Assembly of bearing units with pre-stressed tapered roller bearings

Ing. Pavel Syrovátka

Vedoucí práce: prof. Ing. Dynybyl Vojtěch, Ph.D

Abstrakt

Tento článek pojednává o problematice předepínání kuželíkových ložisek v ložiskových jednotkách používaných v zemědělské technice. V náročných podmínkách mají největší uplatnění robustní a konstrukčně jednoduchá řešení ložiskových jednotek. Tato řešení mnohdy neumožňují stanovit správnou předepínací sílu. Měřením průběhu teploty a pasivních odporů v závislosti na velikosti předpětí, byla určena velikost předpětí, při nichž nedochází k nadměrnému ohřívání ložisek. Pro montáž byla doporučena velikost předpětí, která bude kontrolována měřením pasivních odporů.

Klíčová slova

Předpětí, kuželíková ložiska, diskový podmítač

1. Introduction

Technical progress and society places high demands on the technical advancement in all sectors of industry including agriculture. Increasing the value of the machines can be achieved in several ways. For example it could be development of new technology or optimization of current technology. Optimization of current technologies is considered in this work.

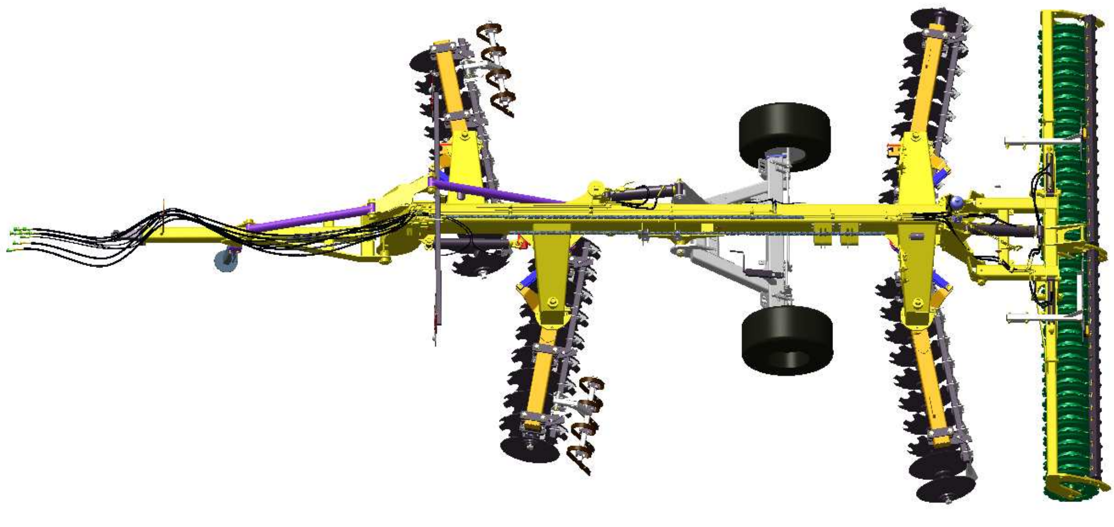

Fig. 1. *Disc cultivator*

For intensive cultivation of crops such as wheat, barley, corn, etc. is required processing of the soil. The historical development of agricultural technology has brought some soil processing technologies, which are effective and economical. These include shallow tillage disc harrows (Fig. 1.). Disc harrow works on the principle of drawn disk that is about 5 to 10 centimeters in the soil, which has the axis of rotation perpendicular to the direction of drive. The achieved result is disrupted top of soil, mixed soil with crop residues and interrupted capillarity of the soil. Individual discs can be separately attached to the suspension design, or about 10 pieces can be mounted on a common shaft (Fig. 2.).

Fig. 2. *Discs mounted on common shaft*

This construction have shaft stored in 2 or 3 bearing units. Bearing units consist of a pair of tapered roller bearings. This is the best combination to resist radial and axial load generated by the weight of machine and by disks angle with the direction of drive.

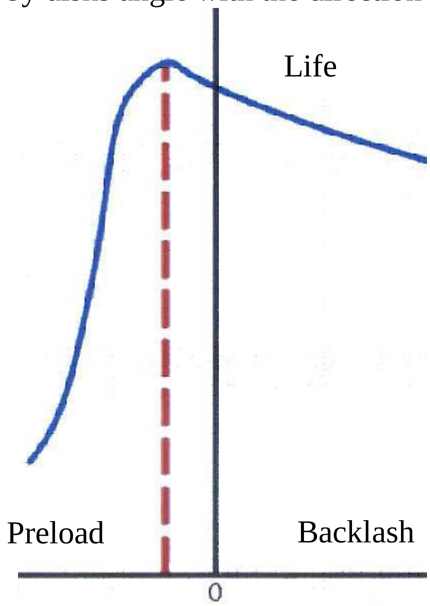

Fig. 3. *Life of tapered roller bearing*

The correct bearing preload affects mainly his life (Fig. 3.). The other parameters such as noise reduction, improved accuracy, etc. in this application are not a big emphasis. The design of this preloaded house bearing does not allow fine tuning and finding tensioning forces. Furthermore, there are no precise operational loads. They are only available to the estimated angular velocity. Proper tension will be determined with thermocouples, which will record the temperature in the generator bearings due to friction torque. Friction torque (torque M) will be recorded and this value will be the standard for installation. The friction torque is composed of rolling friction, sliding friction (deformation at the contact surfaces of roller and ring leads to the sliding surface itself), and the friction caused by shaft seals and wading in grease resistance. In the first phase, we measure the frictional torque and the temperature of the bearings without radial shaft seals. In the next stage we find an increase of frictional torque by

adding radial shaft seals. Size preload is adjusted by changing the number of seals under the cover (Fig. 4.)
Bearing temperature is measured on its outer ring. The temperature of the inner ring is by 5 to 15° C higher. This may cause dilatation of different hollow shaft and the bearing house, along with a different coefficient of thermal expansion of both parts. The result is an X arrangement of tapered roller bearings reducing axial clearance, respectively increasing preload, which will increase the frictional torque and generate more heat. If the system generated enough heat to cool itself, there is a further increase of temperature and preload till the seizure. Standard bearings are capable of operating at temperatures up to 120 ° C, used lubricant Mogul LV 2-3 is able to withstand a maximum temperature of 80 ° C.

2. Goal of work:

The goal is to determine the torque of rotation M of the hollow shaft house bearing assembly for the optimum preload of tapered roller bearings.

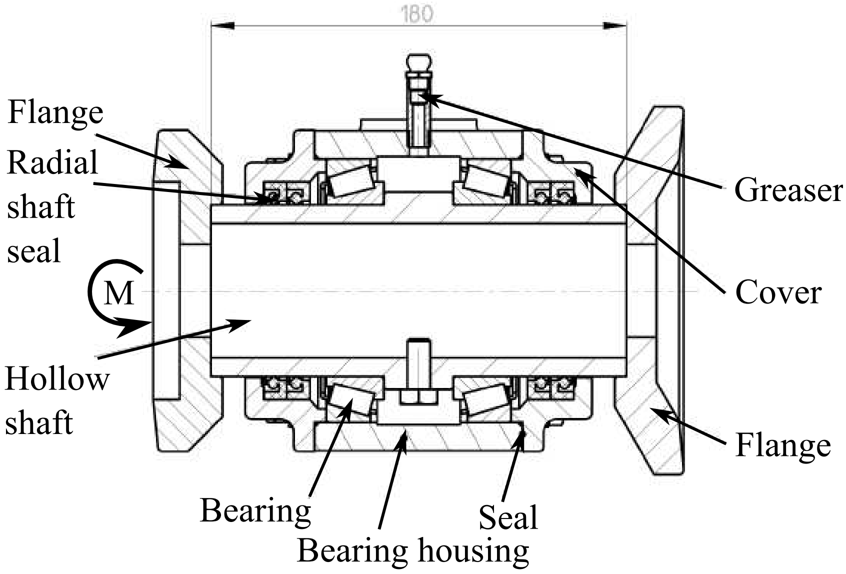

Fig. 4. *Scheme of bearing unit*

3. Design of test equipment

Diagram of test equipment (stand) is in Fig. 5. Measurements were made in the laboratory of Department of Designing and Machine Components, Faculty of Mechanical Engineering, CTU in Prague.
Electric motor is controlled with a frequency convertor. The electric motor is connected to the torque sensor using bellows couplings. The second bellows is connected to the clutch shaft, which transmits torque to the hollow shaft bearing housing (Fig. 6.). Into the bearing housing are drilled two holes with a diameter of 6 mm for thermocouples, which measure the temperature on the outer ring (Fig. 7.). Electric motor and bearing housing are attached with clamps to the grid. Torque sensor and thermocouples are connected to a PC measuring card, which records both quantities (Fig. 8.).

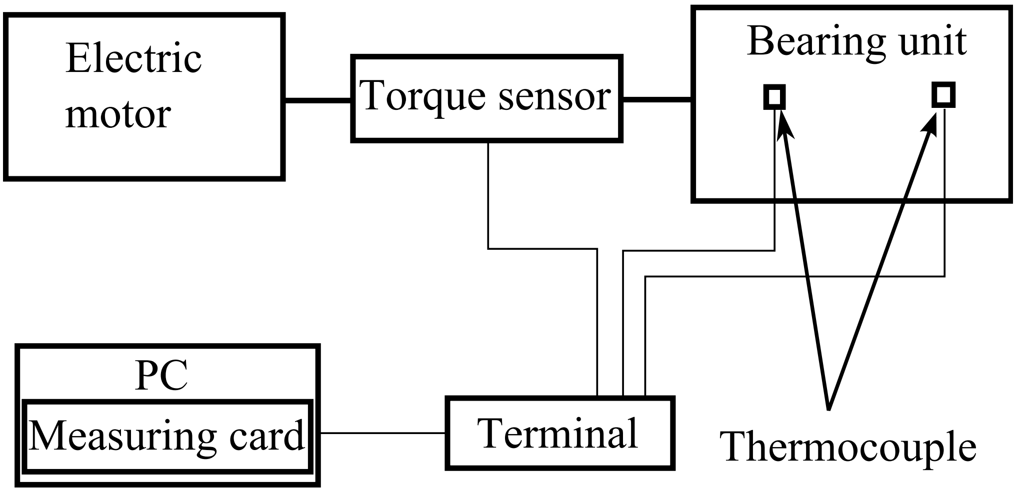

Fig. 5. *Scheme of stand*

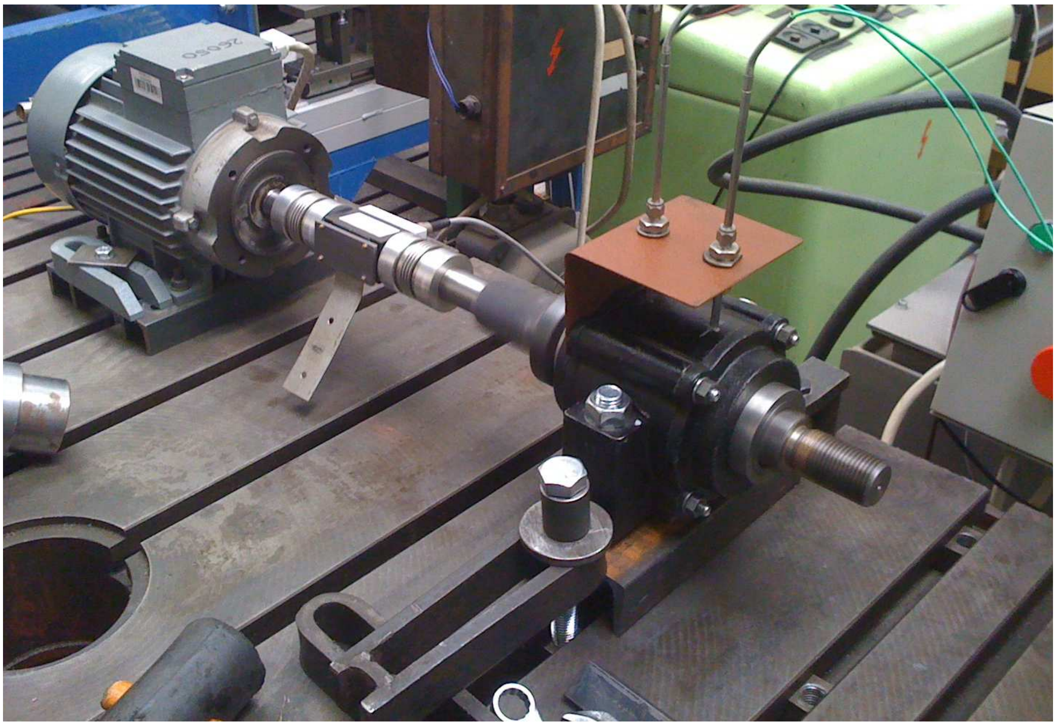

Fig. 6. *Testing stand*

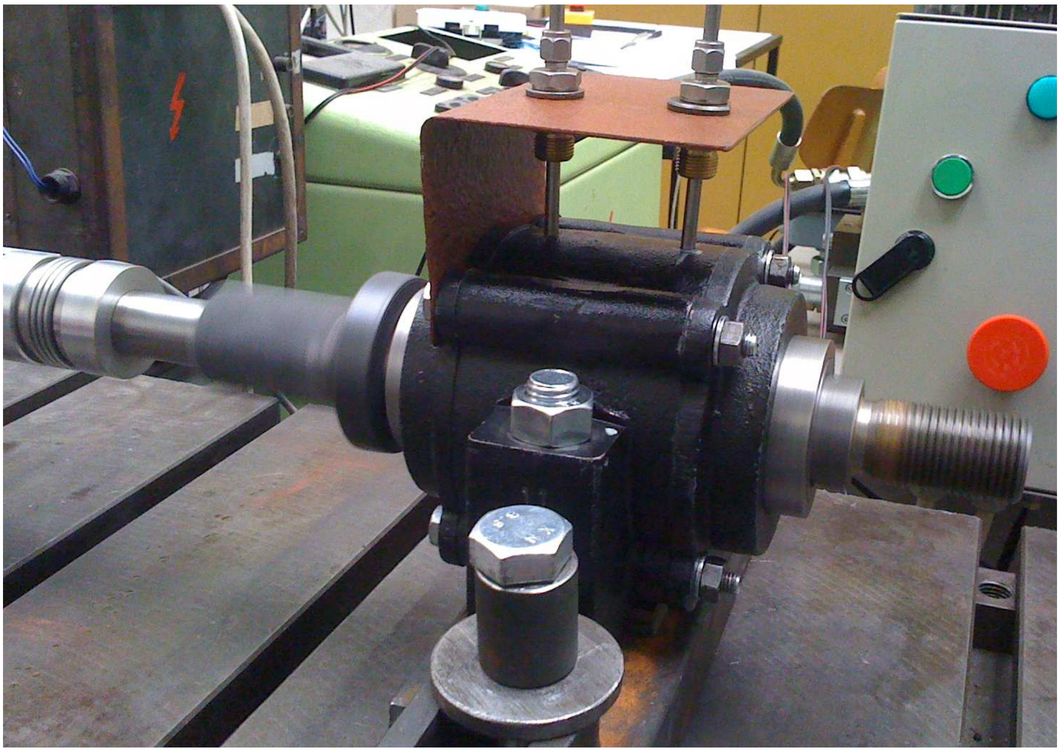

Fig. 7. *Detail of bearing unit with thermocouples*

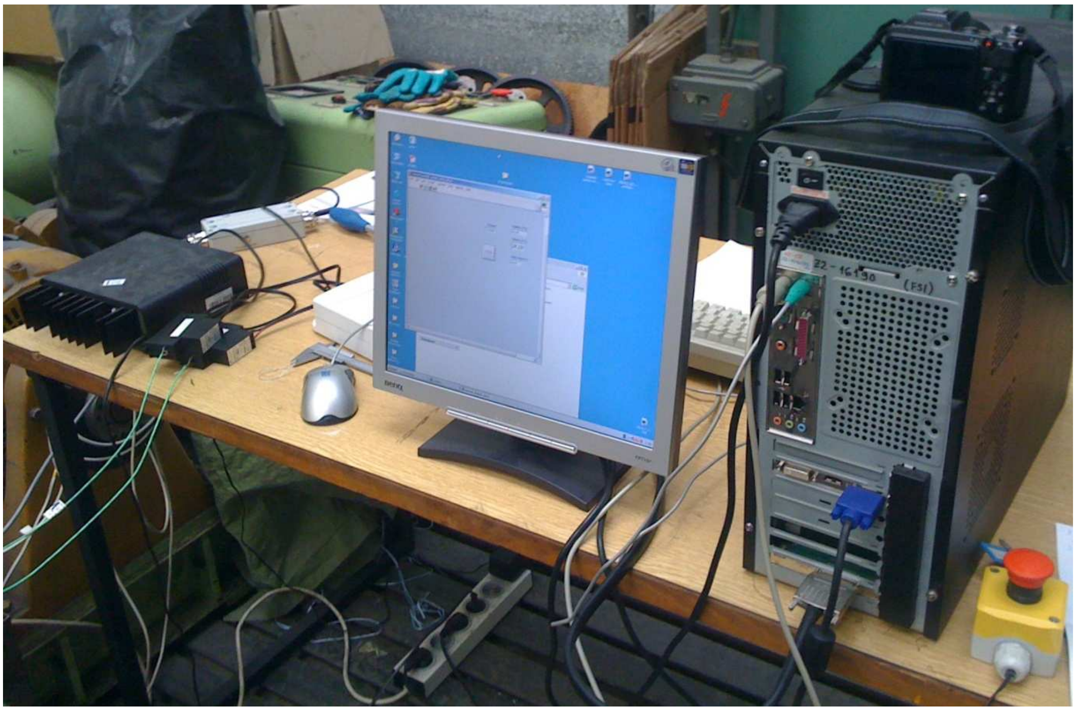

Fig. 8. *PC with measuring card*

4. Components of Test Stand

Electric motor *MEZ Mohelnice 4AP100L-4s*
Torque sensor *HBM T20WN*
Thermocouple *Bartex TBX 68T*
Thermocouple voltage convertor Rawet PXN24
Measuring card *PCI – 6221 from firm National Instruments*
PC software LabWiev 2009

5. Draft of angular velocity

Bearing speed for operation is given by diameter of the disk and the machine speed *v=15km/h*. Diameter of new disk is *D1=600 mm*, diameter of worned one is *D2=500 mm* and less. Speed *v* from the perspective of the manufacturer is maximal and in the actual operation is lower.

$$\omega = \frac{v}{\pi \cdot D} \quad [rpm] \tag{1}$$

$$\omega_1 = 132{,}7\ rpm$$

$$\omega_2 = 159{,}2\ rpm$$

Maximum angular velocity in terms of the theoretical calculation based on approximately *160 rpm*. To accelerate testing, we choose the speed of bearings **200 *rpm***.

6. The measurement procedure

a) Assembling of bearing house assembly, filling the bearing by lubricant Mogul LV 2 – 3.
b) Setting the alignment of electric motor and bearing house, connecting the torque sensor.
c) Setting preload with a seal and tighten screws to specified torque.
d) Insertion of thermocouples into the bearing house.
e) Turn on recording of the moment M and temperatures from thermocouples.
f) Set electric motor speed on drive.
g) Starting electric motor.
h) After stabilizing the temperature in the bearings turning off the electric motor
i) Turning off the recording of torque and temperature.

In other changes preload, respectively change of the seal was not necessary to release the bearing housing from the grate, and analyze the sensor connection moment. It was possible to go from point 3.

7. Results

The results of warming of the bearing unit are in Fig.9

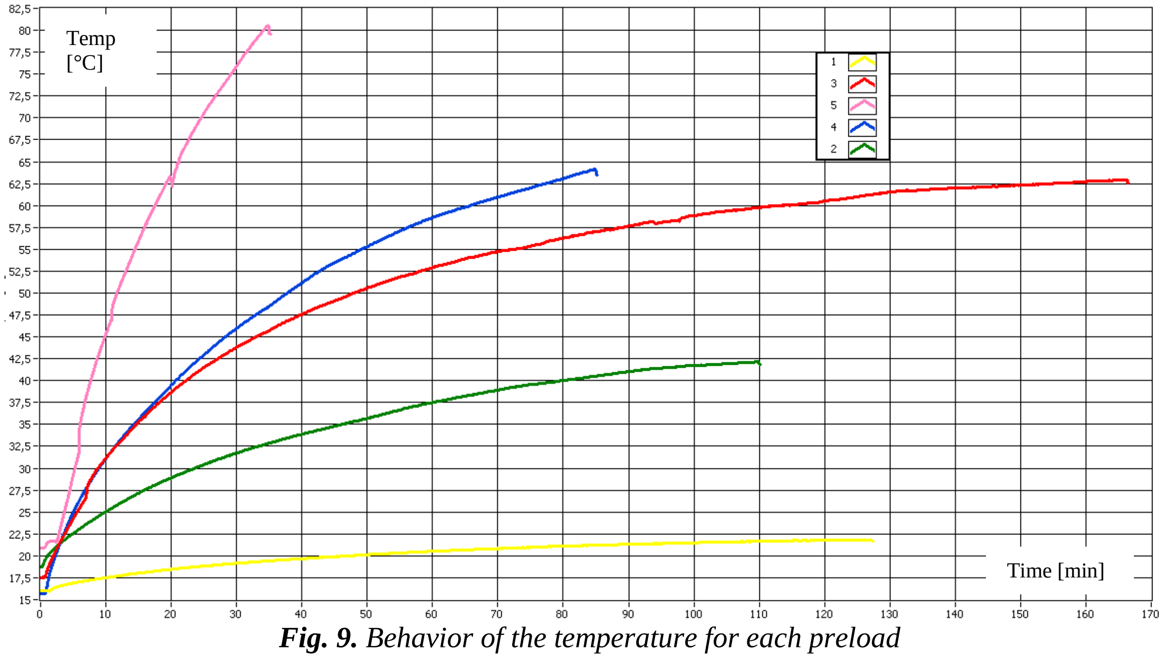

Fig. 9. *Behavior of the temperature for each preload*

Table 1. - *List of individual measurements*

Number of measur.	**Radial shaft seal**	**Color in graph**	**Number of seals**	**Screw torque [Nm]**	**Angular velocity [rpm]**	**Starting torque M [Nm]**	**Ending torque M [Nm]**	**Ending temp [°C]**
1	No	yellow	2	50	200	1,5	1	22
2	**No**	**green**	**1**	**17**	**200**	**4,5**	**3,3**	**42**
3	No	red	1	30	200	11	5,5	62
4	No	blue	1	50	200	11	6,5	64
5	No	pink	0	30	200	15	7	81

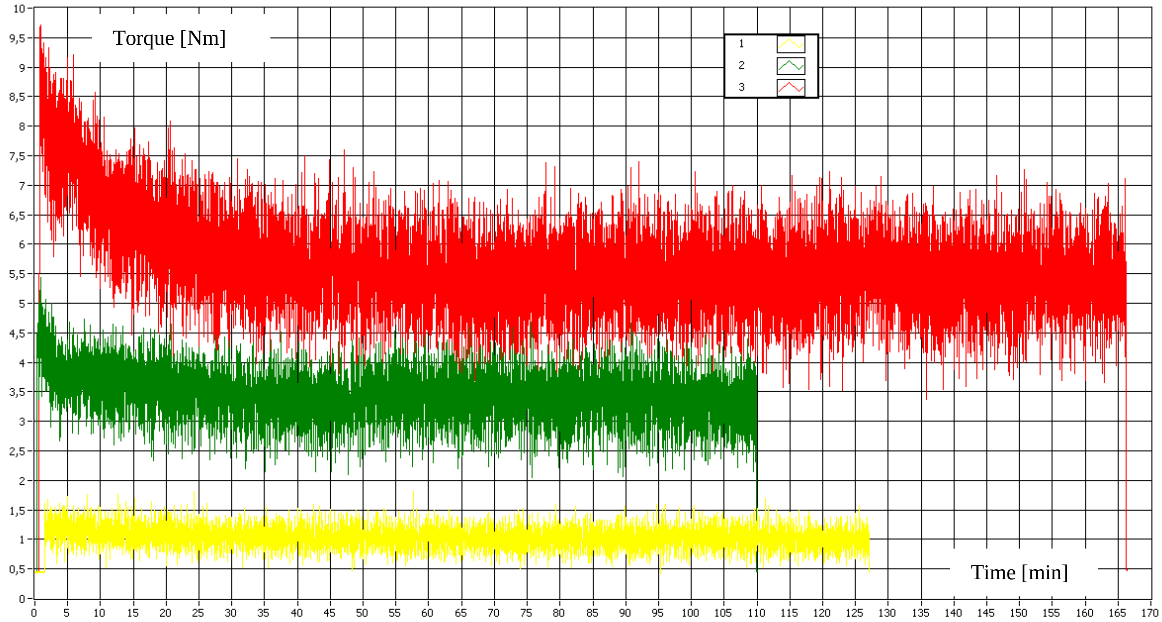

Fig. 10. *Torque behavior of measurement No.1, No.2, and No.3.*

Measurement No.1 (2 seals, without radial shaft seals) did not show any increase in temperature. After two hours bearing was heated at temperature from 16° C to 22° C. The temperature increase is minimal and can be considered as the lower value of preload. The values of torques are enlarged for clarity 10 times.

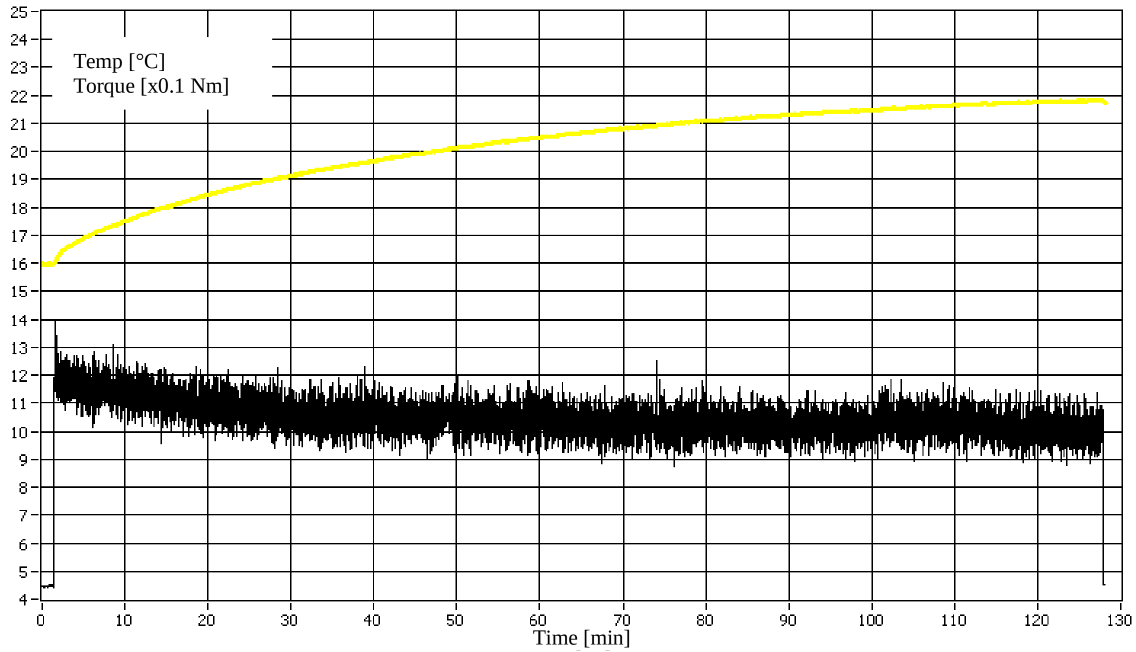

Fig. 11. *Temperature (yellow) and torque (black) behavior of measurement No.1*

Measurement No. 2 (1 seal, without radial shaft seals) showed quiet operation and after 1 h and 50 minutes, the bearing heated from 16 ° C to 42 ° C. This preload can be set as a maximum. The operation will increase the load bearing reactions and thus greater heating of bearings. On the other hand, we can expect running-bearing and thus reduce preload, and reduce heat in the loaded condition.

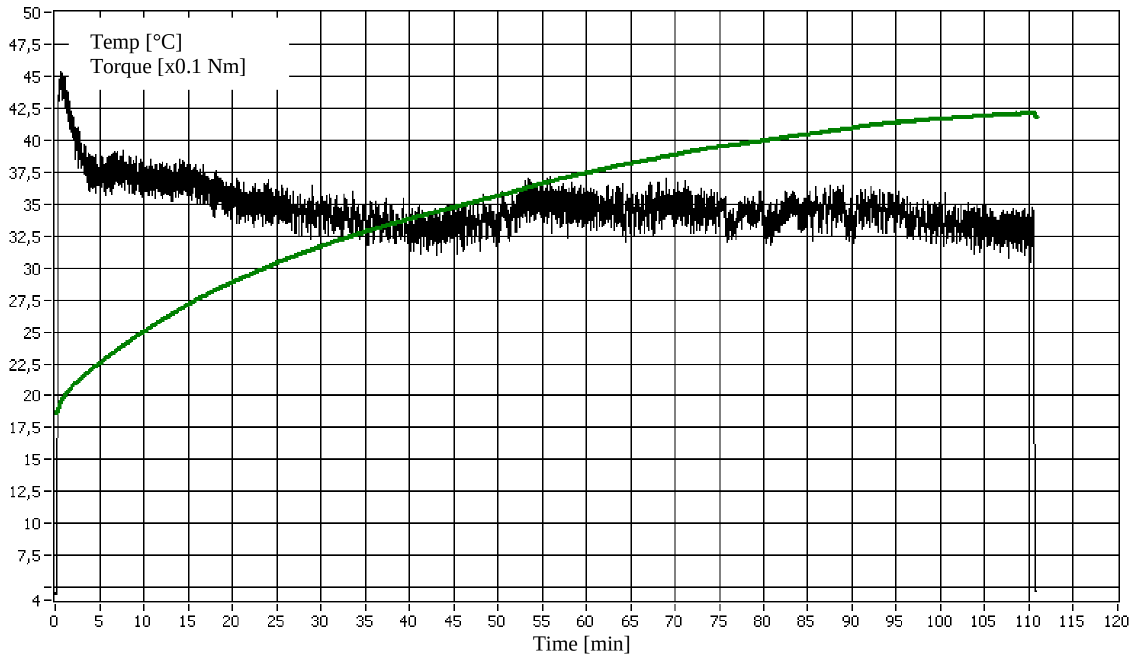

Fig. 12. *Temperature (green) and torque (black) behavior of measurement No.2*

Measurement No.3 and No.4 (1 seals, without radial shaft seals) and No.5 (no seals, without radial shaft seals) showed a faster increase of temperature and equilibrate at 62 ° C, the other more. This setting is no longer appropriate, given that operation will increase in the bearing reactions due to external loading.

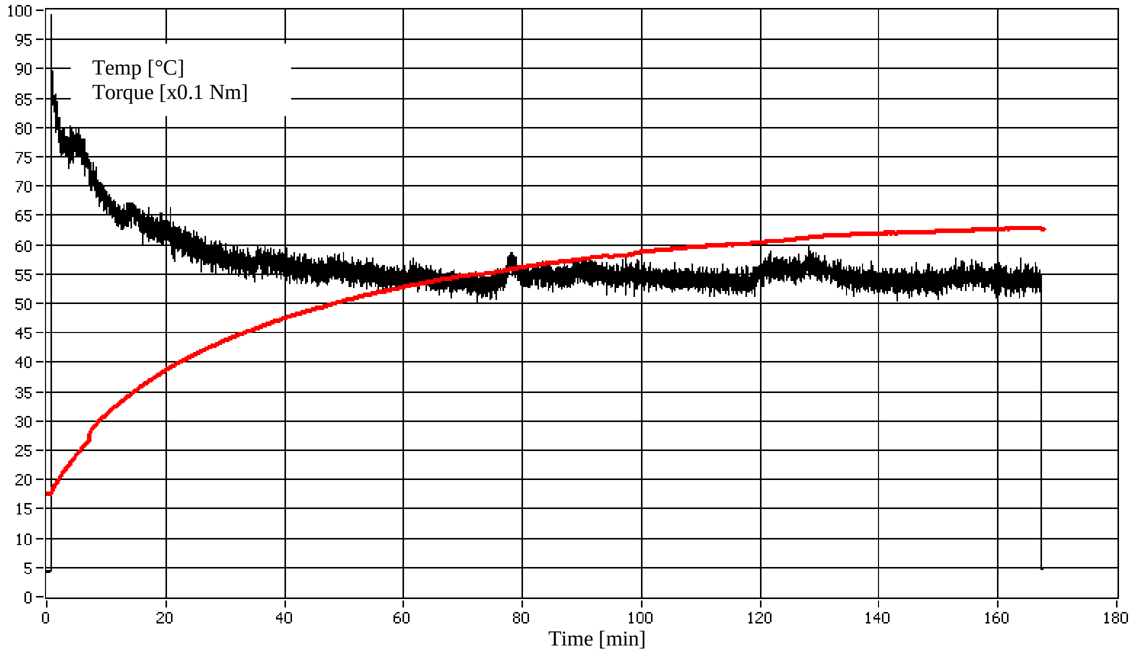

Fig. 13. *Temperature (red) and torque (black) behavior of measurement No.3*

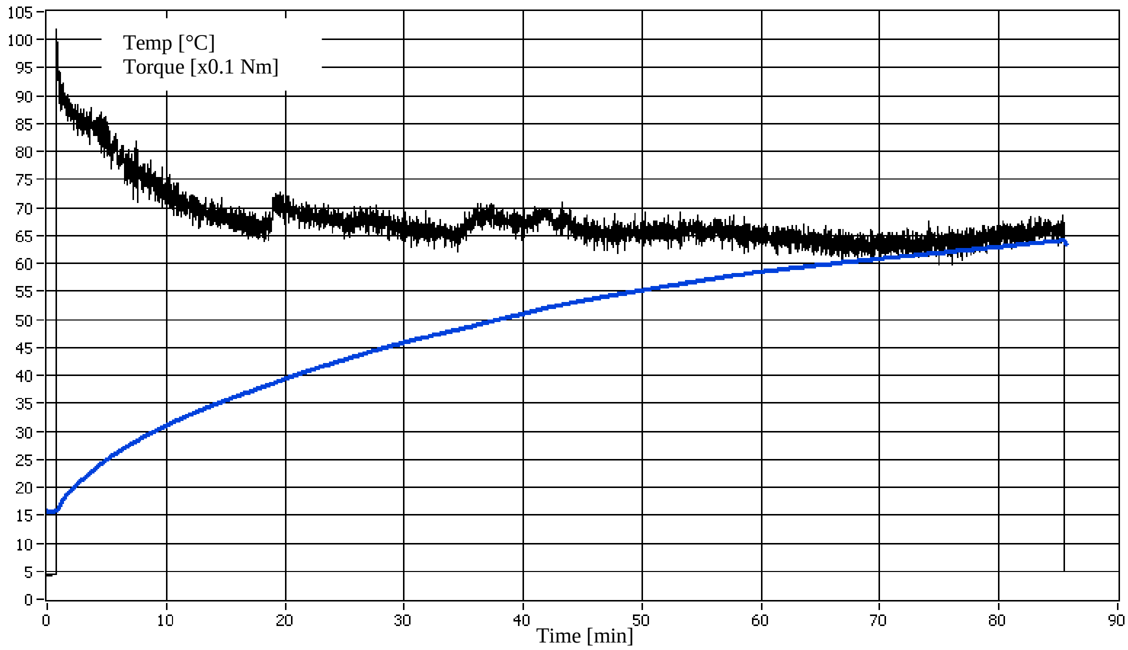

Fig. 14. *Temperature (blue) and torque (black) behavior of measurement No.4*

Radial shaft seals were added to the bearing housing for measurement No. 6 (1 seal, with radial shaft seals) and the measurement had the same value of bearing preload as measurement No. 2. Seal blades are lubricated with grease. The increase of torque M by adding seals is about 10 Nm. Measurement No. 6 goes only few minutes and it is not plotted. Measurement No. 7 continues the measurement No. 6. After one hour of measuring bearing house was heated from 18 °C to 58° C. Increased warming is caused by a bearing house larger friction from the seals.

Measurement No.8 (1 seal, with radial shaft seals) had the same value as the No.2 preload was used new radial shaft seals. The temperature increase is comparable with the measurement of No.7. In Fig. 15 is a noticeable decrease in torque M caused by running-in of seals.

Table 2. - *List of individual measurements*

Number of measur.	Radial shaft seal	Color in graph	Number of seals	Screw torque [Nm]	Angular velocity [rpm]	Starting torque M [Nm]	Ending torque M [Nm]	Ending temp [°C]
2	**No**	**green**	**1**	**17**	**200**	**4,5**	**3,3**	**42**
6	Yes	no plot	1	17	200	15	11	-
7	Yes	purple	1	17	200	11	6,5	58
8	**Yes**	**orange**	**1**	**17**	**200**	**14**	**7,5**	**53**

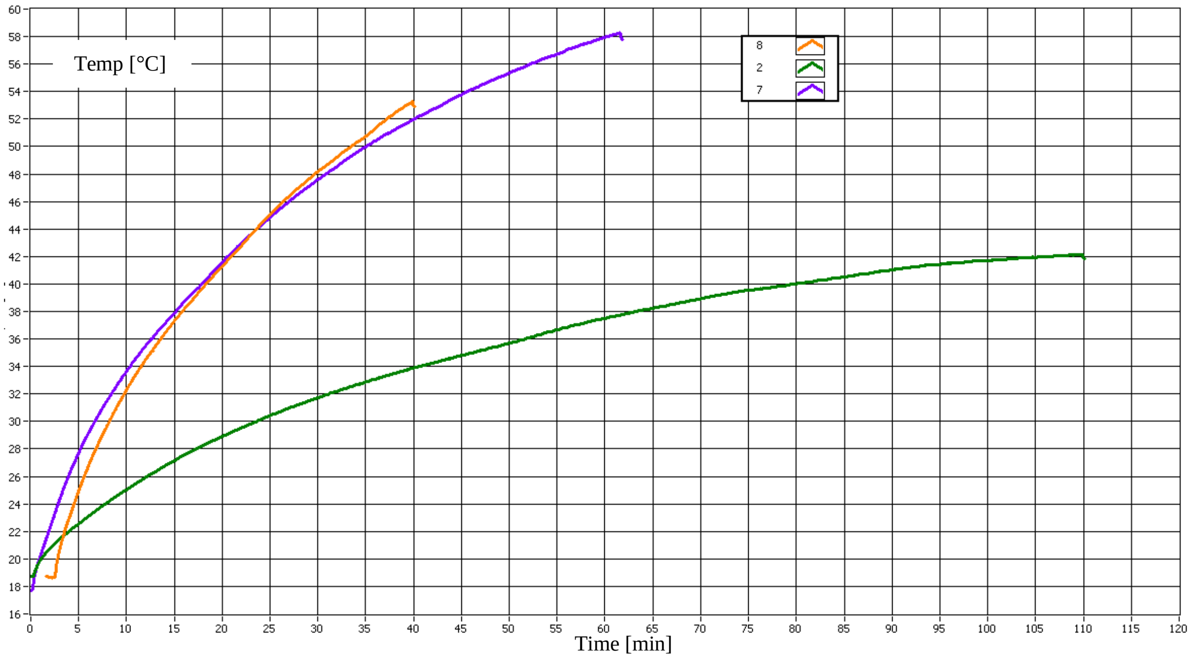

Fig. 15. *Temperature behavior of measurement No. 2, No. 7, No. 8*

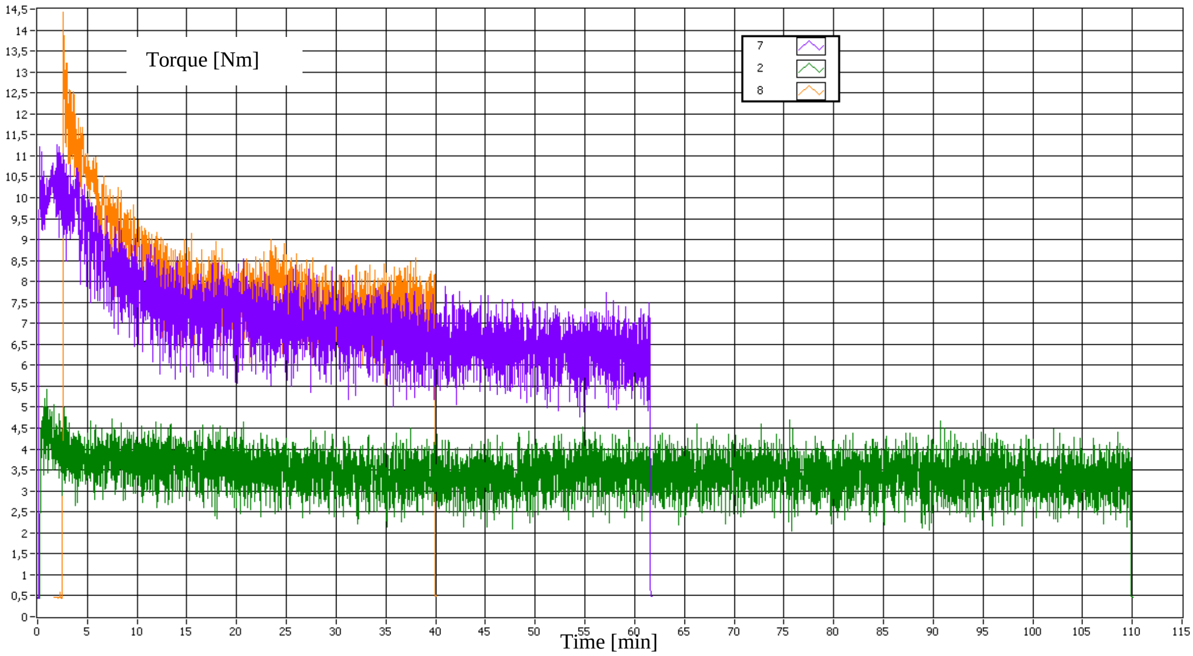

Fig. 16. *Torque behavior of measurement No. 2, No. 7, No. 8*

8. Recommendations for installation

a) During assembly of bearing house lubricate bearings and edges of radial shaft seals with grease.
b) Assemble a house without a seal.
c) Try if the hollow shaft rotates after tightening.
d) In case of excessive force, or if you cannot turn hollow shaft, it is necessary to add another sealing under cover.
e) Turn prepared crank up 10x or 15x hollow shaft for running seals.
f) Check with torque wrench torque M of hollow shaft. It should be between 10 to 15 Nm.
g) If no torque M in the desired range, it is necessary to increase the seal to lose momentum M or add additional sealing to reduce the torque M.
h) Fill the bearing unit with grease.

9. Conclusion

During the measuring temperature rise bearing house loaded only by its own preload, we found the value of torque M (frictional torque) and the values increase in temperature for each fitting setting. Used seals, which set the level of preload tapered roller bearings, are not suitable for fine tuning optimal preload. The Fig. 9. shows big differences between the settings of 1, 2, or without seals. For measurement No. 2 was achieved starting torque 4.5 Nm only because they were cramping screws and caps bearing housing only tightening torque 17 Nm. This value is not suitable for running as there is permission and disgruntled by preload or loss of some element bearing house during operation. For better tune preload recommend using a thinner seal.

Adding radial shaft seals torque M increased by 10 Nm. Seals will be important in spreading the blades, which reduces the frictional torque.

The values of moment M should be in the preload between 10 Nm to 15 Nm. At the moment there is a lower value of play in the bearings, which may not be noticeable because the shaft seals Cup. A higher value can cause overheating and bearing seizure.

List OF symbols

v	machine speed	[km/h]
D	diameter of disk	[mm]
ω	angular velocity	[rpm]
T	temperature	[°C]
M	torque	[Nm]
t	time	[min]

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