TEMPERATURE MEASUREMENT OF AN ELECTRIC MOTOR

Ramia Deeb
Doctoral Degree Programme (1), FEEC BUT
E-mail: xdeebr00@stud.feec.vutbr.cz

Supervised by: Vladimír Aubrecht
E-mail: aubrecht@feec.vutbr.cz

ABSTRACT

The article deals with a measurement of both heating and cooling characteristics of DC and AC-motors. The measurement was done using thermistors, that were positioned at the surface of the DC-motor, while thermocouple and IR camera were used for measuring characteristics of the AC-motor. The measurements were performed at the different machine- loads.

1. INTRODUCTION

Temperature is one of the most important thermodynamic properties, that determine the state of a material and appears in many physical laws. It is so important in a temperature field to know the basic methods of heat measurement, which is the one of few quantities that cannot be measured directly. For this purpose, many methods exist such as using thermistors, thermocouples and IR camera.

2. INSTRUMENT DESCRIPTION

2.1 Thermistor is thermally sensitive resistor whose primary function is to demonstrate a change in electric resistance with a change in the body temperature. Thermistor can have a large positive temperature coefficient of resistance (PTC device) or a large negative temperature coefficient of resistance (NTC device), which depends on the type of material system.

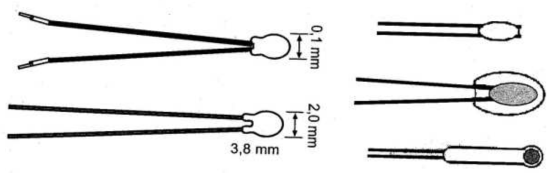

Fig 1: Examples of thermistors [3]

Temperature characteristics of a resistance: The term zero-power resistance applies to thermistors operated with negligible self-heating. The approximately linear relationship between the logarithm of resistance and inverse absolute temperature is given by:

$$\ln R_T = A + \frac{\beta}{T} \tag{1}$$

where: T: absolute temperature (K).

β: material constant of the thermistor.

The temperature coefficient of resistance α is defined as:

$$\alpha = -\frac{\beta}{T^2} \qquad (2)$$

The thermistor advantages are high temperature sensitivity, small size, simple transfer of resistance to electrical voltage or current and the possibility of direct measurement of the thermistor resistance at a greater distance. It is considered as one of the most commonly used sensors.

2.2 Thermocouple is a pair of electrically conducting and thermoelectrically dissimilar materials coupled at an interface, the legs are thermo elements. The Seebeck effect produces a voltage in all such thermo elements, where they are not at a uniform temperature. The electric interface between dissimilar electric conductors is a real thermoelectric junction. The free end of thermo element is a terminus.

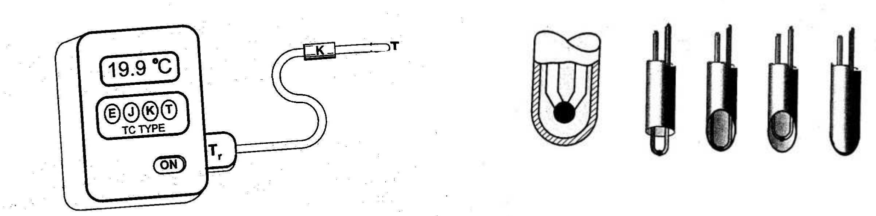

Fig 2: Examples of thermocouples [1], [3]

The Seebeck effect, which converts temperature to voltage, is used for thermoelectric thermometry but is also a primary low-frequency noise source in all low-level electronic circuits.

$$\Delta E = \int_{T_1}^{T_2} \sigma(T)dT = E(T_2) - E(T_1) \qquad (3)$$

where: ΔE is the increment of electromotive force between a pair of points, separated by any distance, between while the difference of temperature is:

$$\Delta T = (T_2 - T_1) \qquad (4)$$

$$\sigma = \int_{0}^{T_{abs}} \left(\frac{\tau}{T_{abs}}\right)dT \qquad (5)$$

where: σ: is absolute Seebeck coefficient.

τ: is Thomson coefficient.

2.3 Infra-red (IR) thermometry is one of noncontact temperature measurements. The principle consists in measurement the body’s surface temperature according to the electromagnetic radiation emitted from the body and received by the camera sensor. Since the electromagnetic waves originating from mechanical movement of particles can be characterized by their intensities and wavelengths, both of these characteristics are related to the temperature (the hotter object, the shorter wavelength).

3. RESULTS AND ANALYSIS

Measurement was realized on DC motor with four loads (100%, 75%, 50% and 25% of nominal load). Three thermistors were used for the measurement. Arithmetic means of the measurement values obtained by the 3 sensors are presented in Figs. 1 and 2. Duration of the measurement was 2 hours. The first hour corresponds to DC motor running at a specific load (heat characteristic) and the last hour applies to the machine stop (cooling characteristic).

Parameters of DC machine measurement were as follows:

24 V, 30 A, 1.6 Nm, 2p = 4, passive cooling

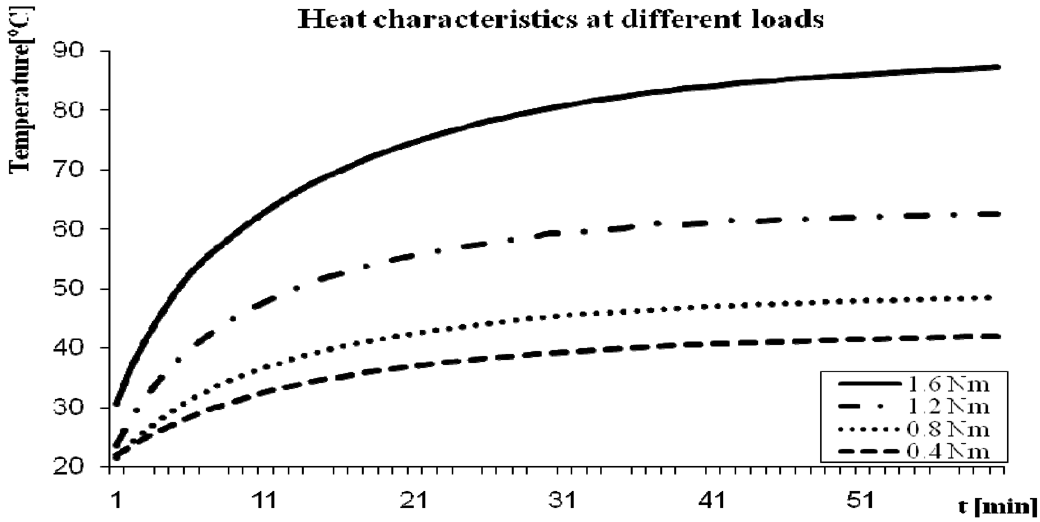

Fig 3: Heat characteristics at different loads

It can be seen from the Fig.1, that at the nominal load of 1.6 Nm the temperature reached about 90 °C, while at load of 1.2 Nm the temperature value reached only about 60 °C and at load of 0.4 Nm the temperature value was about 35 °C. From the results follows, that half of the nominal load leads to the temperature decreasing by about 50%.

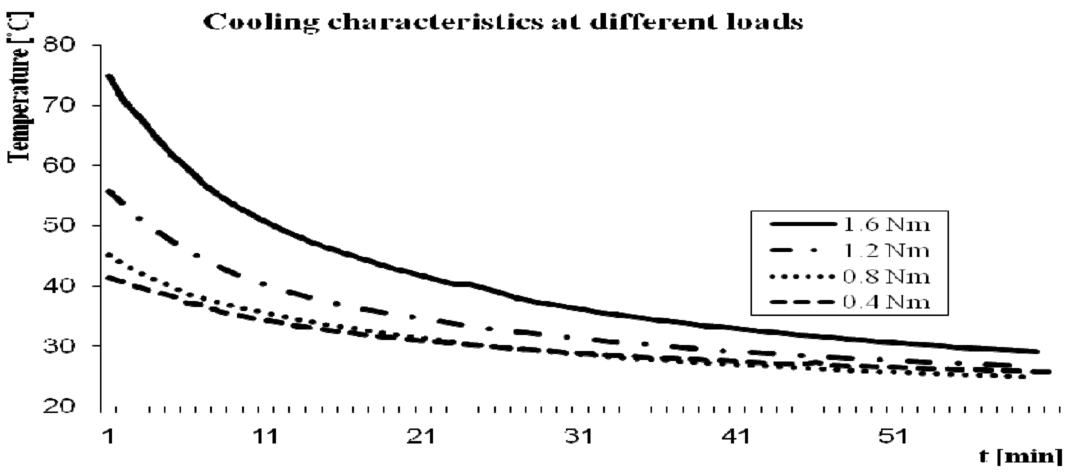

Fig 4: Cooling characteristics at different loads

In Fig. 2, one can note that at nominal load of 1.6 Nm the temperature decreased most rapidly. The temperature decreased by about 30 °C within 20 minutes, while during the following 40 minutes, the temperature decreased by about 10°C.

From the results (cooling characteristic) it can be noticed, that about an hour (for all loads) was needed to reach the normal temperature about 25 °C.

Parameters of an AC machine measurement were as follows:

AC-motor: BovANG BY 92BL48, 48 V, 4000 rpm, 2200 W, Class F

Presented measurements were done in the case of no load.

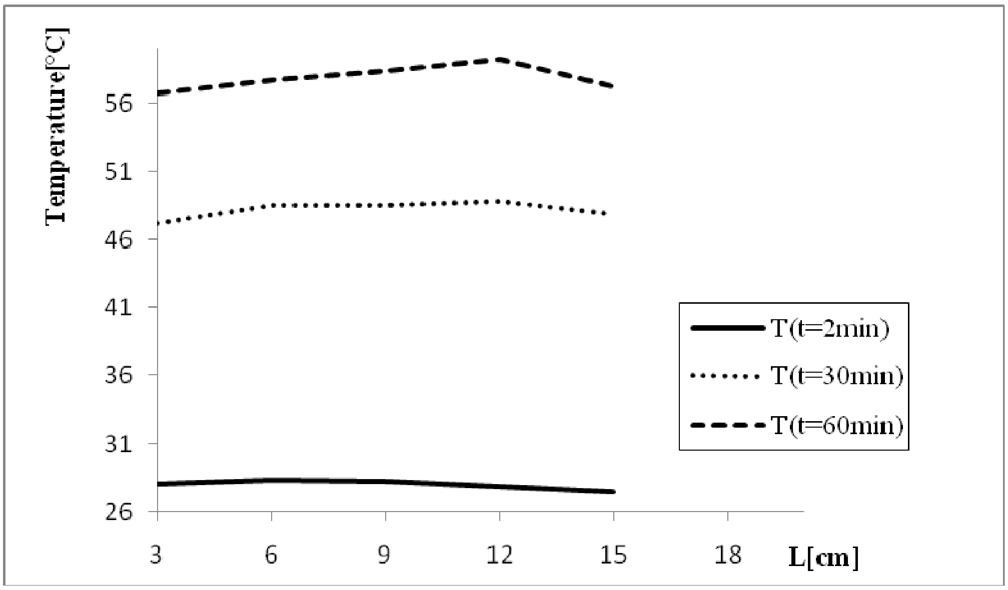

Fig 5: Temperature measurement using thermocouple

Fig 5 shows the temperature values at various points of the motor surface. The temperature in the middle of the surface is higher in comparison with the edges of the surface. The closer to the heat source (windings) the temperature is higher.

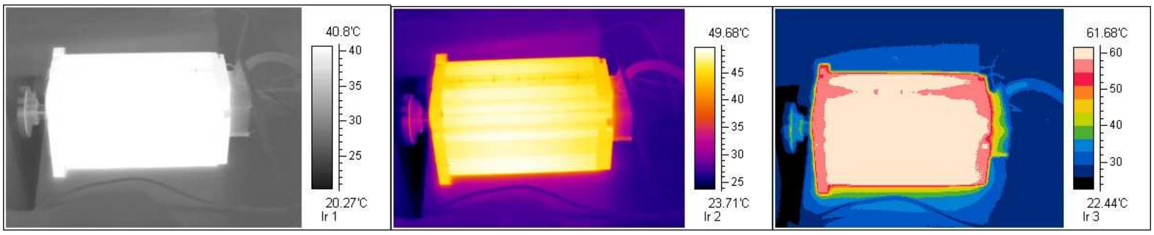

Fig 6: Temperature measurement using IR camera

The measurement were done using IR camera (Model: Sat-Hy 6800) at different times (t=10, 30, 60 min), while the measurement period was one hour. The areas are colored according to its temperature depending on the wavelength of the radiation that the camera sensor received.

4. CONCLUSION

Various methods of temperature measurement have been reported in the paper – thermistors, thermocouples, IR thermometry. In spite of the advantages of using these method, many disadvantages exist:

Measurement using thermistor contains:

- Uncertainty, which is given by the uncertainty value of thermistor resistance.
- Self-heating errors: the current that measures sensor resistance heats also the sensor causing rise in its temperature that is known as Joule loss($R.I^2$). In fact the sensor indicates temperature higher than the real temperature.

Measurement using thermocouple

The uncertainty of temperature measurement due to the nonlinearity results from inverse polynomial.

Measurement using IR camera

The measurement error due to the uncertainty of the correct values of emissivity of the body surface.

ACKNOWLEDGEMENT

Author gratefully acknowledges financial support from the projects FEKT- S- 10- 10 and GA102/09/1875

REFERENCES

[1] John G. Webster: The measurement, Instrumentation and Sensors, CRC Press LLC, ISBN 3-540-64830-5

[2] Yunus A. Cengel, Michael A. Boles: Thermodynamics- An Engineering Approach, 5th edition, McGraw-Hill, 2006, ISBN 978-0073107684

[3] Kreidl Marcel: Měření teploty, BEN – Technická literatura, Praha 2005, ISBN 80-7300-145-4