TEMPERATURE MEASUREMENT IN TECHNICAL APPLICATIONS

Miloslav Linda, Gunnar Kunzel, Monika Hromasova
Czech University of Life Sciences Prague
linda@tf.czu.cz, kunzel@tf.czu.cz, hromasova@tf.czu.cz

Abstract. Our objective is to carry out measurements and target the issues of electrothermic diagnostics. Electrothermic diagnostics may be carried out either using contact or non-contact type measuring systems. An example of non-contact type measuring system is the infrared spectrometry used for system analysis. Compared to contact-type measurement, infrared spectrometry has a number of advantages but, on the other hand, it also comes up against some considerable difficulties. When temperatures of the functional parts of mobile engines are analyzed, infrared spectrometry is accompanied by difficulties that make the method inapplicable. Contact-type measurement has the advantage of easy interpretation of the measured variable; its disadvantage is inapplicability to rotating engines or rotating parts of mobile equipment. This paper evaluates and compares individual methods used in electrothermic diagnostics. In particular, both, infrared spectrometry measurement carried out on a harvesting thresher and analysis of insulating materials samples for heat conduction by contact-type measurement, are examined. Advantages and disadvantages of the individual methods are investigated, and recommendations concerning application of the results on machines are provided. Our aim is to provide methodology guidance for application of the analyzed methods.

Keywords: TC meter, thermal conductivity, temperature, sensor, ZigBee, ADT7410, thermocouple.

Introduction

In designing and dimensioning a device, it is always necessary to take into account the mechanical overload of the system which generally results in increased temperature of the equipment/device as a whole. When the temperature excessively grows, destruction of the device may take place. The system mechanical overload may be caused by overload of or damage to the sliding and bearing housings. Measurement of temperature of critical parts enables replacing the damaged parts in time. Predictive maintenance of the system may also be used to some extent.

The system may be checked by means of temperature measurement or by modeling situations occurring in various operation conditions. Temperature measurement devices may carry out either contact or non-contact type measuring. Modeling may be carried out in one of the following two programs: MATLAB or COMSOL Multiphysics.

Materials and methods

1. Non-contact type measurement – infrared spectrometry

Non-contact type temperature measurement works on the infrared principle. Electromagnetic radiation is processed by a detector in wavelength ranging from 0.4 µm to 25 µm. That covers a large part of infrared spectrum enabling thus measuring temperatures from -40 ºC to +10 000 ºC. Each material radiates in a different way, therefore, each material can be characterized by a variable expressing the intensity of radiation. At the beginning of measurements, it is appropriate to check whether such value corresponds to the measured material. The reason is simple. Materials (especially metals) are often covered by various surface layers which impact on the intensity of radiation of the material. Such surface layer may either consist of a coating or material corrosion layer. The surface characteristics include, e.g., surface reflection where the sensor records a reflection of radiation from a heat source which is located near the measured electric machine. The presence of another heat source may introduce a certain error into the measurement.

For demonstration measurement, the thermal imaging camera FLIR i50 including QuickReport™ software for analysis of radiometric images enabling changing temperature ranges, emissivity, reflected temperature, atmospheric temperature, relative humidity and distance from the object is used. Thermogram sequences are saved in QuickPlot.

2. Measuring device for contact-type temperature measurement

The demand for development of thermal diagnostics systems resulted in development of a device for measurement of temperature and evaluation of the measured curves.

Fig. 1 shows a photograph of the measuring device. The communication part for connection to the computer via USB connector and preparation for the Zigbee module is visible; the connector part and switching transistor; the sensor blocks (ready to be used) are in the background.

Up to 16 sensors may be connected to this device.

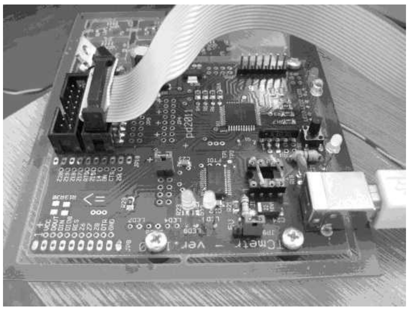

Fig. 1. **Prototype of the measuring device**

Fig. 2 shows a user application for control of the device. The application is equipped with several modules, for data recording, output block control and control of the connected sensors. It has one switched output transistor for control of a selected device.

After activation/loading of the device it is necessary to carry out initialization, during which the application finds the connected devices and ascribes addresses to the connected switches. The equipment communicates via the virtual serial port. During initialization, it is not necessary to enter transmission parameters; they are already preset. The application will find a port to which the equipment is connected. During Compliance Check Communication, the equipment sends the addresses of the connected sensors that are active and faultless. The selection of a certain number of connected sensors is depicted in the figure.

Subsequently, it is possible to carry out individual measurements, or repeated sets of measurements according to the setting. The equipment is ready for connection of a wireless Zigbee module for communication with the computer. The measurements may be carried out in several operation modes with high or standard accuracy (depending on the parameters of the sensor used) and with technical delay during individual measurements.

The application is able to test communication for the possibility to test transmission errors in practical applications.

The results are arranged in a table and graph of the measured values which are only illustrative, i.e., excluding the option to work with the values. To enable the analysis of values, the data are continuously exported into a file from which the data can be further processed in table processors.

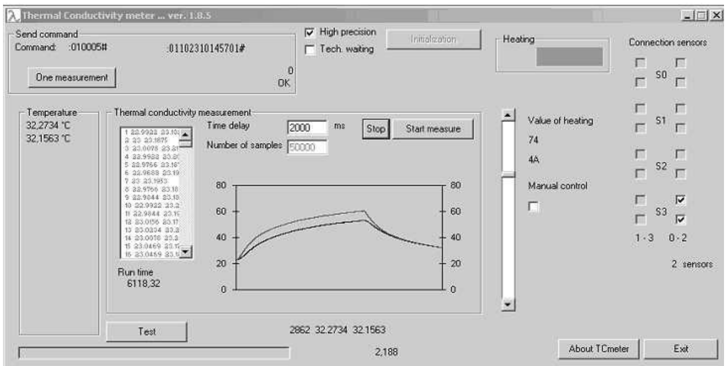

Fig. 2. **Measuring application**

3. Temperature sensors ADT7410

Technical parameters: the employed temperature sensor has temperature accuracy ±0.5 ºC from -40 ºC to + 105 ºC, fast first temperature conversion on power-up of 6 ms, I^2C-compatible interface, temperature range: -55 ºC to + 150 ºC, voltage range: 2.7 V to 5.5 V, critical over-temperature interrupt, and 13 or 16 bit temperature A/D converter.

4. Electrothermic diagnostics of insulating materials

A more effective exploitation of energy sources requires minimization of thermal losses that accompany technology processes or heating of working, residential and other premises. Limitation of losses results in increasing thermal resistances of insulating material while achieving the lowest specific thermal conductivity.

To analyze the heat conductivity of insulating material samples, the designed device consists of a heat source, a set of sensors and the measuring device proper. The user application Lambda meter (Fig. 2) was especially programmed for the latter solution. At the moment, the sensors are connected in twos to enable measurement of both, the surface "temperature gradient" and specific thermal conductivity of insulating materials.

Results and discussion

1. Non-contact type measurement – infrared spectrometry

The measurement has been carried out on several drives of the harvesting thrasher Massey Ferguson CEREA 7278. We carried out measurements on various types of mechanical drives influenced by machine operation during rape seed harvesting (Fig. 3 – 7). Another example is the local temperature increase in the distribution cabinet of the control system of the harvesting thrasher (Fig. 7).

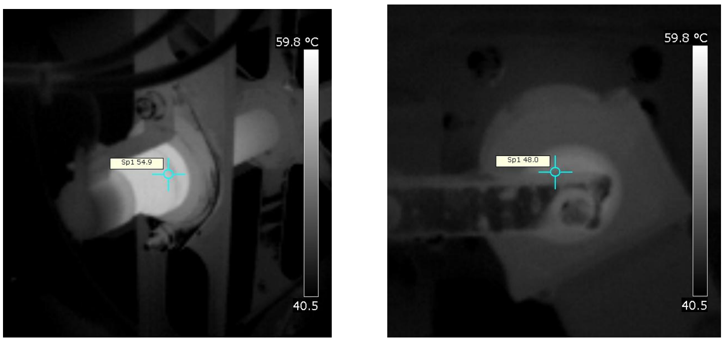

Fig. 3. **Measurement of bearing of the axial fan and drive of sieving mechanism**

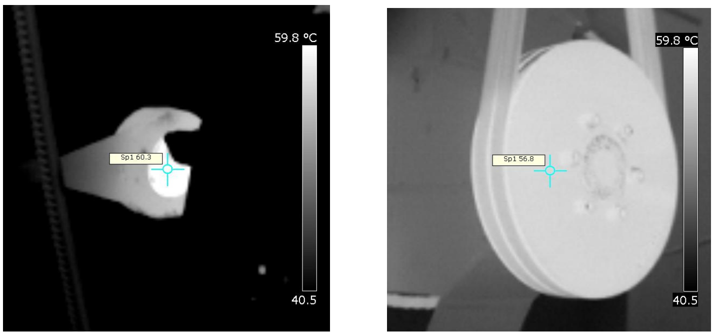

Fig. 4. **Measurement of the sieving box drive**

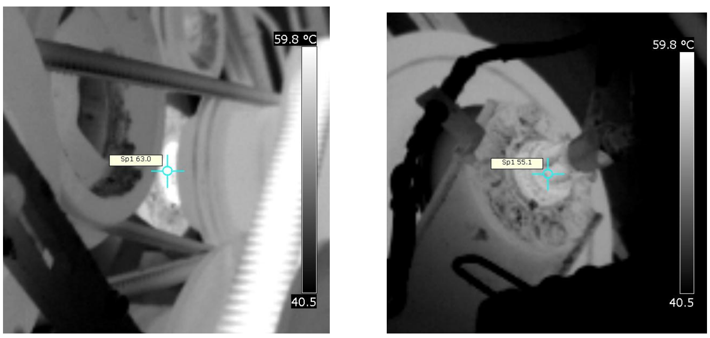

Fig. 5. **Measurement of the threshing drum drive**

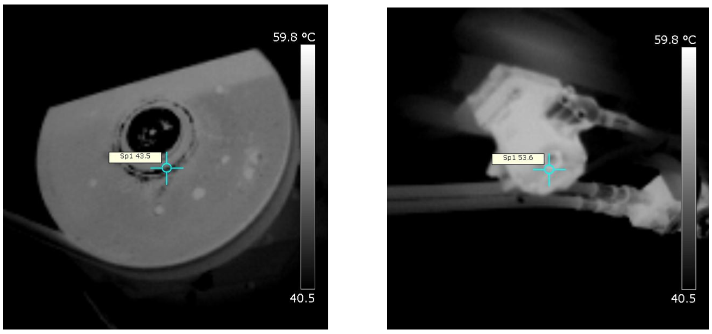

Fig. 6. **Measurement of both the drive of the straw shredder and the drive of husk distributor**

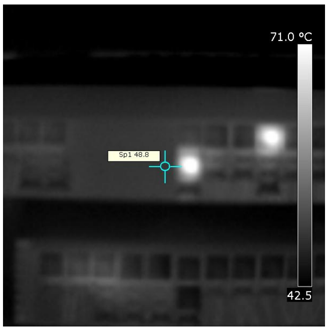

Fig. 7. **Measurement of the distribution cabinet of the machine controlling part, analysis of switching elements**

2. Temperature contact-type measurement – Electrothermic diagnostics of insulating materials

Fig. 8 shows an experiment - measurement of insulating properties of a brick sample.

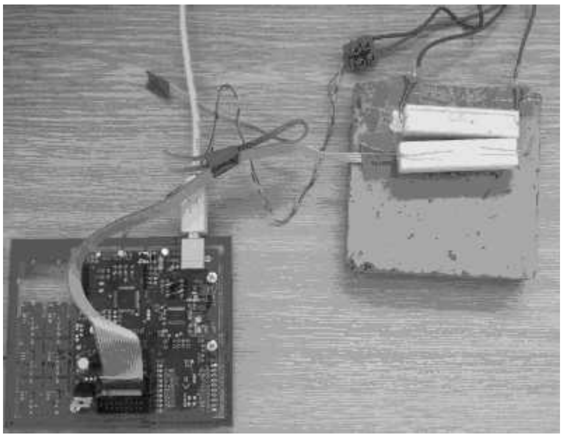

Fig. 8. **Experiment**

Fig. 9, Fig. 10, Fig. 11 and Fig. 12 show the results of measurement of the thermal conductivity on the surfaces of brick, Ytong, concrete and beech samples. The results show how conductivity differs; e.g., the brick sample has higher thermal conductivity than Ytong.

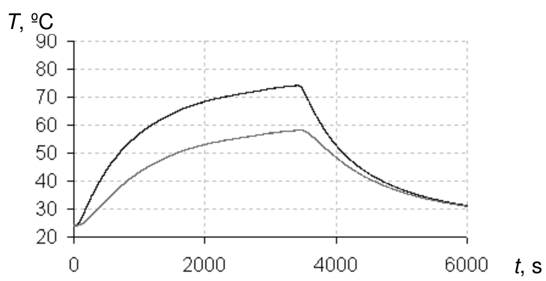

Fig. 9. **Measurement of insulating material – brick**

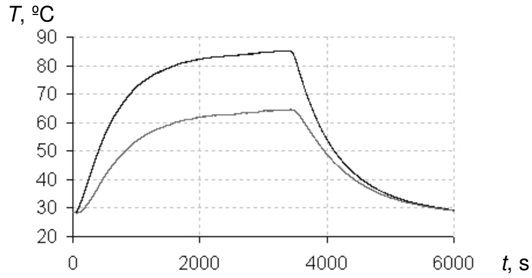

Fig. 10. **Measurement of insulating material – Ytong**

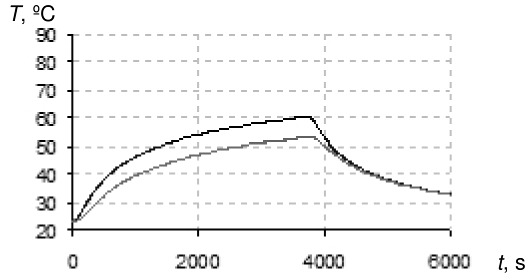

Fig. 11. **Measurement of insulating material – concrete**

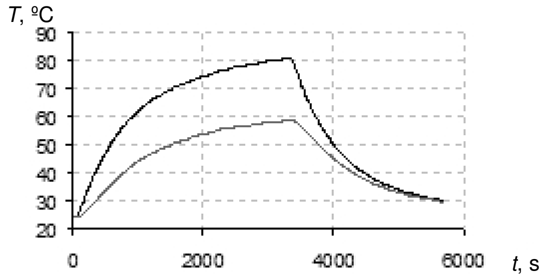

Fig. 12. **Measurement of insulating material – beech, perpendicularly to fibers**

We are planning to perform similar measurements on composite materials. The samples (Fig. 13) sized 100x100x20 mm with appropriate surface quality have already been prepared.

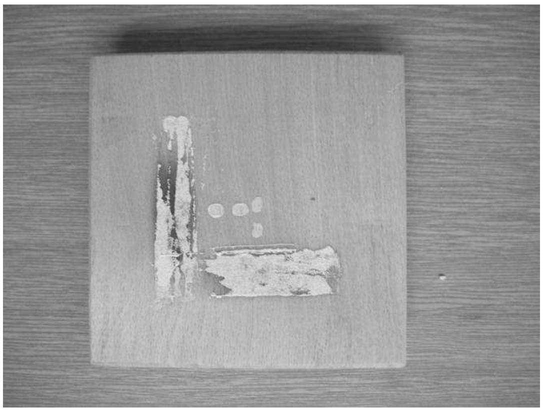

Fig. 13. **Prepared samples 100 x 100 x 20 mm**

Conclusions

The paper describes practical solutions of temperature measurements in technical applications. The first presented method is the non-contact type measuring which belongs to off-line diagnostics where the measurement is repeatedly carried out in specified intervals. The second presented method is contact type measurement which may be used to determine temperature at a given spot while simultaneously recording the engine load. This approach enables to determine more accurately the possible errors of the tested equipment.

The infrared spectrometry applied to agricultural machines comes up against difficulty that it is not possible to set constant load of the machine and set satisfactory conditions during the measurement preparation phase. Hence, when such measurement is repeated it is not sufficiently probative.

Acknowledgements

The paper was compiled with the grant support of the Central Grant Agency of the Czech University of Life Sciences Prague. Grant "Electrothermic diagnostics of insulating materials", No. 20113006; 31200/1313/3131.

References

1. Ďaďo, S., Kreidl, M. Sensors and measuring circuits. 2nd edition. Prague: CTU in Prague, 1999. 315 p. ISBN 80-01-02057-6.
2. Kreidl, M. Measurement of temperature, sensors and measurement circuits. 1st edition. Prague: BEN, 2005. 240 p. ISBN 80-7300-145-4.
3. Křemen, J. Continuous dynamic system and its simulation on a computer. 1st edition. Prague: SNTL, 1981. 160 p.
4. Kubalčík, M. Practice from the subject of system identification. 1st edition. Zlín: TBU in Zlín, 2006. 97 p. ISBN 80-7318-497-4.
5. Svítek, M., Borka, J. Modeling of systems and processes. 1st edition. Prague: CTU in Prague, 2001. 135 p. ISBN 80-01-02361-3.
6. Voráček, R. et al. Automation and automation technology. 2nd edition. Prague: CP Books, 2000. 218 p. ISBN 80-7226-247-5.