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Characterization of copper and nichrome wires for safety fuse

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Abstract. Fuse is an important component of an electrical circuit to limiting the current through the electrical circuit for electrical equipment safety. Safety fuses are made of a conductor such as copper and nichrome wires. The aim of this research was to determine the maximum current that can flow in the conductor wires (copper and nichrome). In the experiment used copper and nichrome wires by varying the length of wires (0.2 cm to 20 cm) and diameter of wires (0.1, 0.2, 0.3, 0.4 and 0.5) mm until maximum current reached that marked by melted or broken wire. From this experiment, it will be obtained the dependences data of maximum current to the length and diameter of wires. All data are plotted and it's known as a standard curve. The standard curve will provide an alternative choice of replacing fuse wire according to the maximum current requirement, including the wire type (copper and nichrome wires) and wire dimensions (length and diameter of wire).

1. Introduction

We often hear the fuse in everyday life. Electrical installation uses as a safety fuse for limiting the electric current flowing in the electrical circuit. The use of a safety fuse is essential to limit the electric current flowing in the electronic equipment so that electronic equipment be durable and not easily damaged by high currents. If the electronic device is written 2 A, the maximum current in the electronic device is 2 Ampere [1-3]. So we have to choose a wire that is able to flow through the maximum current 2 A. If the current flows more than 2 A (beyond the ability of fuse wire), the wire will break. The mechanism of breaking the fuse wire is the maximum current in the wire produces high heat, because the heat in the wire exceeds the melting point of the wire, the wire will melt and eventually the wire would break up [4-8]. Therefore, the importance of knowing the dependence of wire resistance to temperature (melting temperature and ambient temperature), the type of wire and wire dimensions to be used as a fuse wire.

Fuse wire is a conductor. Conductor is a material that is easy to conduct electric current [1-8]. Some wire conductors being sold in the market are copper and nichrome [9-10]. Based on the above background, the researchers are interested to characterize the copper and nichrome wire to a safety fuse.

When an electric current flowing in the conductor, the electrical energy is converted into heat continuously. Heat is generated from collision events charge carriers that move with the metal atoms. Heat conductor will be red because the electrons in the skin conductor moved from the tracks to the track lower while emitting a photon with a wavelength that is emitted in the region of the color spectrum of red (λ = 650 nm - 700 nm) [3, 8, 11]. If this heat causes the conductor is at its melting point, the wire will melt and eventually the wire will break. The electric current is decided wire called breaking current (maximum current that can flow in the wire) [4-12].

Dependence resistance to the type of wire and wire dimensions (length and diameter) is defined as:

$$R_o = \frac{\rho \ell}{A} = \frac{4\rho\ell}{\pi d^2} \tag{1}$$

With R_0 is the initial resistance of wire, ρ is the resistivity, *A* is the cross-sectional area of the wire (area of the circle), ℓ is the length of the wire and *d* is the diameter of the wire [1-10].

The dependences of the resistance on the temperature to be formulated as:

$$R_{T_{melt}} = R_o\left[1+\alpha\left(T_{melt} - T_o\right)\right] = \frac{4\rho\ell}{\pi d^2}\left[1+\alpha\left(T_{melt} - T_o\right)\right] \tag{2}$$

R_T is the resistance wire on the melting temperature (resistance on maximum current), T_0 is the initial temperature (20°C), temperature coefficient constants at 20°C [1-10].

According to Ohm's law formula:

$$I_{max} = \frac{V_{in}}{R_{T_{melt}}} \tag{3}$$

Dependence maximum current to the wire type and dimensions (length and diameter) is defined as:

$$I_{max} = \frac{V_{in}\pi d^2}{4\rho\ell\left[1+\alpha\left(T_{melt} - T_o\right)\right]} \tag{4}$$

With Vin is the input voltage of the power supply (current source). Resistivity, temperature coefficient and the melting point of the wire can be seen in Table 1 [4-12].

Table 1. Value of resistivity (ρ), temperature coefficient (α) at 20°C, and melting point (T_{melt})

materials	ρ (10^{-8} Ωm)	α $(°C)^{-1}$	T_{melt} (°C)
Copper	1.68	0.0068	1083
Nichrome	100	0.0004	1672

2. Experiment

Tools and materials used in this study is a multimeter, power supply (current source), micrometer screw and two types of wire conductor (copper wire and nichrome). Experiments carried out by flowing or varying the electric current until it reaches the maximum value on the copper wire and nichrome indicated with melted wire. Wire length varied from 0.2 cm to 20 cm while the variation of the wire diameter is 0.1 mm; 0.2 mm; 0.3 mm; 0.4 mm and 0.5 mm respectively. The series of these experiments are shown in Figure 1.

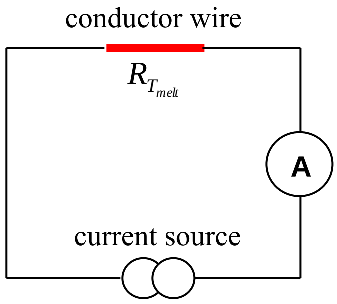

Figure 1. The series of wire conductor is connected to the current source [12].

Wire conductors (copper and nichrome) is connected to the current source and the ammeter in series to the wire. A symbol in the circuit of Figure 1 is ammeters. Volume on the current source is increased step by step until the wire broke. Flows were recorded on ammeter shortly before dropping out is the maximum current that can flow in the wire. Meanwhile, when the wire breaking ammeter will show zeros because the breakdown of the circuit in the measurement system.

3. Results and Discussion

Experiments carried out by flowing or varying the electric current until it reaches the maximum value on the copper wire and nichrome indicated with melted wire. The dependence of the maximum current on the length and diameter of the wire, expressed in a graph called a standard curve. Standard curves will provide instructions to select the fuse wire as needed. Fuse wire options include the type of wire (copper wire and nichrome) and wire dimensions (length and diameter of the wire). The dependence of the maximum current on the length of wire for copper and nichrome wire is shown in Figure 2.

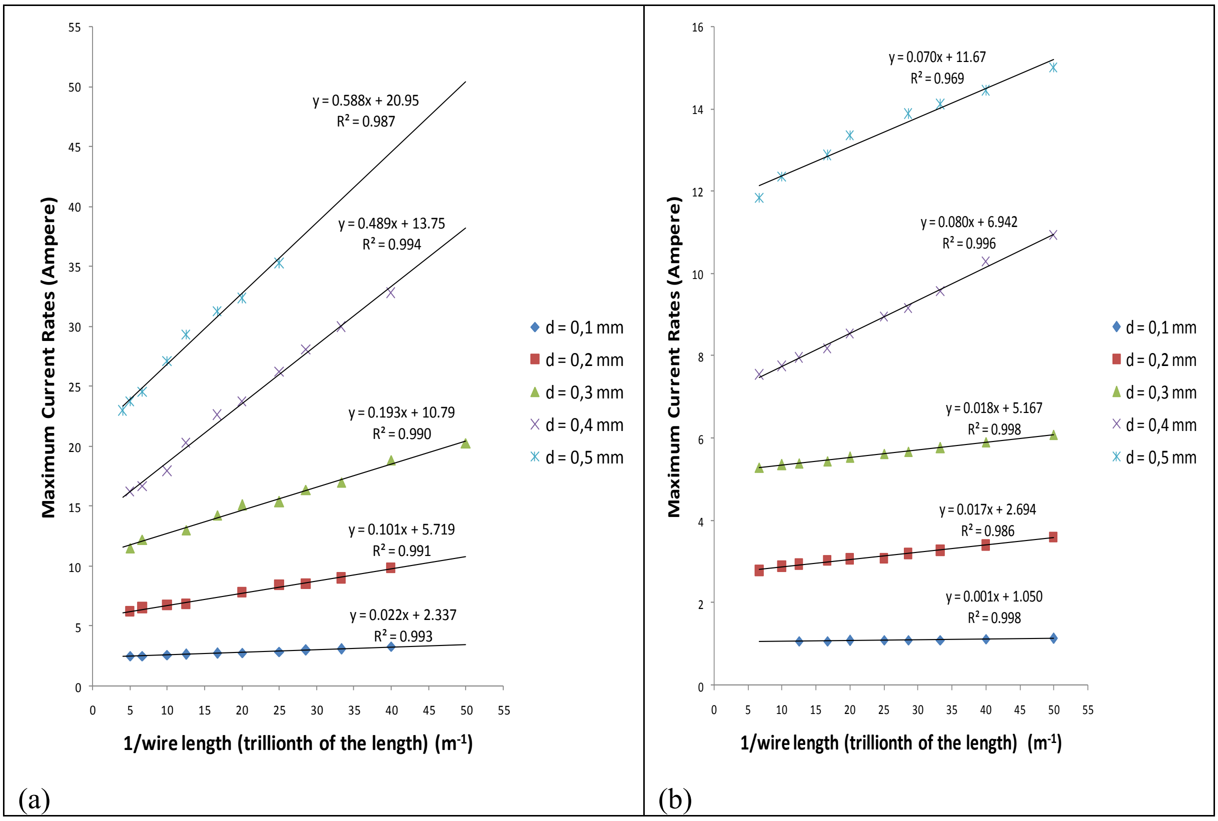

Figure 2 The standard curves for (a) copper wire, (b) nichrome wire, the relationship between the maximum current to trillionth of the length of wire for each wire diameter.

From Figure 2 (a), on the same type of wire (copper wire), and on the the same diameter, maximum current is inversely proportional to the length of the wire. These results are in accordance with the equation (4). Based on the equation (1), if the length of the wire is great, the wire will have greater initial resistance. Because the wire resistance is great, electric current flowing in the wire will be small.

At different wire types (Figure 2), the length and diameter of the wire is the same, it appears that the maximum current of copper wires is greater than nichrome wire. This difference is caused by the resistivity and the melting point of the wire. The maximum current is inversely proportional to the wire resistivity and melting point (according to the equation (4)). In Table 1, the resistivity and

melting point for a nichrome wire is greater than copper wire, so that the resistance at nichrome wire will be greater than copper wire. Therefore, the electric current can flow (maximum flow) on the nichrome wire will be smaller than the copper wire.
The dependence of the maximum current on the wire diameter for the copper and nichrome wire are shown in Figure 3.

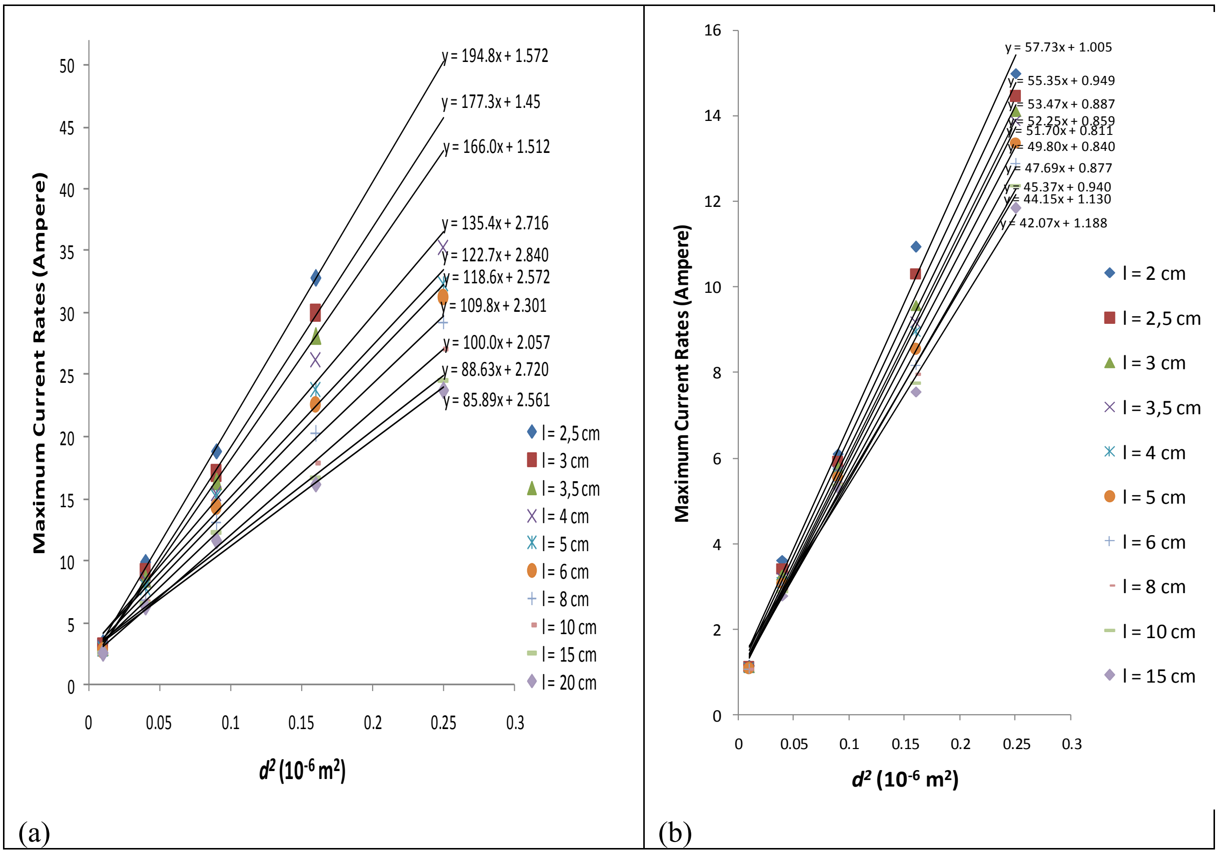

Figure 3. The standard curve for (a) copper wire, (b) nichrome wire, the relationship between the maximum current to the square of the diameter for each wire length.

From Figure 3 on the same wire length, maximum current is proportional to the square of the diameter. These results are in accordance with the equation (4). If the wire diameter is great, on the wire would have a small initial resistance. Because the wire resistance is small, the electric current flowing in the wire would be great.
Fuse is an important component of an electrical circuit to limiting the current through the electrical circuit for electrical equipment safety. Safety fuses are made of a conductor such as copper and nichrome wires. The aim of this research was to determine the maximum current that can flow in the conductor wires (copper and nichrome). In the experiment used copper and nichrome wires by varying the length of wires (0.2 cm to 20 cm) and diameter of wires (0.1, 0.2, 0.3, 0.4 and 0.5) mm until maximum current reached that marked by melted or broken wire. From this experiment, it will be obtained the dependences data of maximum current to the length and diameter of wires. All data are plotted and it's known as a standard curve. The standard curve will provide an alternative choice of replacing fuse wire according to the maximum current requirement, including the wire type (copper and nichrome wires) and wire dimensions (length and diameter of wire).
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3. Consclusion

By knowing the maximum current dependence on the type of wire and wire dimensions, will allow one to determine or replace the fuse wire as needed. The maximum current depends on the type of wire that is on the resistivity and melting point of the wire. The electrical current is inversely proportional to the resistivity and melting point of the wire. In the same type of wire, the maximum current depends on the dimensions of the wire (proportional to the square of the diameter and inversely proportional to the length of the wire). Standard curves of the experimental results provide guidance for selecting the fuse wire in accordance with current needs. Selection of fuse wire on the standard curve covering the type of wire (copper wire and nichrome) and wire dimensions (length and diameter of the wire).

4. References

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