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EXPERIMENTAL STUDY OF BEARING BOXES FRICTION DEPENDING ON LOAD SPEED AND OIL TEMPERATURE

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***Abstract*—**The subjects of this paper are the bearing boxes of a testing rig for chain drives. Friction in transmission without bearings is calculated by subtracting the bearing friction from the global friction. This is why it is of maximal importance for the correct evaluation of experimental measurements on the rig to have accurate data on the friction on bearing boxes. Bearing boxes friction is measured depending on rotational speed, load and lubricating oil temperature.

***Keywords*—**Bearing boxes, friction, load, speed, viscosity

I. INTRODUCTION

THIS paper deals with the first stage of research on chain drive friction: evaluation of bearing boxes friction of a basic chain drive with transmission ratio equal to 1. The final goal of the research is the evaluation of friction losses in chain drives depending on rotational speed, tensioning, temperature and quality of lubrication.

Very few experimental results on chain friction have been published. Technique for measuring friction loss in the timing chain and in the guides of an engine, using specific equipment developed on a full engine is presented in [1]. The results are timing chain system losses separated into components, at a constant speed and temperature, with no reference on tensioning.

The research developed at the Transilvania University of Brasov is using a friction chain rig with the functional diagram presented in Fig. 1. It allows to control and measure the rotational speed at input shaft, chain tensioning (F) and temperature of the lubrication oil used for chain and bearing boxes. The measured input torque (T) is a sum of the friction torques from: input bearing box $T_{fbearing1}$, output bearing box $T_{fbearing2}$ and from the chain T_{fchain}. Friction in the chain is then calculated by subtracting the bearing boxes friction from the measured input torque [2]. An accurate measurement of the bearing boxes friction is very important.

This paper presents the measured friction torque in bearing boxes, depending on rotational speed, load and lubricating oil temperature.

The global friction on these bearing boxes is a sum of friction in bearings and sealing elements, with important influence of the lubricating circuit. It is difficult to separate and identify with accuracy each friction and evaluate all the influences [3].

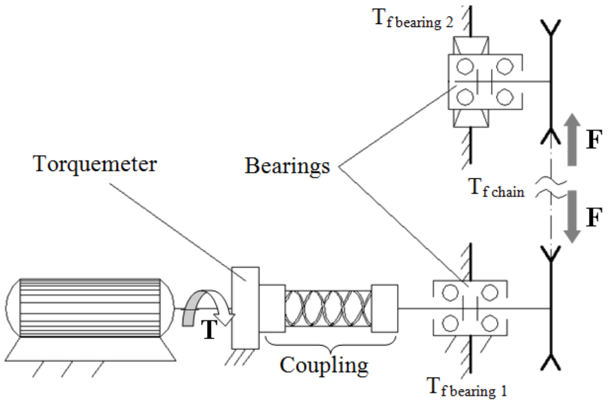

Fig. 1. A functional diagram of the friction chain rig.

As presented in the calculus model of bearing friction from the producer [4] and from other experimental measurements [5], the global friction depends on rotational speed, radial load (there is no axial load in this case), bearings and sealing types, type of lubrication and oil viscosity. Calculus relations show that the friction torque in a bearing increases with the increase of applied load, an increase of rotational speed and increase of lubricant viscosity. The analyses of these influences on bearing boxes friction is presented in [6]. Author's opinion is that theoretical models cannot be considered as highly accurate and only experimental measurements of bearing boxes friction, copying exactly the conditions of functioning give an accuracy of results.

II. BEARING BOXES DESCRIPTION

Figure 2 presents the lower bearing box. The upper bearing box is similar but not identical. Both bearing boxes consist of: one deep groove ball bearing 6206 (1), which takes radial force and possible axial forces in both directions; one single row cylindrical roller bearing with two shoulders NU 2305 (2), taking the most important radial force; sealing rings (3) at both ends; lubrication with low pressure oil circuit.

Both bearing boxes are loaded with radial force F positioned as in the chain drive tensioning situation. Radial forces on bearings depend on the position of force F. There is no influence on the bearing friction from the torque used for mounting or demounting the sprockets.

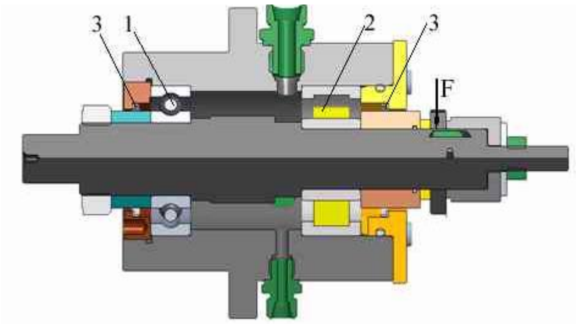

Fig. 2. Lower bearing box.

III. Equipment and Testing Procedure

The measurement device for the bearing boxes friction is adapted on the chain friction rig presented in Fig. 1. Fig. 3. shows the functional diagram of the bearing boxes friction measurements device. The upper and lower bearing boxes are coaxially mounted, head to head, connected with a mobile coupling [2]. The connection must assure that the torque is transmitted between the two shafts but also that the reduced loads on shafts end are only radial forces and not bending moments.

The radial force F is applied through the tensioning system of the testing rig and a rigid element, mounted on the sliding carriage and the upper bearing box. It is placed exactly in the position where it acts in the case of the chain drive.For correct measurements, mostly important is that the same conditions of running are used as in the case of testing the chain drive. The same tensioning device, lubrication and drive systems and their instruments for measurement and control are used (see Fig. 1.).

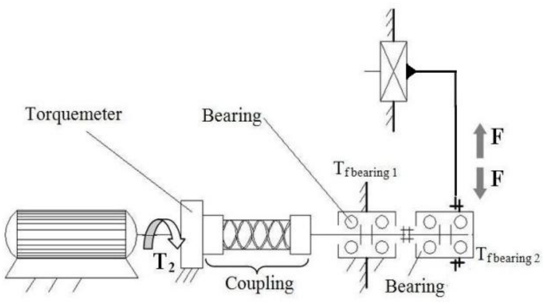

Fig. 3. A functional diagram of the bearing friction measurement device.

The testing procedure and preparation of the rig are presented in detail in [7]. Several aspects like deformations, time depending parameters, measurement conditions and strictly following procedures have maximal importance.

The testing program is consisted in steps of constantly controlled parameters (rotational speed, tensioning force and oil temperature). The first step is usually longer since it must check and adjust the oil temperature and also stabilize the temperature distribution on all the elements of the rig. The time for each step is minimum 250 seconds. The role of these steps is to stabilize the system and create the steady state conditions. The readings that count in the evaluation of bearing friction are only the one of the steady state period [7].

Bearing friction torque (T_b) has been measured for:

1) Rotational speed, n: 500, 1000 1800, 3000, 5000 rot/min;

2) Tensioning force, F: 0.5, 1, 2, 3 kN;

3) Oil temperature for bearings lubrication, t:35, 50, 60 °C.

The tests have been repeated 3 times and an average of the results has been considered.

The oil used in bearing lubrication is Castrol Edge 5W30 and the measured viscosity depending on temperature is presented in Fig. 4., showing a sharp decrease with the increase of temperature at lower temperatures.

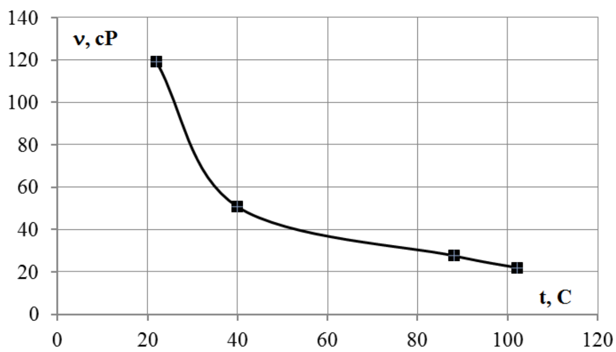

Fig. 4. Kinematic viscosity versus temperature.

IV. Experimental Results

Fig. 5. presents the diagrams for bearing boxes friction torque depending on rotational speed and tensioning force, for three steps of lubricating oil temperature.

Fig. 6. presents the diagrams for bearing boxes friction torque depending on oil temperature and tensioning force, for four steps of rotational speed.

Fig. 7. presents the diagrams for bearing boxes friction torque depending on tensioning force and oil temperature, for four steps of rotational speed.

Fig. 8. presents the diagrams for bearing boxes friction torque depending on oil temperature and rotational speed for four steps of the tensioning force.

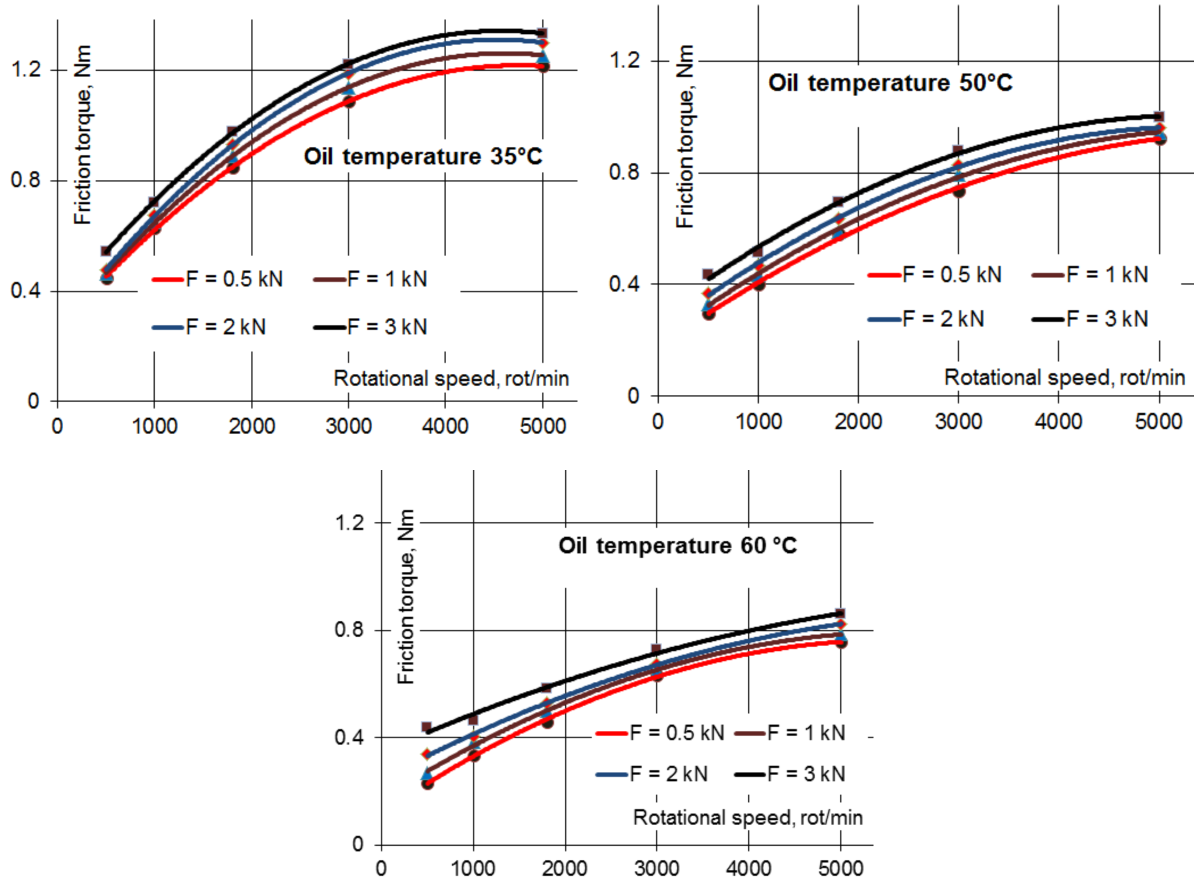

Fig. 5. Bearing boxes friction torque depending on rotational speed.

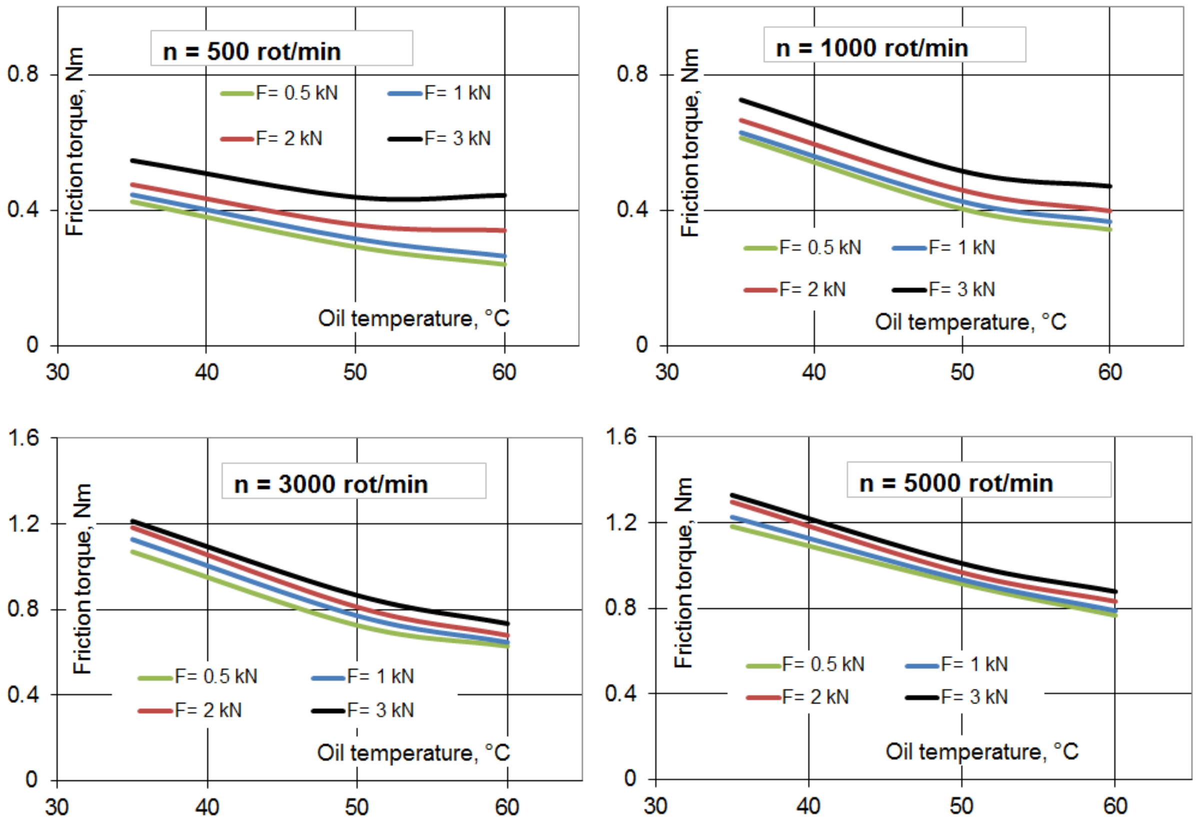

Fig. 6. Bearing boxes friction torque depending on oil temperature.

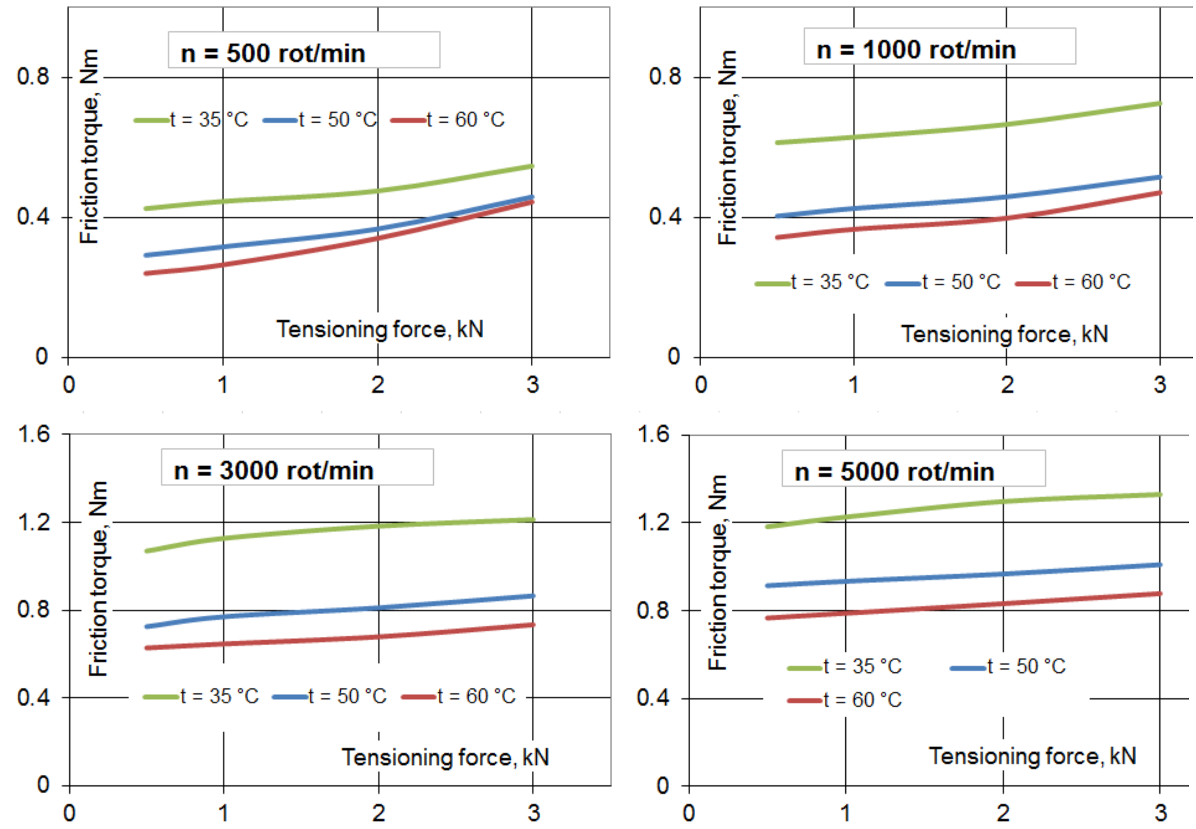

Fig. 7. Bearing boxes friction torque depending on load.

The results show the increase of bearing friction with rotational speed and load and also with a decrease of oil temperature (an increase of viscosity). The trends are according to the theoretical models from [4], analyzed in [6].

The influences of speed, temperature and load on bearing friction torque are:

1) *Speed influence* (see Fig. 5.): a 10 times increase in the rotational speed (from 500 to 5000 rot/min) generates an approx. 3 times increase of the friction torque. Speed influence is bigger for lower speed than for higher speed (convex shape of the T_b (n) curves); Speed influence is bigger for smaller temperatures 35 °C (higher viscosity) than for higher temperatures 60°C (lower viscosity); The curves T_b (n) tend to be linear in case of high loads and high temperatures (low viscosity);

2) *Temperature influence*: (see Fig. 6.): an increase in temperature from 35 to 60°C (3 times decrease of viscosity) generates a maximum 50% decrease in the friction torque; The influence is smaller in the case of high loads and small rotational speed;

3) *Load influence* (see Fig. 7.): a 6 times increase in the load (0.5 to 3 kN) only generates an increase with 20-40% of the friction torque, the bigger influence is in the case of low rotation and higher oil temperatures (low viscosity).

V. Conclusion

Friction in bearing boxes can be theoretically evaluated based on models for friction in bearings and sealing elements. An accurate evaluation needs, however, experimental measurements since the differences between friction behaviors of different bearings are impossible to predict.

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