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Temperature Investigations in Two Type of Crimped Connection Using Experimental Determinations

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Abstract**—**In this paper we make a temperature investigations in two type of superposed crimped connections using experimental determinations. All the samples use 8 copper wire 7.1 x 3 mm2 crimped by two methods: the first method uses one crimp indents and the second is a proposed method with two crimp indents. The ferrule is a parallel one. We study the influence of number and position of crimp indents. The samples are heated in A.C. current at different current values until steady state heating regime. After obtaining of temperature values, we compare them and present the conclusion.

Keywords**—**Crimped connections, experimental determinations, heat transfer temperature.

I. Introduction

CRIMPING is the most used new method of pressure connection for permanent electrical contact in electrical and electronic equipment.

Crimp connection performance and reliability are affected by many factors: material, conductor size, crimp method, number of crimp indents, locations of crimp indents, tensile strength. Effects of one of these factors are discussed in [1]–[4].

There are two basic classes of permanent electrical connections, metallurgical and mechanical. Metallurgical connections include soldered, brazed and welded connections. Mechanical connections include crimped, insulation displacement, press in and wrapped connection [5].

In this paper we study crimped connections by making an investigation in two types of crimped connections using experimental determinations.

We use 8 copper wire 7.1 x 3 mm^2 crimped by two methods: the first method uses one crimp indents and the second is a proposed method with two crimp indents located as shown in Fig. 1.

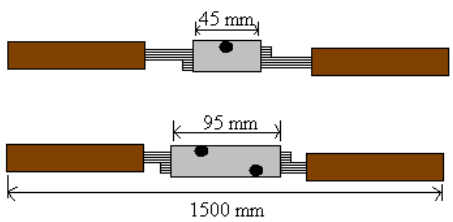

Fig. 1 Two type of crimped connection

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II. Methodology

All the samples are using the same 8 copper wire 7.1 x 3 mm^2 cuted in the same length of 1500 mm. Before jointing, the insulation of each end of conductor was removed and cleaned to minimize the oxidation of conductor. The used ferrule is a parallel one type, having 45 mm length for the samples crimped with the first method and 95 mm for the other.

The samples were heating in the same time at different current density values – starting from a small value and ending at rated current density. The circuit for heating process is presented in Fig. 2.

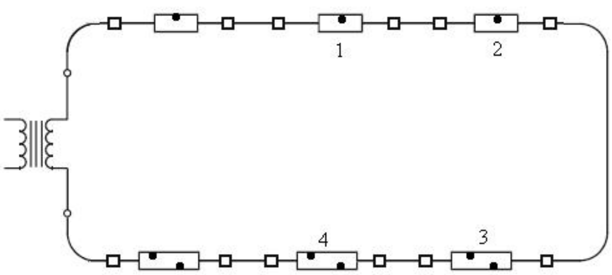

Fig. 2 The circuit for heating test

In Table I are presented the samples characteristics.

TABLE I
Samples Details

Samples	Dimensions	Indent number	Indent position
1		1	one side
2	8 × 7.1 × 3 mm^2	1	one side
3		2	one side and opposite side
4		2	one side and opposite side

III. Experimental Results

The experimental results were obtained by heating the samples in alternating current using various current density values: - 3 A/mm^2, 4 A/mm^2, 5 A/mm^2, 6.7 A/mm^2 until the steady state regime is established. The temperature was measured in the middle of ferrule using a thermo resistance Pt100 like in Fig. 3. The tests were made according to EN 61238 – 1/2003.

The experimental results of heating test for different current density values are presented in Figs. 4-7.

Fig. 3 The samples for heating test

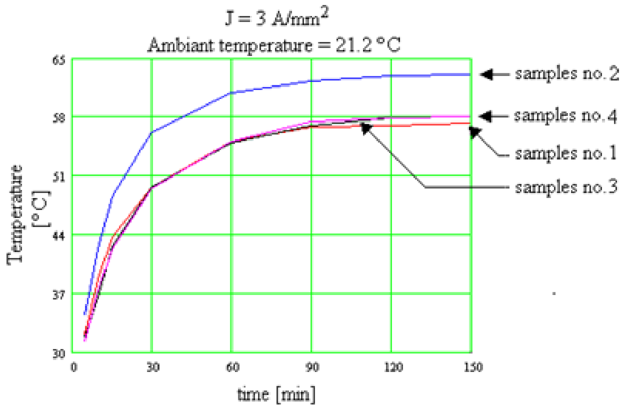

Fig. 4 Temperature curve for current density $J = 3\ A/mm^2$

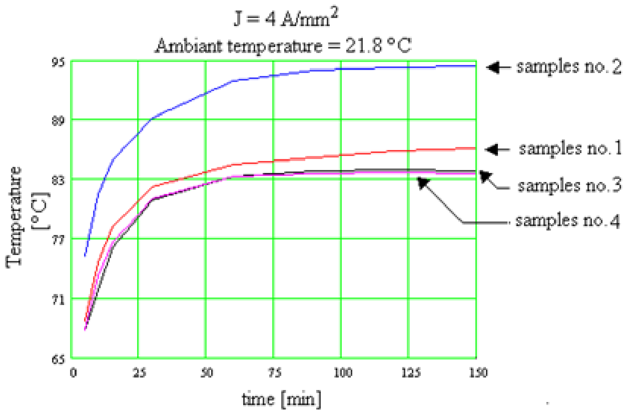

Fig. 5 Temperature curve for current density $J = 4\ A/mm^2$

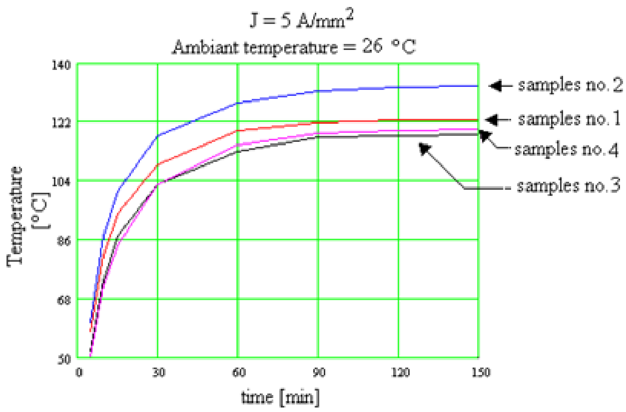

Fig. 6 Temperature curve for current density $J = 5\ A/mm^2$

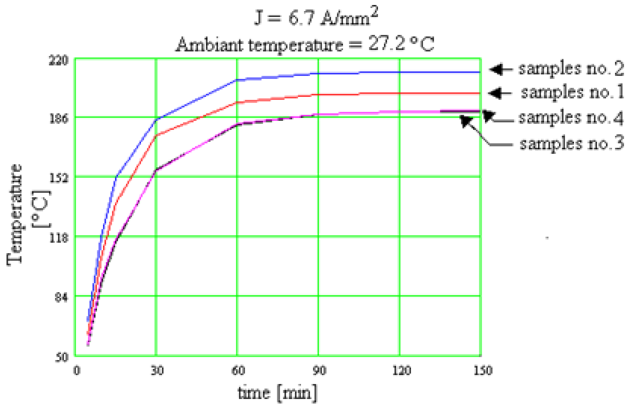

Fig. 7 Temperature curve for current density $J = 6.7\ A/mm^2$

IV. Data Analysis

A. Heating Uniformity

It is well known that the temperature rise process of a uniformly heated solid body, with uniform distributed constant heating sources, follows an exponential law. In Figs. 8-11 such exponential time variation of the temperature rise (solid line) and experimental data (dot line) are shown for the four studied samples, at current densities of 3 and 6.7 A/mm^2.

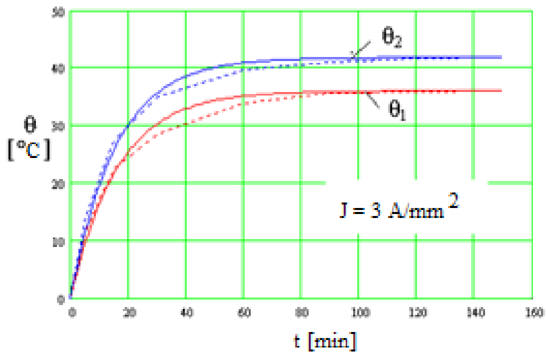

Fig. 8 Temperature rise versus time for samples 1 - 2, $J = 3\ A/mm^2$

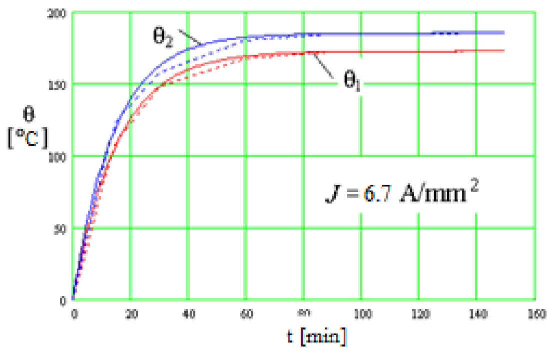

Fig. 9 Temperature rise versus time for samples 1 - 2, $J = 6.7\ A/mm^2$

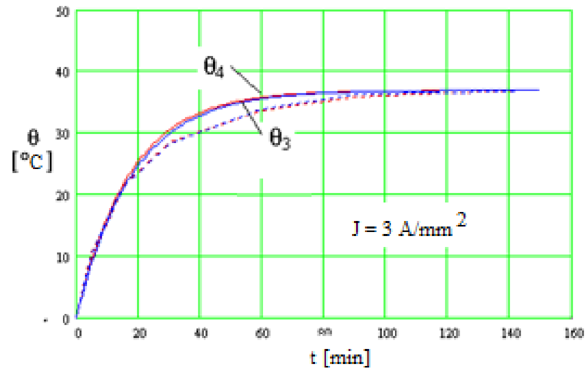

Fig. 10 Temperature rise versus time for samples 3 - 4, $J = 3\ A/mm^2$

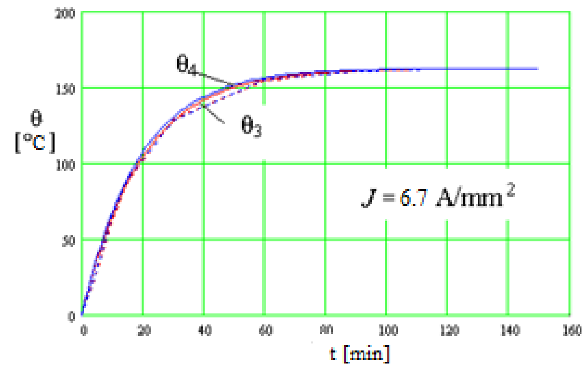

Fig. 11 Temperature rise versus time for samples 3 - 4, $J = 6.7\ A/mm^2$

The corresponding steady state temperature rises Θ_m in [˚C] and the thermal time constants τ in [min] for J = 3 A/mm^2 and 6.7 A/mm^2 are given in the Tables II and III.

TABLE II
TEMPERATURE RISE AND THERMAL TIME CONSTANT, $J = 3\ A/MM^2$

Sample	1	2	3	4
Θm [˚C]	36.1	41.9	37	37
τ [min]	16.4	15.7	17.2	18.1

TABLE III
TEMPERATURE RISE AND THERMAL TIME CONSTANT, $J = 6.7\ A/MM^2$

Sample	1	2	3	4
Θm [˚C]	172.8	185.3	162.7	162.9
τ [min]	15.4	14.3	19.4	18.5

It can be seen that the measured data do not fit with the exponential law, especially for current density 3 A.mm^2. This is because the losses are strongly no uniform distributed, being localized around any of contact resistances. At higher current density the conductor temperature are higher and the temperature distribution become more uniform, reducing the influence of conductive thermal flux.

B. Production Stability

It can be observed also in the two tables that the statistical straggling, from 5.8 to 12.5˚C, of the steady state temperature rises for identically manufactured samples 1 and 2, with only one indent, is much larger than less than 1˚C, for the last two samples, with double (opposite side) indents.

C. Dependence of the Temperature Rise on Current Density

The experimental obtained steady state temperature rises of the ferrule versus the square of current density is shown in Figs. 12, 13.

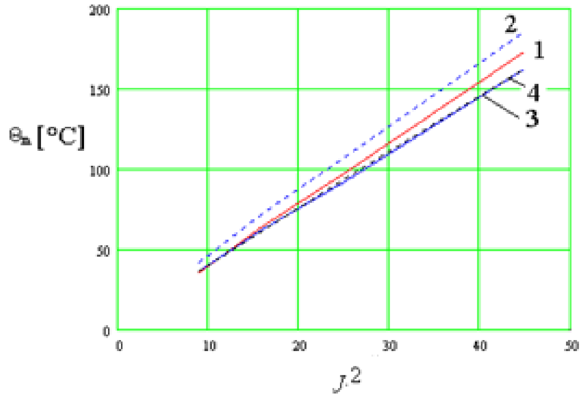

Fig. 12 Steady state measured temperature rise versus square of current density J^2

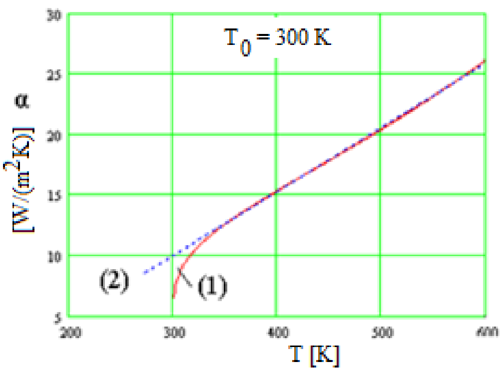

Fig. 13 Heat transfer coefficient calculated with (1) and (2) (dot)

For the double indented samples 3 and 4, for which the steady state temperature rise is almost the same at given current density, the variation of the temperature rise with the current density can be analyzed.

The steady state temperature rise must be proportional with the square of current density J^2 and with the resistivity rise and inversely proportional with the temperature rise of surface heat transfer coefficient.

The last one can be evaluated with the following equation [6]:

$$\alpha = 1.33\left(\frac{T-T_0}{L}\right)^{0.25} + 5.67\cdot 10^{-8} c_r T_0^3 \left(1+\frac{T}{T_0}\right)\left[1+\left(\frac{T}{T_0}\right)^2\right] \ [\mathrm{W/(m^2\cdot K)}] \quad (1)$$

where T and T_0 are the absolute temperatures of surface and cooling medium, L the external diameter of cylindrical ferrule

(~40 mm), c_r = 0.6 the radiation coefficient.

For T_0 = 300 K and 350 <T< 600 (1) can be approximated with:

$$\alpha \approx 10\,(1+0.0053)(T-T_0). \quad [\mathrm{W}/(\mathrm{m}^2\times\mathrm{K})] \tag{2}$$

In this case, the expected steady state temperature rise of sample 4 for J = 6.7 A/mm^2 should be:

$$\theta_s = 37\cdot\frac{1+0.0039(190.1-58.2)}{1+0.0053(190.1-58.2)}\cdot\left(\frac{6.7}{3}\right)^2 = 164.5[^\circ\mathrm{C}] \tag{3}$$

This value is very close to measured value of 162.9 (<1% difference).

V. Conclusion

The experimental results of heating test show that the difference between the over temperatures corresponding to different samples of the connection with two indents are much smaller than in the case of only one indent.

Also, analyzing the results it can be seen that the steady state temperature for samples with 1 indent are different (5˚C - 12˚C), the difference increases with density current. For samples with 2 indents the temperature values are almost the same.

The experience shows that the steady state temperature rise of the connections with only one indent can be from 3 to 17% higher than of the connections with two indents. So, taking also into account their higher reliability, the last should be preferred, in spite they are more material and manufacturing time consuming.

Acknowledgment

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