oil temperature (decreasing oil viscosity). Friction in the cylindrical joints of the chains is the main friction that must be considered [7]. According to Stribeck's curve, this variation shows the presence of boundary or mixed friction in the joints of the chain. A decrease of chain oil temperature from 100 °C to 70 °C determines a decrease of chain friction of about 9 % of the global friction in this basic transmission.

The values of the global friction torque are bigger during decreasing temperature than during increasing temperature. The difference could be explained by the difference between the temperature of the oil and the temperature of the parts involved in friction (links, sprockets, even bearings casings). During increasing temperature, temperature of the parts is lower than the measured oil temperature, so at the contact in joints, conditions of lower temperature create lower friction. For the cooling process, temperature of the parts is bigger than the measured oil temperature, so, at the contact in joints, conditions of higher temperature create higher friction.

The difference between measured torque at 100 °C and measured torque at 70 °C, ΔT_f 100-70, represents chain friction reduction with reducing chain oil temperature. Figure 6, a presents ΔT_f 100-70 resulted from tests at different rotational speed. Figure 6, b presents the calculated gain in power obtained by reducing chain temperature from 100 to 70 °C, ΔP 100-70. Influence of speed on torque reduction is not very important, but at level of power reduction it becomes really important.

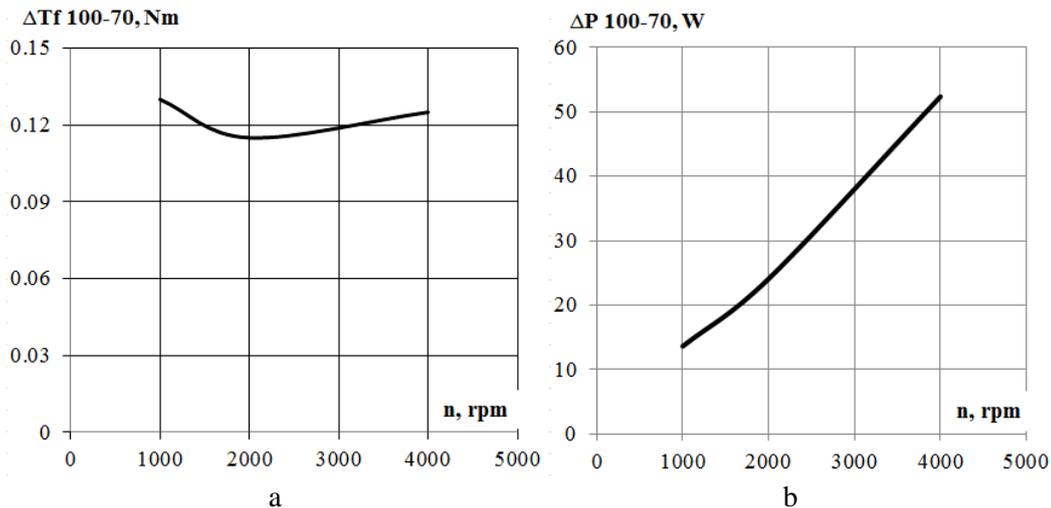


Figure 6. Torque (a) and power (b) gain reducing chain temperature from 100 to 70 °C vs. rotational speed.

3. Conclusion

This paper shows that friction in silent chains increases with increasing oil temperature.

The reduction of silent chain friction by reducing the functioning temperature of the chain may be a very simple direction in improving the efficiency of combustion engines and this paper gives information on how much power may be saved with this solution.

4. References

- [1] Holmberg K, Andersson P and Erdemir A 2012 Global energy consumption due to friction in passenger cars *Tribol. Int.* **47**
- [2] Hyakutake T, Inagaki M, Matsuda M, Hakamada N and Teramachi Y 2001 Measurement of friction in timing chain *JSAE Review* **22:5**
- [3] Papuc R, Gavrilă C and Lates M T 2017 Tribological tests of steel on polyamide 66, polyamide 46 type surface contacts *MATEC Web Conf.* **126** 02003
- [4] Papuc R, Gavrilă C and Lates M T 2017 The study of chain link/guide contact in relative alternative translational motion *MATEC Web Conf.* **126** 01003
- [5] Lates M T, Velicu R G and Papuc R 2014 Multiscale modeling of chain-guide contact by using tests and FEM *WCCM 2014*
- [6] Velicu R and Lates M 2015 On the measurement procedure for testing friction in bearing mountings *AUO-FMTE XXIV (XIV)*
- [7] Niemann G 1975 *Machinenelemente Band II* (Berlin: Springer Verlag)