JOURNAL OF THEORETICAL
AND APPLIED MECHANICS
3, **38**, 2000

MEASURING SYSTEMS FOR INVESTIGATION INTO THERMAL PHENOMENA APPEARING IN DRIVE SYSTEMS WITH ELECTRIC MICROMOTORS

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The thermal phenomena occurring in mechatronic devices may affect the device performance characteristics in various ways. Electrical drive systems are main sources of heat emission inside the device. The paper touches upon the problems of modelling and identification of thermal models of drive systems, that are useful tool for predicting thermal behaviour of the devices analysed by means of simulation. The measuring systems designed to support such works are presented.

Key words: electric drive systems, thermal models, measuring systems

1. Introduction

Mechatronic devices i.e. the devices in which mechanical functions are realised in response to signals generated in microprocessor control units, operate in the presence of various physical phenomena. Many of those phenomena depend strongly upon temperature of the device subassemblies. The temperature is a result of ambient conditions as well as thermal phenomena inside the device itself.

The rise in subassemblies temperature caused by the emitted heat may exert either positive or negative effect on the device properties. Sample positive effects are: improvement of media lubrication properties, increase in elasticity of plastic and rubber elements e.g. insulation coating, acceleration of chemical reactions in devices which operate in low temperatures. The negative effects are: e.g., intensive ageing of materials, deterioration of subassemblies performance characteristics, irreversible magnetic losses in permanent magnets (Kaszuwara and Wojciechowski, 1994).

The electric drive systems are subassemblies, in which thermal phenomena reveal particularly intensively. In general such drive system may be expressed as a serial connection of three components:

- Control unit
- Electric motor
- Transmission unit

as well as the feedback signals (Fig.1).

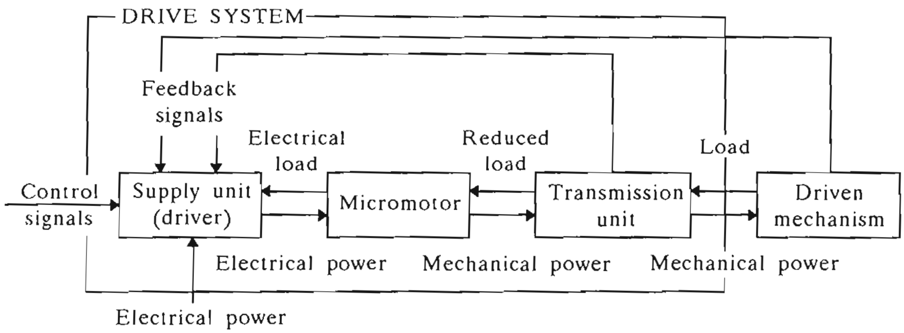

Fig. 1. Functional subassemblies of the electric drive system

In any device thermal power is emitted in each unit in which conversion of energy takes place. In the supply units heat is emitted due to electrical losses. The effect this heat exerts may be reduced by locating these units as far away as possible from those elements of the device that are particularly sensitive to temperature changes. Heat emitted in transmission results from mechanical losses, mainly due to friction. The heat emission that takes place in electric micromotors is particularly burdensome because of vicinity of the driven elements. For example high temperature of the motor shaft causes deformation of the plastic pinion fixed to it. The problem of thermal effects has a special meaning in those mechatronic devices that operate in the presence of thermal phenomena. An additional heat source may disturb their operation or even prevent it. Such a case occurred in thermal printer when a special, temperature sensitive paper was blackened by warmed up step motor employed in driving of the paper transportation unit.

The above discussion proves that designers of mechatronic devices should have at their disposal software tools for calculating predictable temperature rises in subassemblies of the device being designed. Simulation of thermal states requires reliable models of heat emission, accumulation and distribution phenomena to be developed. The concept of modelling adopted for this purpose consist in distinguishing the so called *homogeneous thermal bodies* within the device structure. Such bodies characterise the constructional elements inside which the temperature distribution may be neglected. Graphical illustration of such models is the so called thermal net diagram (cf Dudzikowski and Kubzdela, 1994; Hering, 1980; Pełczewski, 1956), Fig.2.

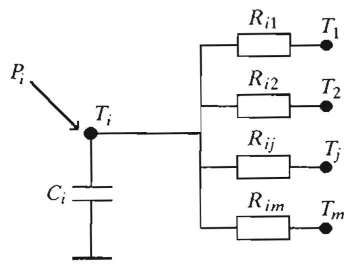

Fig. 2. Equivalent thermal diagram of one homogeneous body selected from a set (see text)

The thermal balance of a thermal homogeneous body is described by the following ordinary 1st order differential equation

$$C_i \frac{dT_i}{dt} + \sum_{j=1}^{m} \frac{1}{R_{ij}} (T_i - T_j) = P_i \tag{1.1}$$

in which

C_i – thermal capacity of the analysed ith body
m – number of bodies adjacent to the selected one
P_i – heat emitted in the ith body
R_{ij} – thermal resistance between the ith and jth bodies
T_i – temperature of the ith body.

Modelling of the thermal structure of devices and identification of their coefficients requires experimental analysis to be performed. In the paper the author summarises his own experience as well as his collaborators, in building measuring systems used for investigation into thermal states in mechatronic drive systems.

2. Modelling

Modelling of the thermal structure of the device requires analysis of temperature effect on the device characteristics as well as determination of heat flows between constructional elements. An example of such an analysis for the DC micromotor with ironless rotor (Fig.3) is presented below.

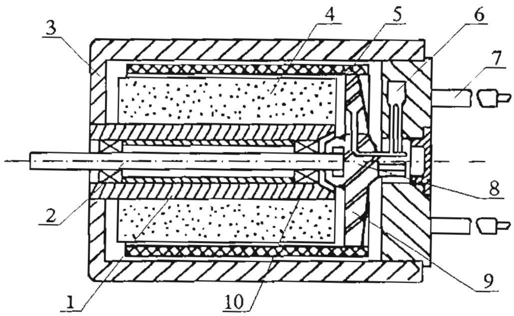

Fig. 3. Cross section of the DC micromotor with the ironless rotor (Tabuchi, 1982); 1 – sleeve, 2 – shaft, 3 – case, 4 – magnet, 5 – armature, 6 – brush, 7 – lead, 8 – commutator, 9 – hub, 10 – bearing

This kind of motor is commonly used in precision devices as driving motors (Tetsugu, 1981). The basic mathematical model of the DC micromotor is described by the two differential equations (Kenio and Nagamori, 1989; Jaszczuk et al., 1991)

$$
\begin{aligned}
u &= R_t i + L\frac{di}{dt} + K_E\omega \\
K_T i &= (J_s + J_h)\frac{d\omega}{dt} + K_D\omega + (M_F \operatorname{sgn}\omega + M_h)
\end{aligned}
\tag{2.1}
$$

in which

i	–	armature current
J_h	–	moment of inertia of driven elements
J_s	–	moment of inertia of the rotor
K_D	–	viscous damping constant
K_E	–	voltage constant
K_T	–	torque constant
L	–	inductance of the armature
M_F	–	static friction torque
M_h	–	load torque
R_t	–	resistance of the armature
u	–	control voltage
ω	–	angular velocity of the rotor.

The rise in the temperature of motor elements, which occurs during motor operation, particularly in positioning systems (Kenio and Nagamori, 1989; Makiuchi, 1981), changes the motor characteristics, especially due to the rise in armature resistance

$$R_t = R_0[1 + \alpha(T_r - T_0)] \tag{2.2}$$

R_0 – armature resistance at a temperature T_0
α – thermal coefficient of the magnet induction
T_0 – reference temperature of motor parameters
T_r – instantaneous temperature of the rotor.

A visible result of this change is an increase in the motor electromechanical time constant. The rise in the magnet temperature causes an induction decrease in the air gap and furthermore a decrease in the torque as well as voltage constants

$$\begin{aligned} K_E &= K_{E0}[1 - \beta(T_s - T_0)] \\ K_T &= K_{T0}[1 - \beta(T_s - T_0)] \end{aligned} \tag{2.3}$$

where
K_{E0} – voltage constant at temperature T_0
K_{T0} – torque constant at a temperature T_0
T_s – instantaneous temperature of the stator
β – thermal coefficient of the magnet induction.

Eqs (2.3) are unimportant the case of magnets made of *Alnico* due to a small value of β coefficient. Their influence on motor operation is essential when the ferrite magnets are applied.

Eqs (2.2) and (2.3) can be used only in the case when the rotor and magnet temperature rises are known. While developing the thermal model of motor it is necessary to distinguish at least two thermal bodies, the temperatures of which determine the motor parameters. On the assumption of a possibly small number of bodies it is decided that the two-element structure is sufficient for the goal of the work. Additionally, it is useful to spot that there is no direct way for the heat flux between the rotor and environment. This enables to make the thermal diagram for the motor as shown in Fig.4.

The structure is then described by the two thermal balance equations of the rotor and stator, respectively

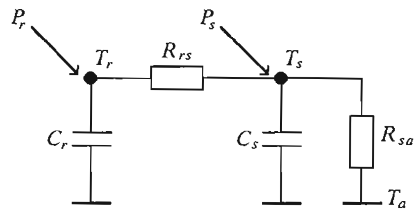

Fig. 4. Diagram of thermal structure of the motor with the ironless rotor

$$
\begin{aligned}
&C_r\frac{dT_r}{dt}+\frac{1}{R_{rs}}(T_r-T_s)=P_r\\
&C_s\frac{dT_s}{dt}+\frac{1}{R_{sa}}(T_s-T_a)+\frac{1}{R_{rs}}(T_s-T_r)=P_s
\end{aligned}
\tag{2.4}
$$

where

C_r – thermal capacity of the rotor
C_s – thermal capacity of the stator
P_r – heat emitted in the rotor
P_s – heat emitted in the stator
R_{rs} – thermal resistance between the rotor and stator
R_{sa} – thermal resistance between the stator and ambient
T_r – rotor temperature
T_s – state temperature.

The next step in the modelling process consists in description of the heat sources appearing in Fig.4. Winding losses as well as eddy current losses are appear due to electrical effects. The sources associated with mechanical properties include; friction in bearings and commutator as well as resistance to rotor motion due to the airflow in the air gap. A share of mechanical losses in the global balance of losses is very small (Jaszczuk et al., 1991) and therefore may be neglected. Additionally, there are no eddy current losses in the motor with the ironless rotor. Due to this in the model only the rotor winding losses are included

$$P_r=i^2R_t \tag{2.5}$$

and no losses associated with the stator

$$P_s=0 \tag{2.6}$$

It is also convenient to define the thermal power input to the stator as

$$P_{rs} = \frac{1}{R_{rs}}(T_r - T_s) \tag{2.7}$$

At the stage of modelling the literature data, own experience and sometimes additional tests are employed. Such tests had to prove whether approach consisting in considering the whole stator as one thermal body is justified. The confirmation obtained by modelling the static temperature distribution (Wierciak and Tański, 1998a) can not be reliable because of arbitrary assumed coefficients describing the heat flow through the air gap. The current data may be obtained only from experiment. A special measuring stand is used for this purpose. The stand measures simultaneously temperature in selected elements of an object (Fig.5). The acquisition of data should be performed under conditions similar to those observed in typical object operation.

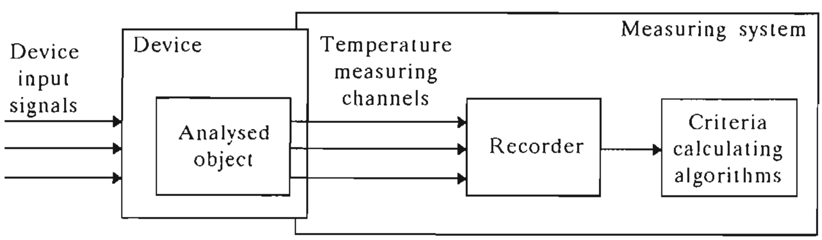

Fig. 5. Block diagram of the system for verification of the model structure

In the case discussed above the maximum difference between the temperatures in selected points of the stator relative to the stator temperature rise was adopted as a criterion for the approach assessment (Layer and Gawędzki, 1991). To perform the experiments a special object was constructed by installing temperature sensors inside the motor (Fig.6). As an exemplary object the PBM-40 motor (Długiewicz, 1984) was employed. The motor has the outside diameter of 40 mm and the maximum output power of 5 W.

Analysis of time series obtained while supplying the motor with fixed rotor with the constant voltage (Fig.7) shows that the assumptions the model structure are true. At the stator temperature rise of 50 K, on the adopted criterion relative temperature differences do not exceed 10%, what is satisfactory for a majority of modelling purposes.

In view of the special features of the ironless rotor motor (i.e. rotor made of copper and resin) the assumption that the temperature within the entire rotor is constant does not require verification.

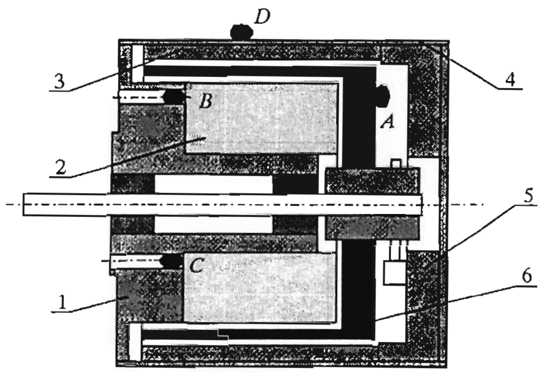

Fig. 6. Locations of temperature sensors in the PBM-40 motor (Wierciak and Tański, 1998a); 1 – sleeve, 2 – magnet, 3 – keeper, 4 – housing, 5 – cover with brushes; 6 – rotor; A – rotor temperature sensor; B, C, D – stator temperature sensors

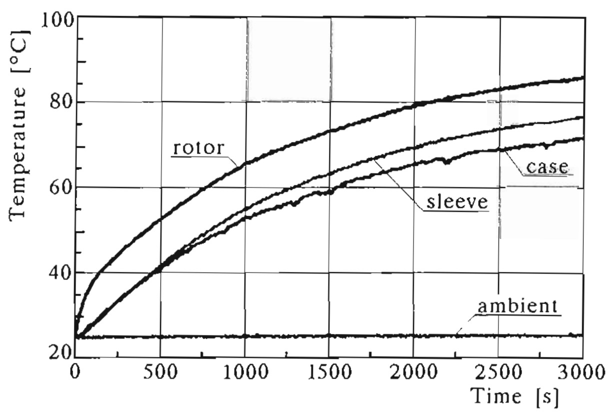

Fig. 7. Temperature responses of elements of the PBM-40 motor "suspended" in the air (Wierciak and Tański, 1998a)

3. Identification of thermal parameters

Application of the model described above in engineering and research studies requires the knowledge of electromechanical as well as thermal parameters of the motor. Using definitions based to determine thermal capacities and resistances leads to significant errors. In the case of thermal resistances it is the result of limited knowledge about mechanisms of the heat flow through various media inside the mechatronic devices as well as heterogeneity of the selected body surroundings. In the case of thermal capacities fundamental problems arise to determine which constructional and non-constructional elements (e.g. air layer) belong to the bodies distinguished in the model. For all those reasons the results suffer from big errors reaching 100% and more. Many years' work has convinced the author that the experimental identification of thermal coefficients is necessary. In such an approach the identification method and construction of a measuring system are based each time upon the model equations analysis.

3.1. Thermal resistances

Analysing the simplest thermal balance equation of the body that contacts only its surroundings it is obvious to state that determination of the thermal resistances should be performed by examining the steady thermal states of the object. Then it is possible to neglect the accumulation component of the equation to obtain the relation

$$\frac{1}{R_{ij}}(T_i - T_j) = P_i \tag{3.1}$$

and after the transformation

$$R_{ij} = \frac{1}{P_i}(T_i - T_j) \tag{3.2}$$

Calculation of the resistance value requires then temperature of the analysed body, temperature of its surrounding as well as heat flow between the body and surroundings in the steady state to be known. Theoretically two methods are possible. The first one assumes the temperature difference between both bodies to be set and maintained while the heat flux is measured. The second relies upon providing the body with thermal power of definite value and measuring temperatures of the body and its surroundings. Due to essential problems associated with the measurement of heat flow between the objects the second method is practically employed.

In the discussed case of the DC micromotor simple transformations of Eqs (2.4) out to substitution into Eq (2.7) yields

$$R_{rs} = \frac{T_r - T_s}{P_r - C_r \frac{dT_r}{dt}} \qquad\qquad R_{sa} = \frac{T_s - T_a}{P_{rs} - C_s \frac{dT_s}{dt}} \tag{3.3}$$

According to the above equations calculation of the resistances R_{rs} and R_{sa} requires knowledge of the temperatures of rotor, stator and surroundings, respectively, as well as the powers P_r and P_{rs}, while dynamic components are neglected because of the lack of values C_r and C_s. With such assumptions made temperatures and power have to be measured under thermal steady state conditions and then the coefficients are calculated using the simple relations (Wierciak and Tański, 1997)

$$R_{rs} = \frac{1}{P_r}(T_r - T_s) \qquad\qquad R_{sa} = \frac{1}{P_r}(T_s - T_a) \tag{3.4}$$

The final form of computation algorithms is produced after additional simulation experiments. The criteria for methods assessment consist in systematic errors in model coefficients determination. The motor model with the assumed coefficients as well as the model yielded by the proposed method and selected elements of measuring system are included in simulation software (cf Gajda, 1991; Gajda and Szyper, 1998; Wierciak, 1995). The modelled inputs are applied to the object model and obtained simulation data are processed using the constructed algorithms. The differences between the calculated and assumed values of coefficients are used for assessment of the method. The results of thermal resistances determination are presented in Fig.8.

The issues connected with experiments determination of thermal resistances may be regarded as meeting the following conditions:

- Providing the thermal power of known value
- Bringing the object about the thermal steady state
- Measurement of temperatures of the analysed body and its surrounding in the steady state.

3.2. Dynamic coefficients

Determination of the thermal capacity using the method resulting directly from Eq (1.1) suffers from a big error due to the necessity for temperature differentiation. The temperature signals are very noisy, what is easily visible

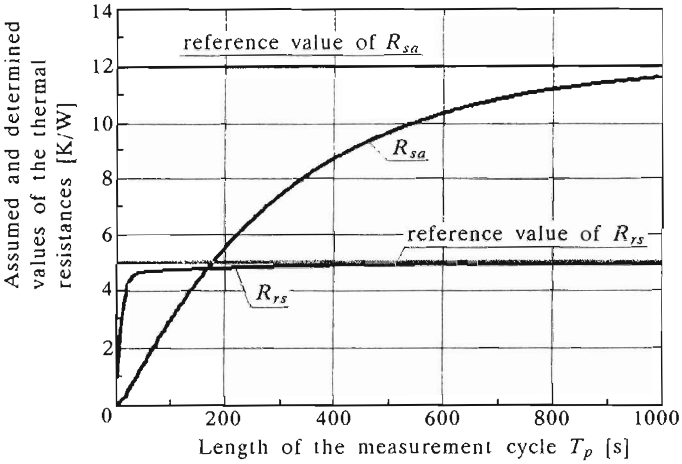

Fig. 8. Assumed and calculated values of the thermal resistances of PBM-40 motor with a fixed rotor in an experiment with the constant supply voltage $U_z = 5\,\mathrm{V}$

upon the responses presented in Fig.7. In the discussed case of DC micromotor it is possible to transform Eqs (2.4) to the general form

$$\tau_i \frac{dT_i}{dt} + T_i - T_j = R_{ij} P_i \tag{3.5}$$

where τ_i means the thermal time constant defined as

$$\tau_i = C_i R_{ij} \tag{3.6}$$

According to Eq (3.5) the examined body is an inertial element. Determination of its time constant consists in registration and analysing of the time response to one of typical inputs (Janiszewski, 1991; Ljung, 1987). When the input thermal power is described by the Heaviside function we have

$$P_i(t) = P_{ic} \mathbf{1}(t) \tag{3.7}$$

where P_{ic} means the assumed value of power. Then the body temperature response is represented by the exponential function

$$\Delta T_i = T_{iu}\Big(1 - \mathrm{e}^{-\frac{t}{\tau_{it}}}\Big) \tag{3.8}$$

where a steady temperature rise in the body is given by the equation

$$T_{iu} = P_{ic} R_{ij} \tag{3.9}$$

A method with stabilisation of the thermal power emitted in rotor windings is adopted to identify the thermal time constants of DC motor rotor and stator

$$P_r(t) = \text{const} \tag{3.10}$$

The temperature responses of both bodies have to be analysed on the following assumptions:

— temperature of each body surrounding does not change during the experiment

$$T_s = \text{const} \qquad \text{and} \qquad T_a = \text{const} \tag{3.11}$$

— temperature of the object is equal to the ambient temperature at the beginning of the test

$$T_r\Big|_{t=0} = T_s\Big|_{t=0} = T_a \tag{3.12}$$

While determining the thermal time constant of the rotor with simple approximation of its temperature response in selected time windows, significant systematic errors occur. The simulated responses of the motor (Fig.9) show the reason for these errors. During the measurement cycle the temperature of the stator increases and the conditions of heat emission from the rotor do not fit those obtained from Eqs (3.11).

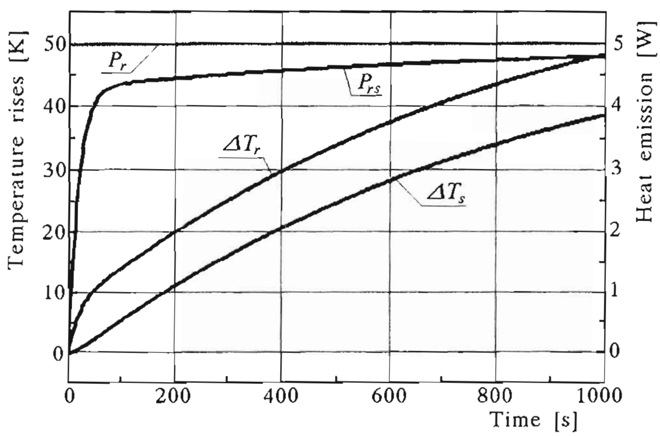

Fig. 9. Thermal responses of the PBM-40 motor with constant heat power $P_r = 5\,\text{W}$ emitted in the rotor and fixed rotor ([26]); $\Delta T_s = T_s - T_a$ – temperature rise of the stator, $\Delta T_r = T_r - T_a$ – temperature rise of the rotor

The above mentioned error may be reduced using the two methods:

- Maintaining a constant temperature of the stator during the experiment for instance by equipping the stand with a cooling system

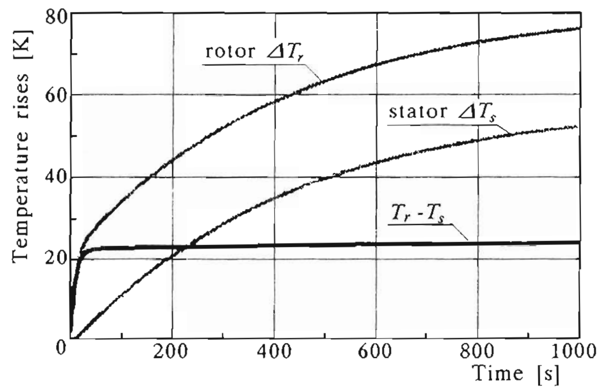

Fig. 10. Temperature responses of the rotor and stator as well as their difference (Tański and Wierciak, 1998)

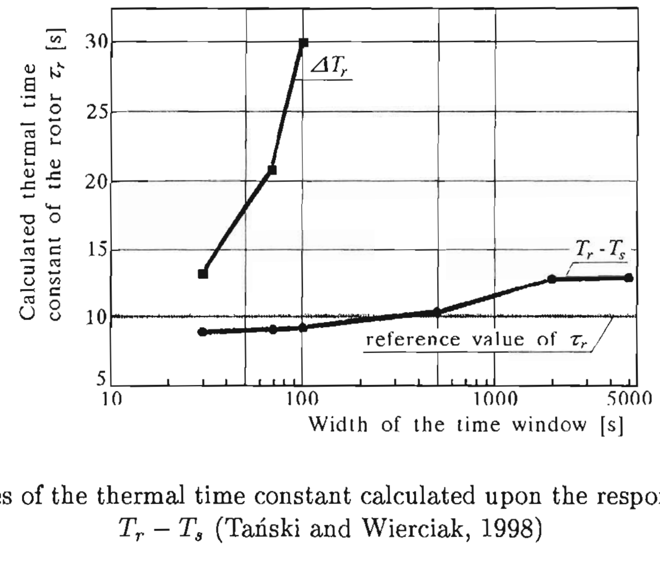

Fig. 11. Values of the thermal time constant calculated upon the responses ΔT_r and $T_r - T_s$ (Tański and Wierciak, 1998)

- Modifying data the processed in a such way that the temperature rise in the stator does not affect results.

In the discussed case identification errors are substantially reduced owing to modification of the rotor temperature response. Subtracting the stator temperature that grows slowly from the temperature of the rotor the exponential curve is being obtained time constant of which is almost equal to those of the rotor (Tański and Wierciak, 1998) (Fig.10).

The results of metrological analysis of the examined algorithms are presented in Fig.11.

The above consideration leads to the conclusion that the experimental determination of thermal time constants requires:

- Providing to selected bodies the thermal power represented by Eq (3.7)
- Maintaining the constant temperature of the body surrounding
- Recording of the temperature response of the body.

4. Test stands

Analysis of systematic error characteristics is the basis to formulate assumptions about the measuring system. Algorithms for the thermal parameter calculation, presented in the previous section, impose requirements for the test stands. These requirements may be reduced to realisation of the two functions:

- Applying input in the form of thermal power step to selected bodies
- Measurement and registration of the temperature responses of the bodies.

The general diagram of the measuring system for identification of thermal models of the objects is presented in Fig.12.

In practice at the stage of measuring system design not only metrological criteria are considered but also some technical and economical factors; i.e., possibility of realising the required measurements and inputs for limited resources are included. In the case of such works performed in the *Division of Design of Precision Devices WUT* (ZKUP PW) technical specification for the stand contains requirements for design of control and measuring channels that are installed in the systems of the structure (cf Jaszczuk et al., 1991) shown in Fig.13.

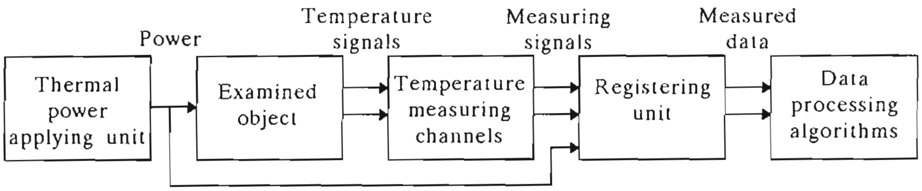

Fig. 12. Diagram of the system for identification of the thermal coefficients of objects models

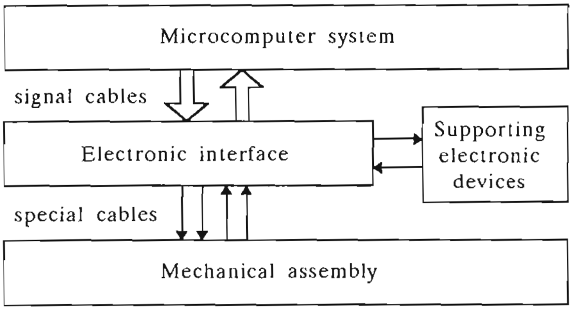

Fig. 13. The structure of test stands in ZKUP PW

Referring to the diagram shown in Fig.12 it may be stated that the registering unit of the stand as well as the data processing algorithms are located in the microcomputer system of the above structure. The examined object is mounted in the mechanical assembly. Below there are described most important details of the measuring and control channels in the systems for analysing thermal states in electrical drive systems.

4.1. Temperature measurements

The basic temperature measurement method employed in the stands consists in using contact sensors of the resistance type. The sensors are small enough ($\phi 2$ mm) to be mounted in selected places of the elements being examined. The test stand is equipped with four identical measurement channels. The block diagram of a single channel is presented in Fig.14.

The problems of using the channels in identification issues can be reduced to maintaining static as well as dynamic measurement errors within the permissible limit (Michalski and Eckersdorf, 1986). The static errors are determined by mathematical processing of the results of channel calibration (Wierciak,

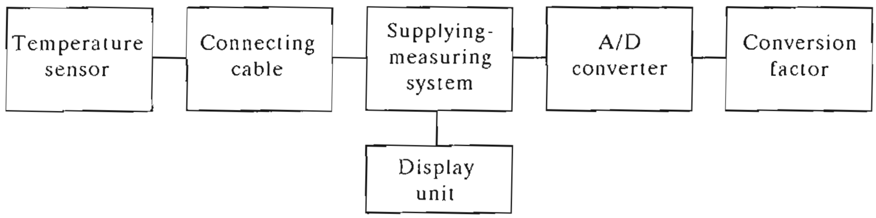

Fig. 14. Block diagram of the temperature measuring channel

1995). The stand measures temperatures within the range of 0°C to 150°C with an error less than 5% of the measured value. The range of admissible temperatures for sensors is −50°C to 180°C. Dynamic errors of channels depend mainly upon the properties of sensors. In metrological analysis it is sufficient to assume that the sensor is a first order inertial element. Time constants of the sensors used in the system determined experimentally are:

7.5 s – in the air
1.3 s – in the water.

In order to reduce dynamical errors the sensors are installed on the surfaces using a special heat-conducting, electrically insulating silicon paste layer.

The stand is adapted for taking non-contact temperature measurements using a pyrometer. This method is used mainly for measurements of the temperature on moving surfaces. However, the experience proves that even in measurement of the temperature of rotating parts of a micromotor, the contact method is more accurate and efficient. Measurements errors when using a pyrometer result mainly from difficulties in determination of emission coefficient of the surface under test. Applying the contact sensors for measurements on the moving rotor requires a special signal transmission unit to be made. Such a unit with slide rings was used during the tests carried out upon the rotating motor (Tański, 1999).

4.2. Realisation of the input

In the studies conducted by the author it is assumed that the resistance losses I^2R are a source of heat supplied to the examined body. If the object includes any resistance element e.g., a coil, then this element is used to provide the required heat by supplying it from the external power supply. The two cases of electrical power stabilisation were solved:

- With power supplied to the resistor
- With voltage induced in resistor being considered.

4.2.1. Stabilisation of power in the resistor

In the first case the electric heater is a pure resistor. Such a situation takes place while examining the DC micromotor with a fixed rotor or when additional electric heaters are engaged. Stabilisation of the heat emitted in the element is realised by means of maintaining the constant value of the product

$$P_r = ui \tag{4.1}$$

which assures a constant emitted power i^2R when resistance R is varying. To realise such an input a special control channel is installed in the measuring system. The block diagram of this channel is presented in Fig.15.

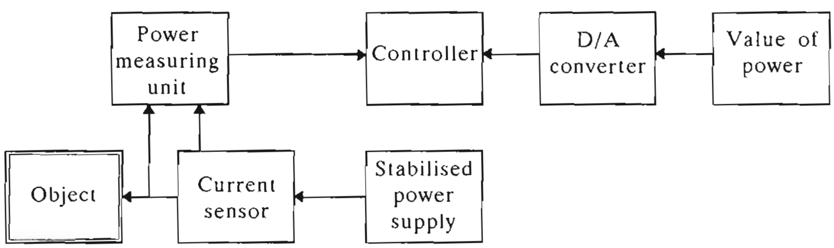

Fig. 15. Diagram of the control channel for supplying the examined objects with constant electrical power

The required value of power is put into the control software. The D/A converter being a part of the control-measuring module installed inside the computer converts this value into an analogue signal applied to the PD controller. The electronic unit measures instantaneous values of the current and voltage and calculates active electrical power. The controller corrects the power supply input so that to maintain equality of the current and assumed values of power.

The real quality of the stepwise input is illustrated in Fig.16. The response of control channel proves sufficient stabilisation of the supplied power during the first period of test, this is particularly important for determination of the thermal time constant of the rotor.

The stand ensures that electric power up to 100 W can be applied while current and voltage values can not exceed 10 A and 10 V, respectively.

4.2.2. Stabilisation of power in windings

Another situation takes place while examining the motor with a rotating rotor. In the windings the electromotive force proportional to the angular

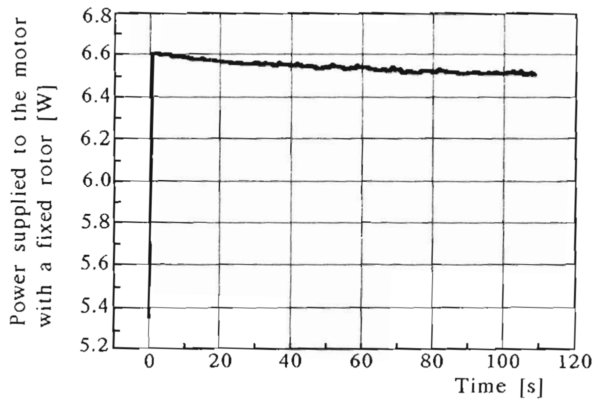

Fig. 16. Stabilisation of electrical power supplied to the PBM-40 motor – attained in the test stand; the required power $P_{rc} = 6.6\,\mathrm{W}$

velocity of the rotor is induced. Stabilisation of the thermal power emitted in windings requires loading the motor with the torque M_h calculated with regard to the induced voltage

$$M_h = K_T \frac{P_{rc}}{U_z - K_E\omega} \tag{4.2}$$

where

- P_{rc} – constant, required value of power
- U_z – constant supply voltage, while the rest of symbols has the same meaning as used previously.

In this case during tests value of voltage constant must be known as well as continuous measurement of velocity is necessary.

Analysis of the simulation results proves that within a wide range of time windows the systematic error in the determined thermal time constant of the rotor does not exceed 6% (Fig.17), but strongly depends upon dynamics of the load-applying channel (Fig.18).

For practical realisation of the method a special load-applying channel was designed and constructed. Its structure is presented in Fig.19.

The motor under test is coupled with the shaft of dynamometer. The dynamometer consists of electromagnetic powder brake and strain gauge transducer of the applied torque. Angular velocity of the motor is measured by a tachogenerator. Stabilisation of power is realised in terms of two closed control loops. The PD controller located in the control software calculates instantaneous values of the applied torque (4.2) so that to maintain a constant assumed value

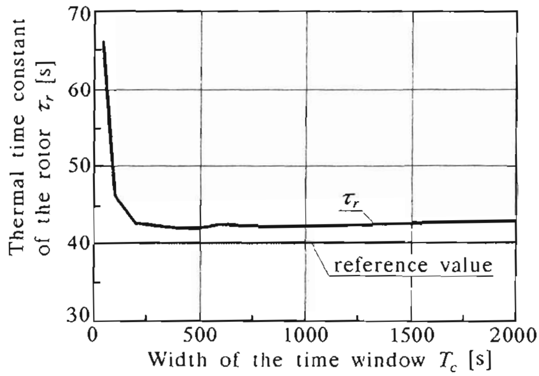

Fig. 17. Effect of time window upon the determined value of thermal time constant of the rotor while stabilising heat emission in windings – as obtained in computer simulation

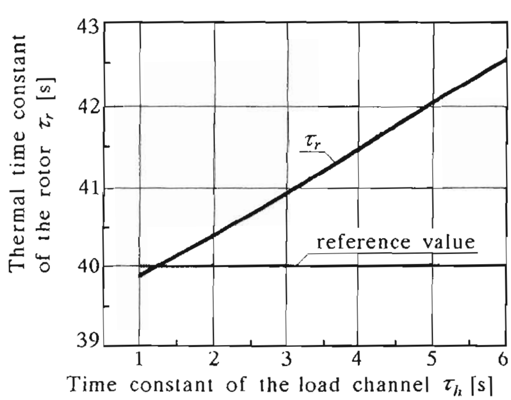

Fig. 18. Relation between the dynamic properties of load applying channel and the determined value of the rotor thermal time constant – results of computer simulation

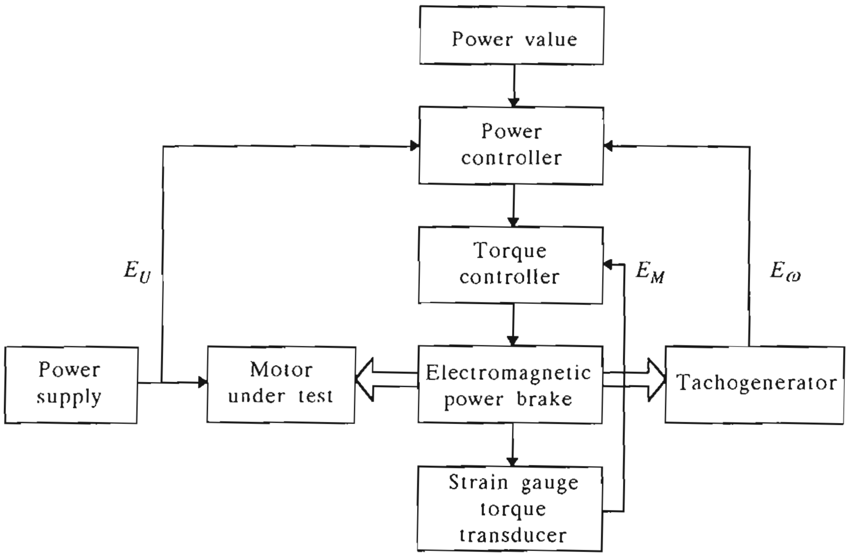

Fig. 19. Block diagram of the control channel; E_u – supply voltage signal, E_M – load torque signal, E_ω – angular velocity signal

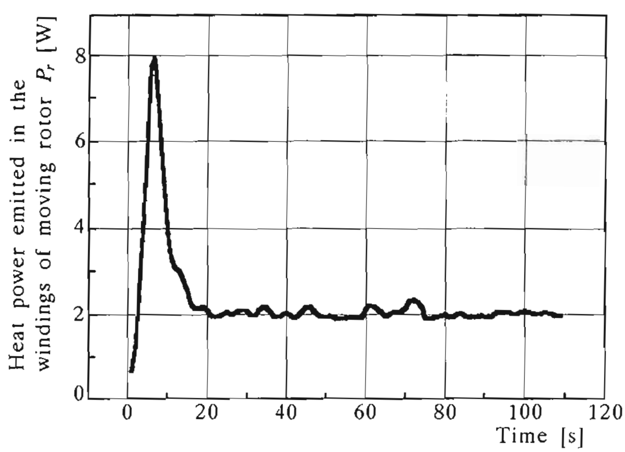

Fig. 20. Stabilisation of heat emitted in the windings of the PBM-40 motor with a rotating rotor; the supply voltage $U_z = 10\,\mathrm{V}$, the assumed value of power $P_{rc} = 2\,\mathrm{W}$

of the power emitted in the motor windings. The torque controller sets the value of brake excitation current to obtain the required load torque measured by the transducer.

Such a complex control system, processing strongly varying signals of mechanical quantities, must operate with large time constants (cf Beauchamp, 1978; Pełczewski, 1980). As it can be conducted from the real response of the load channel (Fig.20) the required power emission in windings of the examined motor is reached about 20 seconds after of the test beginning. The quality of power stabilisation in the following period is also much worse than that obtained for the motor with a fixed rotor.

5. Conclusions

The paper presents the research in IMPh WUT which resulted in building measuring systems for experimental investigations of thermal phenomena occurring in mechatronic drive systems. The experience gathered during these works lead to following conclusions.

- Simulation analysis of methods makes it possible to assess the systematic identification errors, which allows for choosing the right method with no need for costly and time-consuming experimental investigation. The results of simulations make the basis for designing a measuring system, thus eliminating the risk of committing serious conceptual mistakes.
- Application of contact temperature sensors shall be found as an efficient method for temperature measurements in mechatronic devices, even if it needs the special units of signal transmission from the moving parts to be designed and realised.
- While designing and manufacturing the test stands substantial technical restrictions in realising the required heat inputs have to be considered. It seems to be necessary to make quantitative assessment of the inputs already being applied in the described measuring systems as well as detect their influence on the results of identification.

Acknowledgement

Some of the results presented above were obtained within the research project No. 8 T 10A 072 14 sponsored by the State Committee for Scientific Research in the years 1998-1999.

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Systemy pomiarowe do badania zjawisk cieplnych w układach napędowych z mikrosilnikami elektrycznymi

Streszczenie

Współczesne urządzenia mechatroniczne, czyli urządzenia, w których funkcje mechaniczne realizowane są w odpowiedzi na sygnały z elektronicznych układów sterujących, na ogół mikroprocesorowych, działają z wykorzystaniem różnych zjawisk fizycznych. Przebieg wielu z tych zjawisk zależy od temperatury poszczególnych zespołów urządzenia. Istotny wpływ na temperaturę urządzenia mają zjawiska cieplne zachodzące w elektrycznych układach napędowych. W artykule przedstawiono koncepcję budowania cieplnych modeli podzespołów napędowych i zasady identyfikacji ich współczynników. Omówiono problemy związane z budową systemów pomiarowych służących do wspierania tych prac.

Manuscript received December 27, 1999; accepted for print April 13, 2000