ФІЗИКА І ХІМІЯ ТВЕРДОГО ТІЛА
Т. 6, № 4 (2005) С. 525-528

PHYSICS AND CHEMISTRY OF SOLID STATE
V. 6, № 4 (2005) P. 525-528

PACS: 71.20.-b; 71.25.Tn; 78.20.-e

ISSN 1729-4428

Mirosław Pawłot

Dynamics of Temperature Changes in Power Transmission Trunks at Joints of Conductors of Different Cross-Sectional Areas

Lublin University of Technology, (Poland)

Calculations of current-carrying capacity of electrical conductors as a rule are performed at the assumption of infinite length of the conductors. In such a case heat emission proceeds by convection or radiation. The situation is different when short sections of electrical conductors get heated. Then, axial heat flow can occur, which can be of significant effect on the temperature distribution over the conductor and on the shape of heating curves.

The paper presents an analysis of temperature distribution over a 5-meter section of a copper strand of the 16 mm^2 cross-sectional area fed with the use of conductors of 70 mm^2 cross-sectional area at the passage of continuous currents of various values. Experimentally obtained temperature distribution over the conductor and shapes of heating curves indicate considerable effect of axial heat flow in the conductor heating process.

Keywords: conductors of different, obtained temperature, electrical conductors.

Стаття поступила до редакції 27.09.2005; прийнята до друку 15.11.2005

In practice, current-carrying capacity of conductors is determined on the basis of relevant tables. It is known that if in determined conditions (kind of a current, ambient temperature, heat emission conditions, arrangement of conductors etc.) conductor current does not exceed the allowable value the heating temperature – its increment – will not exceed its allowable limit.

Tables that set up allowable values of current-carrying capacity of conductors make an important formulation of empirical knowledge. However, they do not allow for the effect of boundary conditions. An assumed conductor is infinitely long.

In real conditions, it happens for overhead lines that to a power transmission trunk a consumer network that operates occasionally is connected. When the consumer line is idle it does not make a power load but only a heat receiver. In order to model the mentioned situation measurements on a section of an electrical conductor have been performed. From the conductor an additional heat outflow has been forced by feeding the tested section with the use of conductors of greater current-carrying capacity.

Loads that are greater than those given in the tables of allowable values are not desirable because they bring about temperature increments that can be of detrimental effect to the life of applied insulation systems. In the case of bare copper conductors when the temperature gets exceeded by ca 200^0C mechanical strength of the metal gests essentially reduced.

Convective heat dissipation per a length unit through the surface area *s* of an infinitely long conductor is described by the Newton's law that, with the Joule effect taken into account, takes the following form [1]:

$$\Delta P dt = cmd\vartheta + hs\left(\vartheta_{gr} - \vartheta_o\right)dt \qquad (1)$$

where: ΔP – power losses occurring in the considered object s [W/m], t – time, c – specific heat [W/kg deg], m – mass of the considered body, ϑ_O – ambient temperature, ϑ_{gr} – temperature of the heated body, h – heat exchange coefficient [W/m^2deg], s – surface of heat emission from a body of the ϑ_{gr} temperature to its environment of the ϑ_O temperature

In steady state conditions and at the assumption of the current path heating we obtain $d\vartheta/dt = 0$. For an apparatus current path power loses ΔP are resistance losses. If at the heating with current I temperature of the current path grows up to the limit value ϑ_{max} when the path resistance is R_g, then the allowable load current for the conductor is:

$$I = \sqrt{\frac{hs}{R_g}} \cdot \sqrt{\vartheta_{max} - \vartheta_o} \qquad (2)$$

In a general case the heat exchange coefficient h and the path resistance R_g are temperature functions, which renders considerable difficulties in taking practical advantage of the dependence.(2).·

The dependence makes possible to determine temperature increments for electrical conductors only at neglecting boundary conditions i.e. at the assumption that a conductor is infinitely long [2,3].

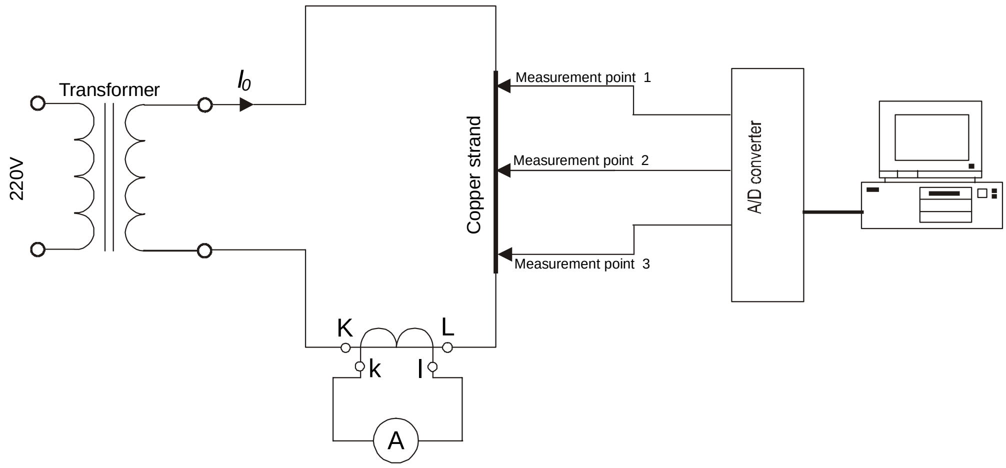


Fig. 1. Measuring circuit for temperatures of a conductor heated with alternating currents.

In order to explain the effect of axial heat flow in a branched circuit on temperature changes in the conductor tests of heating a conductor (copper strand, cross-sectional area of 16 mm^2 and length of 5 m) with alternating currents have been performed. The measuring circuit is presented in Fig. 1. The tested conductor has been fed with the application of a strong-current circuit. Current-carrying capacity of the feeding conductors has been by several times greater than the respective value for the tested conductor section. It has caused additional axial heat outflow from the tested strand.

Fig. 2 presents distribution of temperature increments in the tested conductor in steady state conditions. Differences between temperature increments at the conductor terminals and its midpoint depend on the testing current value and consequently on the value of fixed temperature. They result from the difference in cross-sectional areas of the feeding conductors at the sections AC and BD – 70 mm^2 and of the tested conductor CD – 16 mm^2.

On the basis of heating curves time constants for heating (dependence 3) and cooling down (dependence 4) have been calculated for three points on the tested conductor - at its terminals (C and D) and for its geometric midpoint .

$$\tau_n = \frac{t}{\ln \frac{\vartheta_{max} - \vartheta(t,I)}{\vartheta_{max} - \vartheta_0}} \tag{3}$$

$$\tau_s = \frac{t}{\ln \frac{\vartheta(t,I) - \vartheta_0}{\vartheta_{max} - \vartheta_0}} \tag{4}$$

It shows up that the values of heating time constants τ_n depend on the measurement location. In the geometric midpoint their values are the biggest and theoretical heating curves calculated on the basis of the determined constant (formula 3) coincide with the real curves (Fig. 3). It means that heat exchange at that point proceeds by natural convection and corresponds to the Newton's law for an infinitely long conductor. In such a case heat outflow occurs only from the side surface of the strand. As the conductor temperature around the measurement point No 2 (Fig. 1) is approximately constant (Fig. 2) axial heat flow does not occur in that area.

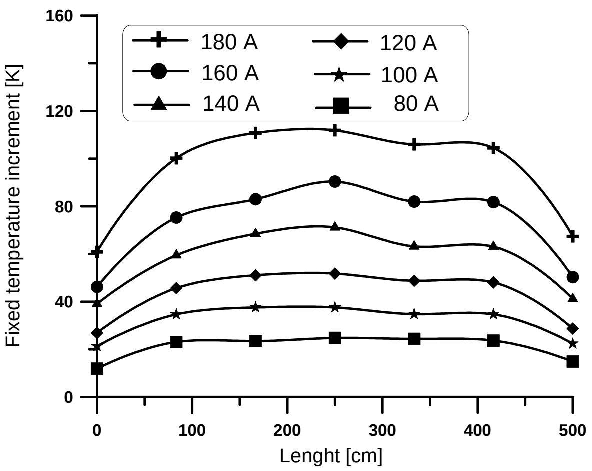
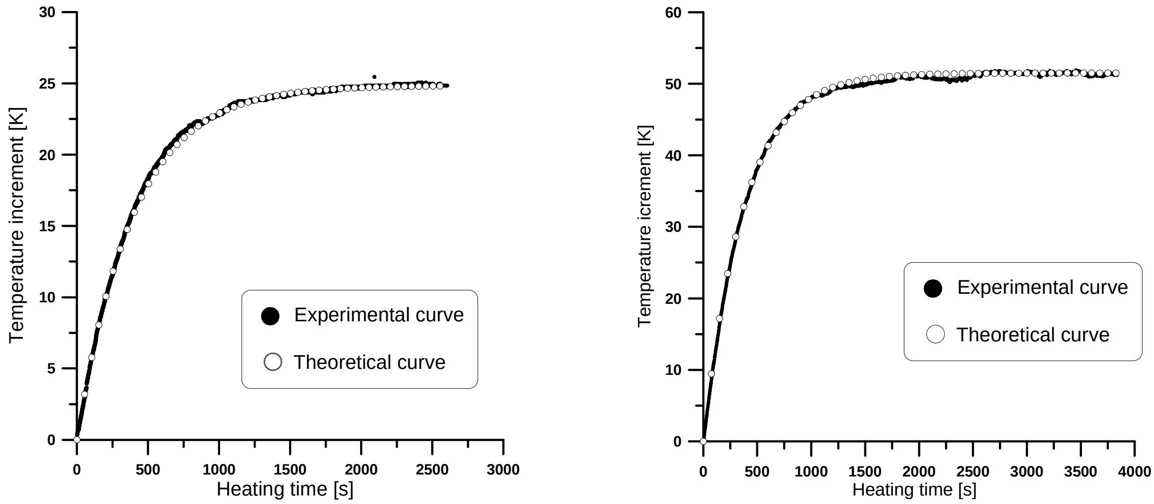


Fig. 2. Distribution of fixed temperature increments over the conductor length for various values of load current

Table 1

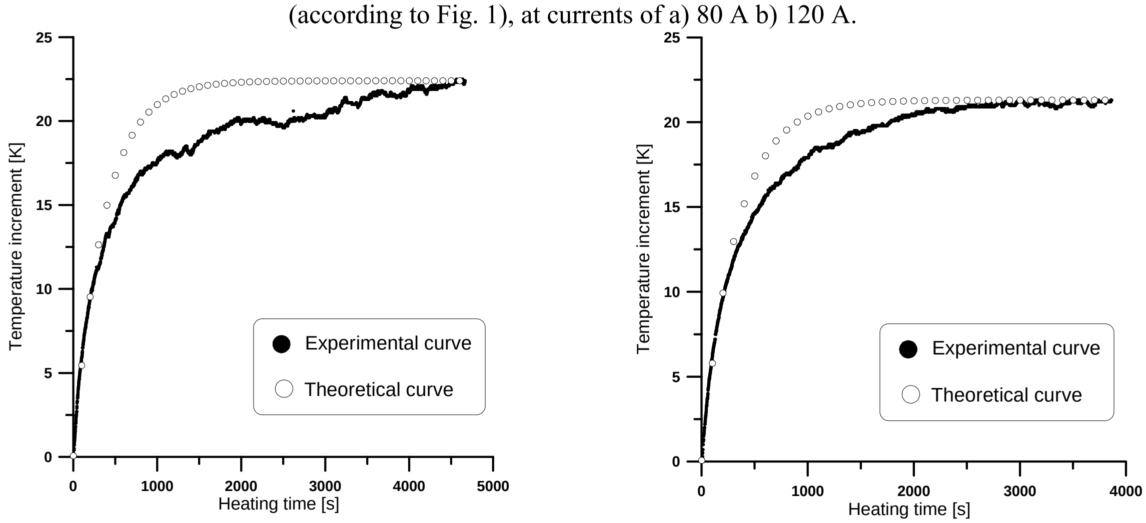
Time constants for heating a copper strand of 16 mm^2, in the ambient temperature of +22 ^{O}C, at natural convection, for three measurement points (Fig. 1)

Load current [A]	Heating time constans τ_n [s]		
	Point 1 Terminal C	Point 2 Midpoint	Point 3 Terminal D
80	288	393	356
100	363	387	322
120	287	370	319
140	322	392	340
160	302	390	297
180	343	384	295
Mean value	317,5	386	321,5
Standard deviation	30,9	8,5	23,8



a) b)

Fig. 3. Example experimental and theoretical heating curves for a geometric midpoint of the conductor (according to Fig. 1), at currents of a) 80 A b) 120 A.



a) b)

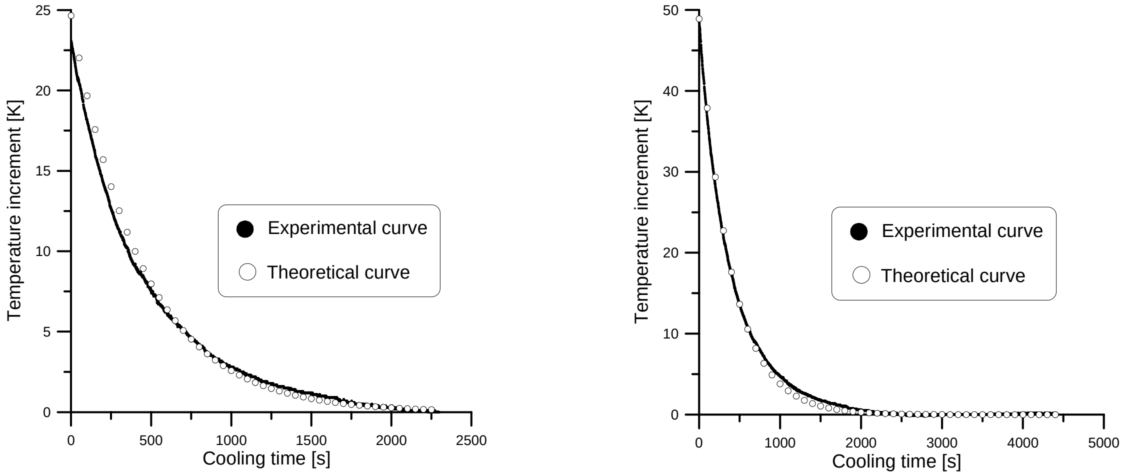
Fig. 4. Example experimental and theoretical heating curves at load current of 100 A, for: a). terminal C, b). terminal D

Results of calculations for points located at the terminals show big differences between experimental and theoretical dependences that follow from the fact that in analytical calculations axial heat flow is not taken into account (Fig. 4).

In the case of cooling down of the conductor, when the testing current is cut off, experimental cooling curves and the theoretical ones (calculated on the basis of the dependence 4) for a geometric midpoint of the conductor coincide with one another (Fig. 5). When temperature increment measurements are performed at the feeding terminals experimental results are not concordant with the theoretical ones. The conductor cools down quicker than it should according to theoretical calculations (Fig. 6), which results from that fact that the feeding conductors additionally absorb heat.

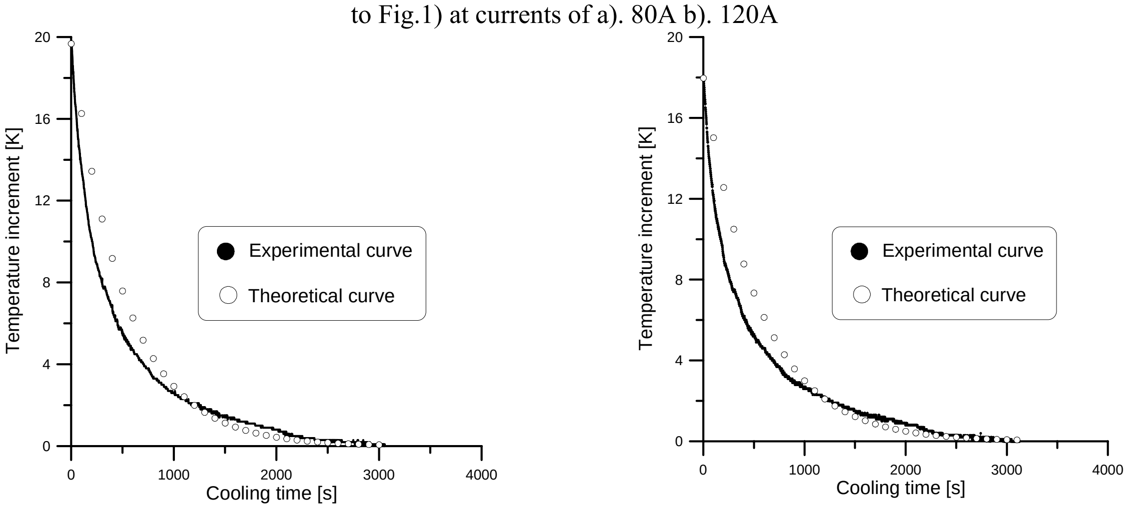
The biggest temperature difference occurs in the initial phase of cooling down. With temperatures of feeding conductors and the tested one getting gradually closer the mentioned difference decreases and finally disappears.

In a general case axial heat flow can occur from or to the fed conductor depending on the difference in cross-sectional areas between a feeding conductor and the fed one. It can bring about changes in fixed temperatures of the conductor during the current passage. The mentioned situation can become even more disadvantageous when fault currents (overload or short-circuit currents) occur, as their duration is considerably shorter than the heating time-constant. Hence, fault states can additionally influence the increase of non-uniformity of the temperature increment distribution over the whole conductor.



a) b)

Fig. 5. Example experimental and theoretical cooling curves for a geometric midpoint of the conductor (according to Fig.1) at currents of a). 80A b). 120A



a) b)

Fig. 6. Example experimental and theoretical cooling curves at load current of 100 A, for: a). terminal C, b). terminal D

[1] Dubicki B: Maszyny elektryczne Podręcznik Inżyniera Elektryka t.I Trzaska. Evert. Michalski. Warszawa (1947).

[2] Д.А. Герасимович, Ю.А. Климович, М.А. Мишина, Г.Г. Ежеников. Расчет нагрева плоских контактных соединений в установившихся и переходных режимах на основе одномерной модели температурного поля. ЭНЕРГЕТИКА нр. 5, Минск, (2003).

[3] А.А. Чунихин. Электрические аппараты. Москва, Энергоатомиздат (1988).

Мірослав Павлот

Люблінський технологічний університет, Люблін, Польща

Обчислення сили струму провідника як правило виконуються в припущенні його нескінченної довжини. У цьому випадку емісія тепла відбувається через конвекцією або випромінювання. Ситуація є різною, коли короткі секції провідника нагрівають, коли може виникнути потік тепла, який вплине на результат на температурних кривих.

Дана стаття подає аналіз зміни температури над 5-и метровою секцією мідного дроту 16 мм^2 перехресно-секційної області з використанням провідника 70 мм^2 при проходженні безперервних потоків різних значень. Експериментально одержаний потік температури у провіднику і форми нагрівання кривих вказують на важливий ефект осьового потоку тепла в провіднику.