International Journal of Advanced Technology and Engineering Exploration
ISSN (Print): 2394-5443 ISSN (Online): 2394-7454
Volume-2 Issue-8 July-2015

The Role of Cold Drawing on Electrical and Mechanical Properties of Copper Cables

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Abstract

The aim of this paper is to evaluate the effect of drawing process on the electrical and mechanical properties of copper wire. Electrical high tension network required cables to conduct electrical flow from one location to the next. The specific electrical and mechanical properties of the cable are affected by the forming that takes place during the drawing processes. The effects of cold drawing on electrical and mechanical properties of (99.9% Cu) copper wire are examined as a function of drawing ratio. Mechanical cold affected the electrical conductivity in copper wire; the result shows that electrical conductivity increased up to $(R_A = 22\%)$ ***at five passes. Also, the microhcrduses (Hv) increased the surface with the increases in reduction area. The investigation shows that the strength of copper wire is explained by the effect of work hardening due to the refining process of microstructure, also the surface temperature copper wire affected by the number of drawing passes.***

Keywords

Copper alloy, conductivity, reduction area, wire drawing, friction coefficient.

1. Introduction

Wiring of electrical systems and equipment is required to conduct electrical flow from one section to the next. The types and properties of the copper wires used depend on the energy consumption and in addition the wire must be durable enough to withstand bending and tension.

Conductivity of wire refers to its ability to carry an electrical charge with minimum resistance. Highly conductive materials are composed of atoms with free valance electrons that can move from atom to atom to transfer charge.

The conductivity of electrical wire depends on its main material. Silver, copper, gold and aluminium are the most conductive metals. Copper ranks as the most widely used material for high tension wiring systems [1].

Deformation in wire drawing is influenced by a number of factors; such as wire chemistry, approach angle of drawing die, fabrication, drawing speed, and reduction are the most significant. The primary emphasis in wiredrawing mechanic is on understanding and defining the relationships that exit between these process conditions and the ersalting thermo- mechanical response of the wire [2]. Drawing is a metalworking process of wires particularly used in the electric and automotive sectors. The process causes of reducing the cross-section by pulling the wire through series of conical dies. During the drawing operation, a plastic deformation is imparted to the material depending on the draw ability of the material [3]. Deformation strain caused by drawing differs from that associated with tensile deformation for the same reduction of area in both cases. This is due to the deformation heterogeneity in the drawn product, associated with localized shears superimposed on the overall external strain [4]. Annealing time and temperature effect the strain in homogeneity of copper wires after drawing through dies with various die- angles and reduction of areas, the results indicate that due to different grain growth kinetics of the coars and fine microstructure both surface and center grains grow but with different rates in applied dies, and hence strain in homogeneity decreases as time and temperature increase [5]. Copper- based alloys with small alloying elements are known to possess the relatively high strength and high electrical conductivity. The heavily cold worked or drawn of copper alloys with relatively high Zn content of 3.5% showed that the tensile strength between (1350 pa to 1800pa) and electrical conductivity about 42% IACS. The results show that the alloy had high possibility for application as electrical conductors with high strength [6-7]. The development of copper alloy wires with high conductivity and high strength has

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been extensively carried out by using cold drawing of (Cu – Ag) alloy [8] and (Cu – Ag – Nb) alloy [9]. However, the relation between the micro-structural evolution under cold drawing and electrical and mechanical properties of copper – zirconium alloy has not been clarified until now. The temperature of wire during process effect the drawing force required, also the interface conductions as well as the lubrication materials has a great effect. The wire die interface temperature is related to the friction coefficient between the wire and the die [10]. The tracing elements in copper wire material are the important variable required for the establishment of high electrical conductivity, most of these elements (Harmful elements) significantly decrease electrical conductivity. Hot rolling increase the mechanical strength of the annealed wire, and retired recrystallization.

Numerous, investigations have shown that very small additions of solute elements may increase the electrical resistively (decrease conductivity) of copper in linear manner [11].

2. Experimental Procedure

The alloy with composition of (Cu –3% zirconium), was prepared by using high purity copper and zirconium, melting in arc furnace and cast into a rod shape of diameter 5 mm using copper mold. The drawing process was carried out for the wires with initial diameter Ø = 5 mm to the final diameter of Ø = 1.70 mm in six draws using a block drawing die with the speed of drawing equal to 1.6 m/s at dray conductions, Figure (1).

The values of wire surface temperature for each draws are shown in Figure (2). Figure (3) shows the relationship between ultimate tensile strength (σ_ULT) and the reduction area (RA%).

Electrical conductivity (IACS%) was measured by a four – probe technique using annealed copper standard sample of 1.725 μΩ. Figure (4) shows the variation of electrical conductivity (IACS%) with reduction area (R_A%) at dray conduction. Typical hardness distribution across the diameter of the wires drawn in various reduction areas under dray conduction are illustrated in Figure (5). As it can be observed the hardness profile is not uniform along the measured paths.

3. Result and Discussion

The values of wire surface temperature in wire drawing process after each draw was recorded as shown in Figure (2). On the base of temperature distribution, we can observe that the surface temperature values increased as the number of draws increased due to the friction force [2]. Figure (3) shows the ultimate tensile strength (σ_ULT) as a function of cold drawing (reduction area R_A%). Linear relationship between ultimate tensile strength (σ_ULT) and reduction area RA% can be reasonably explained due to the refining and work hardening effect.

The electrical conductivity is considered to be decreased by cold working due to the defects like dislocations [6]. Figure (4) shows increase in electrical conductivity by cold drawing. On other side, the decrease in electrical conductivity with increasing in reduction area 27% are considered to be ascribed to the defects like dislocations and interfaces accompanying with refinement. Typical hardness distribution across the diameter of the wires drawn in various route of constant reduction of area is illustrated in Figure (5). As it can be observed the hardness profile is not uniform along the measured paths, being higher in the vicinity of free surface in both routes. This is directly related to the strain in homogeneity in the studied cross sections [12]. Electrical conductivity shows a maximum value of 38% IACS at (R_A= 22%) this is due to the formation of fine not – like deformed microstructure parallel to drawing direction which enhanced the electrical activity through drawing process, Figure [6].

4. Conclusion

Mechanical and electrical properties of drawn copper wire was investigated. The result shows that increases of wire surface temperature with numbered passes in linear relation. Linearity increases of ultimate tensile strength with reduction area up to (R_A= 22%). The electrical conductivity in copper wire increases up to (37%) IACS. Hardness through the C.S area varied according to the number of passes.

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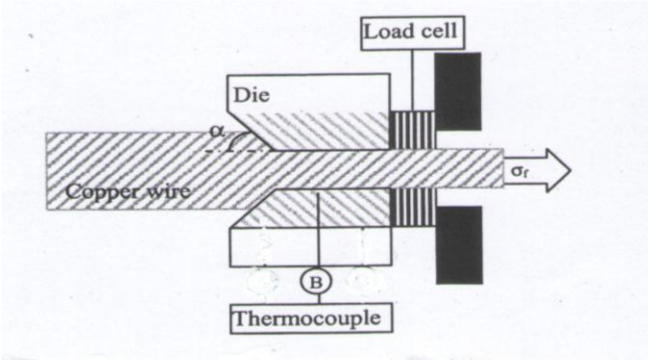

Fig. 1: Schema of the drawing die with thermocouple position

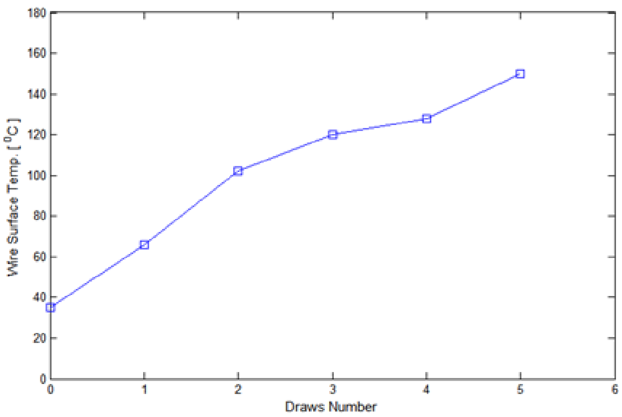

Fig. 2: Relation between wire surface temperature and draws number under dray conduction

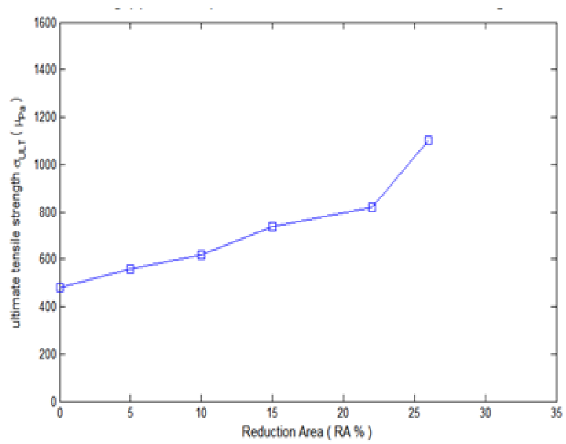

Fig. 3: Relationship between reduction area and ultimate tensile strength

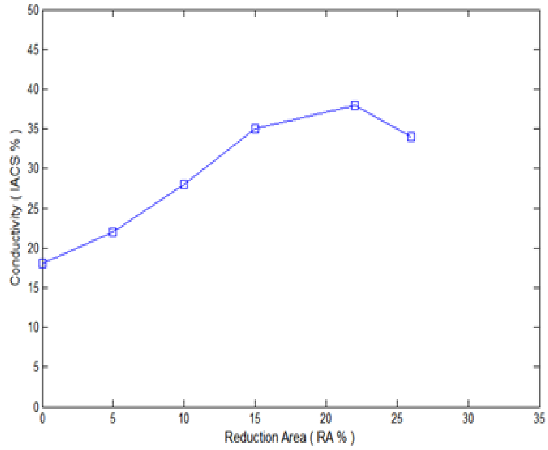

Fig. 4: Electrical conductivity of drawn wire as a function of reduction area at dray conduction

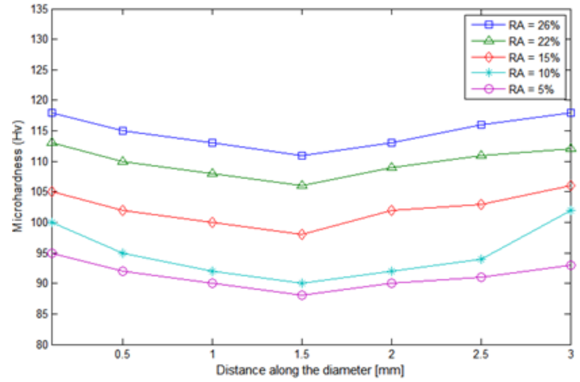

Fig. 5:Mircohardness along diameter of drawn wire at constant reduction

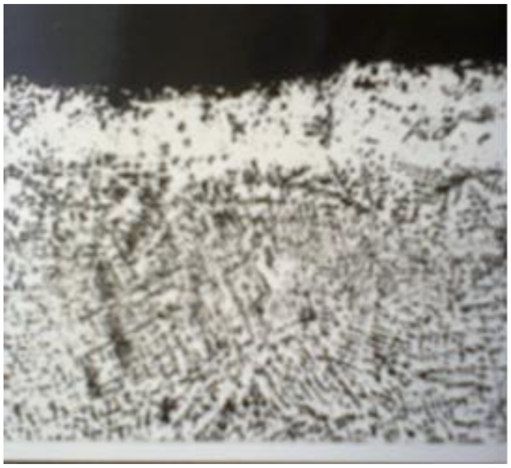

Fig. 6: Shows the information of fine net-like deformed microstructure