THE EVALUATION OF THE RESULTS OF THE MEASUREMENT OF THE TEMPERATURE IN SLIDING JOINT BY THERMOCOUPLE AND THERMAL CAMERA

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Abstract: The friction occurs in place, where moving bodies (e.g. bearings) contact each other and this friction is accompanied by the increase of material temperatures. When the increase of the temperature is very big, the material can seizure thus functional areas can be damaged. This contribution deals with the measurement of the temperature at the surface of the contact area of the rotational sliding pair. The values of the temperature obtained by the thermocouple and by thermal camera during the experiment are compared. The rotational sliding pair was created with a couple of brass bushings. Tests were conducted the equipment Tribotestor M`89 (loading force, sliding speed, duration). The work helps to increase intellectual and practical skills of students of technical universities in those subjects, which deal with methods of temperature measurement and measurement of technical quantities in general.

Key words: temperature, thermocouple, thermal camera, sliding pair

1 Introduction

Machine components are basic elements of all machines, production lines. The active parts of all components are in contact either with the functional part of another component or with the machined material [1]. Damages (defects) of these active parts (functional areas) of the machine components are one of the most common causes of machine failures. Defect leads to the machine components inability to discharge a desired function. The thermal degradation of the material is one of the external signs of damage. The temperature is one of the most monitored parameter in the manufacturing processes, in construction industry or in the energy sector. The temperature is often perceived as a failure parameter.

Two components contacting by their sliding surfaces are denominated as a sliding pair [2]. Sliding bearing is an example of such sliding pair. In principle, the sliding bearing is a friction node, for which irreversible change of mechanical energy to thermal energy is typical [3]. In the contact place, the friction occurs and it is accompanied by materials temperature increase. Very big increase of temperature may result in the seizure of the materials and the consequent damage of functional areas.

This work deals with monitoring of the temperature at surface of the rotary sliding joint and its evaluation. The sliding node consisted of a pair of brass bushings. This pair of brass bushings represented the sliding bearing. The temperature was monitored simultaneously by two techniques, by a thermocouple and a thermal camera.

2 Sliding joint

The equipment Tribotestor M`89 is used to determinate the output characteristics of the rotary sliding joint. This equipment is located in a laboratory of mechanics of the machines at the MTF STU. On the equipment tests primarily focused to detect the friction coefficient in the respective sliding pair for various input parameters such as loading force, sliding speed and the lubricant, are carried out. Software created by MicroStep s.r.o serves for control of the machine and also for recording the test parameters, collection and archivation of measured data. In addition to monitoring of the input parameters, output parameters such as the size of the friction force (resp. friction torque), size of the friction coefficient and temperature in the contact surface of sliding pairs are recorded.

During one test only one sliding pair, which consist of an internal and external bushing (Fig. 1), can be tested. The internal bushing is fixed on a shaft and external bushing is fixed in a housing. The shaft is held to the machine´s spindle by a clamp screw. Housing and external bushing slip on the shaft with the internal bushing. The housing is immovable and selected compressive force acts on it . The size of the loading force can be chosen from the range 0 to 10 kN and it is educed by the spring via stepper electromotor and screw gear. The shaft is powered by an electric motor. The size of the sliding speed can be chosen from the range 0.05 to 5 ms^{-1}.

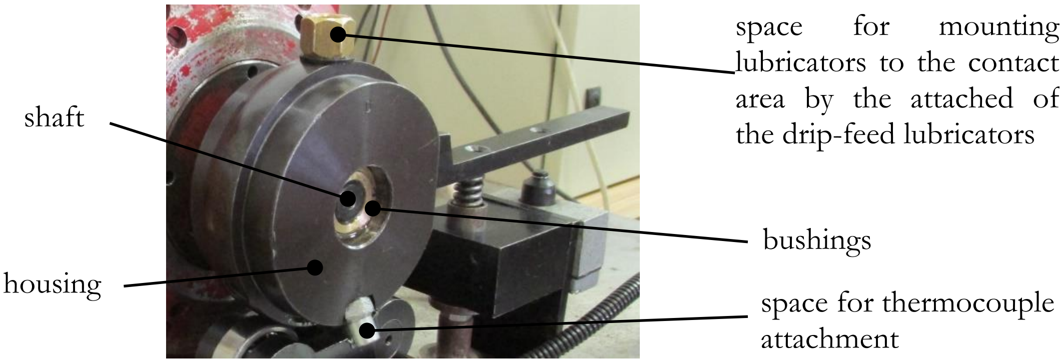
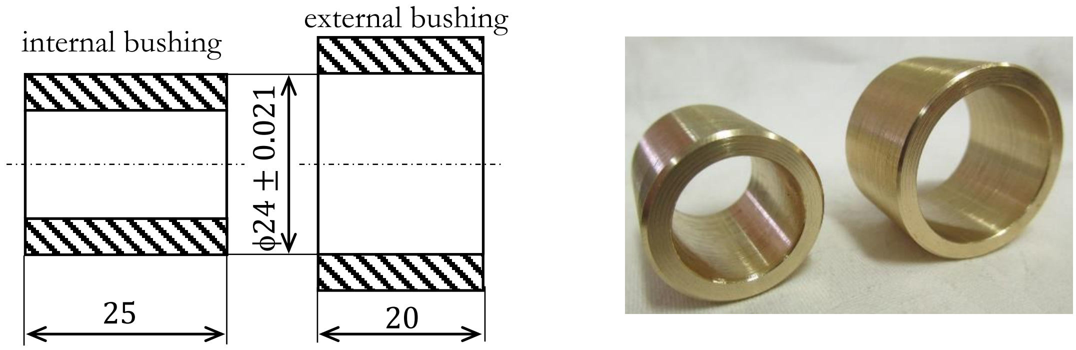


Fig. 1: Sliding pair in the test equipment

Fig. 2a) shows basic parameters of the internal and external bushing. In this paper, results for bushings of brass MS 58 (CuZn39Pb3) are presented (Fig. 2b). After the external bushing was fixed into the housing, the hole for supplying lubricant onto the contact surface was drilled.



a) basic parameters of the bushings b) photograph of bushings

Fig. 2: Brass bushings

3 Measurement of temperature

Temperature of bushings was monitored using a thermocouple and a thermal camera (Fig. 3.) The active part of the thermocouple [4] touches the outside surface of the bushing through the hole in the the housing. The electric potential generated on the thermocouple (type J) is fed to the AD converter, where the potential is processed into a numerical shape. According to the technical parameters of the equipment (Tribotestor M`89), range for the temperature of the testing bushing is from + 20 to + 300 °C. The temperature sensing system is by back couple connected with thyristor regulator of rotations. Thus, it is possible to stop the equipment and stop the testing if the temperature achieves predetermined limit value. All necessary data of the tests are stored in a data file which can be transformed into Microsoft Office Excel.

Fig. 3: Monitoring of the temperature of the sliding joint using a thermocouple and thermal camera

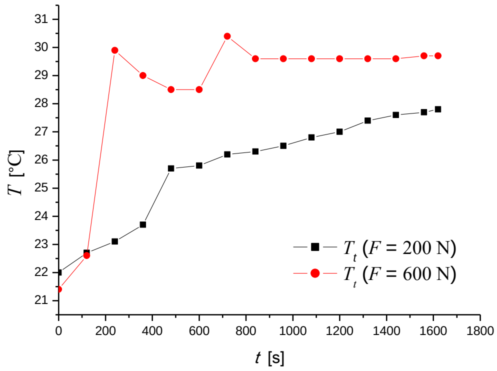


Fig. 4: Variation of the measured temperatures by thermocouple

The surface temperature from the front side of the sliding joint was sensed using thermal camera (FLIR i7). The camera has been fixed in the in the camera stand and thus the same distance and angle of view during whole test was ensured. The thermal camera disposes of the comprendious menu, which is accessible through the control buttons. The thermal camera is equipped by an uncooled array detector with image resolution of 140 x 140 pixels and with special optics, which enables to perform very easyt and accurate measurements at shorter distances. The measuring range of the temperature is from -20 °C to + 250 °C. The recorded data (in JPEG format on a mini SD card) can be evaluated using the program FLIR QuickReport [5]. Thermal field was sensed at the start of the test and then periodically every 120 seconds.

4 Analysis of the measured values of temperature

In the tests input parameters were set as follows: The sliding speed (v = 0.8 m s^{-1}) was constant during whole test (t = 1620 s). Loading was realized in the radial direction to the circuit of the external bushing. Loading was increased from level 50 N to 200 N during run up in duration of 120 s, after this start up the constant level 200 N was held during consecutive 1500 s. The size of compressive force was changed from 50 N to 600 N during run up in the second test. The gear oil Castrol Manual EP 80W-90 was used as lubricant in all tests.

Measurement of the temperature was auxiliary measuring within the experimental investigation of tribological processes in sliding bushings. The principle of temperature measurement is described in the previous chapter. The values of temperatures were recorded and evaluated using relevant software of equipment Tribotestor M`89 and thermal camera.

Figure 4 shows a graph of temperature sensed by thermocouple (T_t).

Figure 5 shows demonstration pictures from thermal cameras, which were sensed at the beginning and end of the test, under load force of 600N.

Each picture was evaluated using the FLIR QuickReport program. Since it is not possible to accurately determine the location of the thermocouple from which the temperature is sensed, we proceeded as follows. In each picture the area of the presumed place of measurement of the temperature using thermocouple was selected. The maximum temperature value from this area was compared with the value of temperature obtained by the thermocouple (Fig. 6).

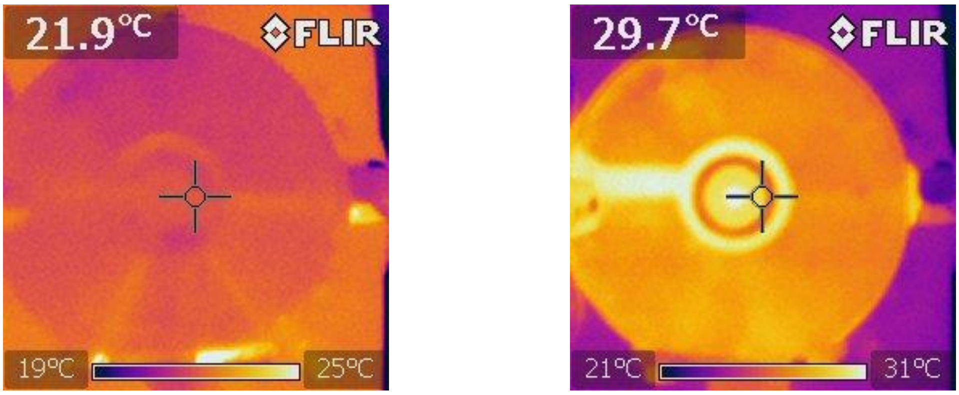


Fig. 5: Pictures obtained by thermal camera at the beginning and end of the test (load force F = 600N)

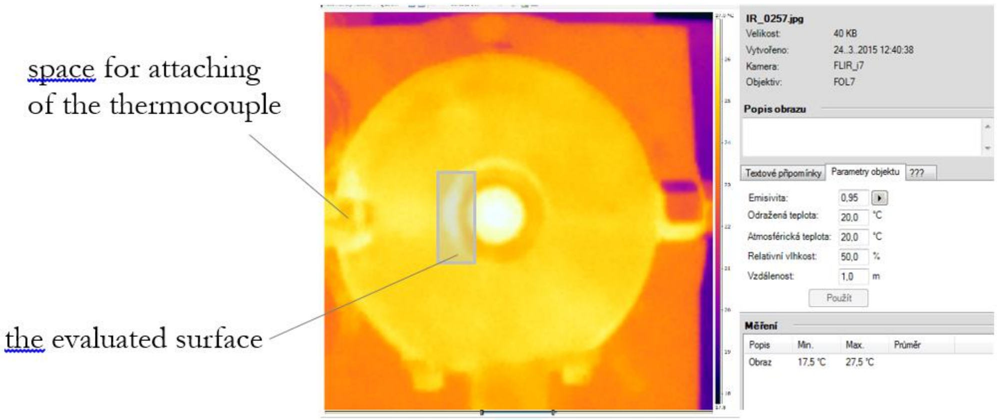
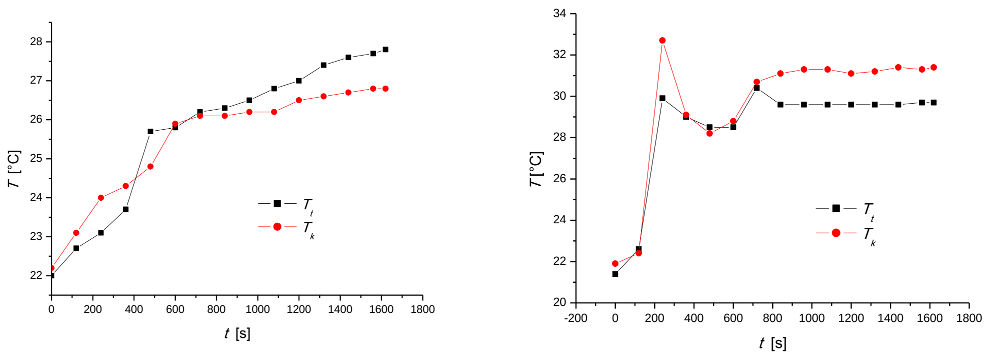


Fig. 6: Evaluated area from the picture

Fig. 7 shows the course of temperatures which were obtained by the thermocouple (T_t) and by the thermal camera (T_k) in both tests. The maximum temperature difference was 1°C when the loading force had the size 200 N. When the loading force was 600 N the temperature difference was 2.8 °C. The maximum temperature that was measured was 32 °C. It can be concluded that differences in values sensed by thermal camera compared to thermocouple are not significant. From this point of view, the monitoring of temperature of the rotary sliding joint is sufficient by thermocouple.



a) for F = 200 N b) for F = 600 N

Fig. 7: Variations of temperatures sensed by thermocouple and thermal camera

For us, it was interesting to examine, whether the sensed values will be alike also at higher temperatures. That was the reason why we sensed the temperature using the same input parameters except lubricant, which was intentionally omitted. In the experiment with loading force F = 200 N, there were not significant temperature differences obtained by thermocouple (temperature at the end of the test, T_t = 44.1 ° C) and sensed by the thermal camera (the temperature at the end of the test T_k = 44.0 ° C).

However, in the test with loading force F = 600 N without lubricant, in time t_z = 428 s after the start, bushings seized. The values of temperatures obtained by a thermocouple (temperature at the time t_z was T_t = 56.0 ° C) and using the thermal camera (the temperature at the time t_z was T_k = 96.4 ° C) were significantly different (Fig. 8). From this last test we can see that, comparing to thermocouple the thermal camera can react faster at quick change of temperature.

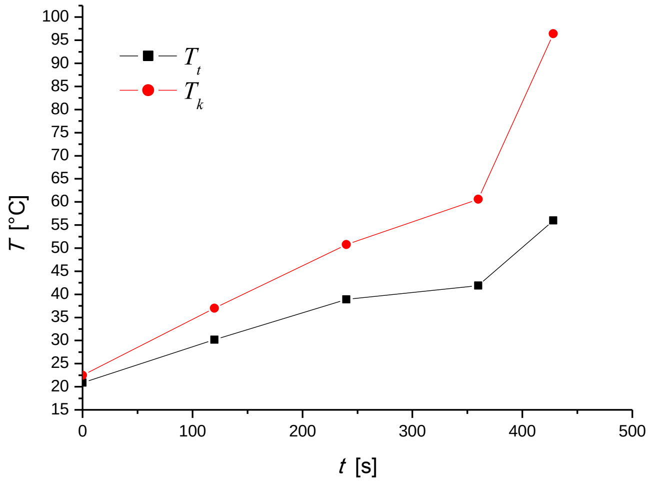


Fig. 8: Variations of temperatures sensed by thermocouple and thermal camera at test with loading force 600 N and without lubricant

Conclusion

In this paper the values of temperature measured by two approaches from the surface of the contact area of the rotary sliding joint are analyzed. Sliding joint was created of the pair of brass bushings and placed to the equipment Tribotestor M`89. Experimental tests executed on this equipment are focused on detecting of the tribological characteristics of the rotary sliding joint. The values of friction coefficient and the temperature in contact surface are recorded during the tests. The results for the coefficient of friction are presented in other papers. The temperature is measured using thermocouple and those values are displayed in the respective data file. Measuring part of thermocouple touches the outside of the external bushing. Considering the heat conductivity of material, there can be delay between increase of the temperature in the place of contact of the bushing and respective reaction of the thermocouple. For this reason, we decided to compare the temperature values gained by thermocouple with the values gained by thermal camera pictures.

Sliding pair was exposed to four tests with the same value of the sliding speed and also the duration of each was same time. Loading force was chosen 200 N and 600 N, at first the tests were realized with lubricant and then without lubricant. In tests, where lubricant was used, the maximum temperature at the contact area at the end of a test was 32 °C. The difference between the temperature at the contact area measured by a thermocouple and a thermal camera was max. 2.8 °C. Even in the test without lubricant and with loading force 200 N significant difference between the compared temperature values (gained by thermocouple and thermal camera was not detected. However, the last experiment with loading force 600 N and without lubricant was prematurely terminated because of degradation of the bushing materials as an effect of the temperature. At the end of the test, temperature value sensed by thermocouple (56 °C) was significantly lower than the temperature recorded using thermal camera (96.4 °C).

Above mentioned techniques of measurement of the temperature pointed that using thermocouple as measurement tool is sufficient in those cases, where the temperature is lower or where the temperature changes gradually. In the case where the values of temperature are higher and change quickly, it is more appropriate to use thermal camera as a measurement tool.

Acknowledgement

This work has been supported by the Grants Agency of the Slovak republic VEGA under the Grant No. 1/0184/14. This publication is the result of implementation of the project: "University Scientific Park: CAMPUS MTF STU - CAMBO" (ITMS: 26220220179) supported by the Research & Development Operational Program funded by the EFRR.

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