An Experimental Investigation for Effecting of Cold Drawing on Electrical and Mechanical Properties of Copper Cables.

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Abstract:

The aim of this paper is to evolut 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. Electrical conductivity increases by cold drawing up to (RA%=22) at five pass number. The conductivity shows a maximum value of 38% IACS at RA22% this is due to the formation of fine net – like deformed microstructure parallel to drawing direction which enhanced the electrical conductivity through drawing process. Moreover, the microhcrduses (H_v) increased from the core of the wire with the increases in reduction area percent. The strength be explained by the effect of work hardening and the refinement of microstructure. The coefficient of fraction and the wire surface temperature was effected by the number of draws under lubraction condution, water soluble oil is more effective in drawing process.

Keyword: copper alloy, conductivity, reduction area, wire drawing, friction coefficient.

Introduction

Electrical systems and components require wrie to conduct electrical flow from one location to the next. The specific properties of the wire depend on the needs of the component and of the energy consumption; 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 minimal resistance. Highly conductive materials are composed of atoms with free valance electrons that can move from atom to atom and transfer charge. The conductivity of electrical wire depends on its main material. Silver, copper, gold and aluminum 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, fabraction, 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- Drawing is a mechanical response of the wire[2]. metalworking process of wires particularly used in the electric and automotive sectors. The process consists 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 drawability 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 to 1800 $14p_a$) and electrical conductivity about 42% IACS. The results shows 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 been extensively carried out by using cold drawing of (Cu – Ag) alloy [8] and (Cu – Ag – Nb) alloy[9]. However, the relation between the microstructural evolution under cold drawing and electrical – and mechanical properties of copper – zirconium alloy has not been clarified until now. Temperature effects on wire – drawing was investigated, the results show that the drawing force and

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temperature depend on interface conditions as well as the wire materials and the temperature reaches a maximum value close to the interface (above the bearing). The wire –die interface temperature is related to the friction coefficient between the wire and the die[10]. Chemistry is one of the most important variables needed for the establishment of high electrical conductivity in copper wire. The most harmful of these elements can significantly decrease electrical conductivity, increase the mechanical strength of the annealed wire, retard recrystallization, and will sometimes include hot shortness during the hot rolling process in the production of rod.

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

Experimental procedures:

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 5mm to the final diameter of Ø 1.70mm 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 friction coefficient was measured at six draws using different types of lubraction oils table (1). The values of wire surface temperature for each draws are shown in Figure (2).

Figure (3) shows the relationship between ultimate tensile strength (σuts) and the reduction area (RA%).

Electrical conductivity (IACS%) was measured by a four – pro be technique using annealed copper standard sample of 1.725μΩ.

Figure (4) shows the variation of electrical conductivity (IACS%) with reduction area (RA%) at dray conduction.

Typical hardness distribution across the diameter of the wires drawn in various reduction area at dray conduction are illustrated in Figure (5).

As it can be observed the hardness profile is not uniform along the measured paths. Five types of lubraction oils were used at six draws to fined the effects of the lubration oils typs on the coefficient of fraction as a function of surface temperature, the results are shown in Figure (6).

Table (1) Specification of lubrication oils

Type of oil	SAE Grade	Specific gravity at 5-6 C°	Flash point C°	Viscosity at	
				40 C°	100 C°
Straight mineral	40	0.904	259	130	100
Phosphate	90	0.920	204	150	15.0
Supper Cutting	30	0.888	260	102	6.6
Water Soluble	50	0.930	220	98	4.8

Fig (7) shows the ultimate tensie strength (σ uts) and the electrical conductivity (IACS%) for various wire reduction area in three dimensions. In this figure the result shows that the reduction area percent has a major effect on bouth of other parameters.

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 (σuts) as a function of cold drawing (reduction area RA%). Linear relationship between ultimate tensile strength (σuts) 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 reduction area 27% are considered to be ascribed to the defects like dislocations and interfaces accompanying with the refinement.

Typical hardness distribution across the diameter of the wires drawn in various route of constant reduction of area are 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].

The coefficient of friction is plotted as a function of the drawn wire surface temperature using different types of lubraction oils figure (6).

The coefficient of friction increases with an increase in surface temperature, the result s o s t a t a er o eff ent of fr t on ere re orded at s r fa e temperat re of 1) when the lubraction oil is straight mineral type.

Three dimension graphs show the behavior of three parmeters in drawing process, reduction area (RA%) ultimate tensile strength (σuts) and electrical conductivity (IACS%) figure (7). The critical value of the electrical conductivity be at RA of 27%.

Conclusion:

Electrical and mechanical properties in copper wire cold drawn under dray and lubrication conductions were examined as a function of reduction area percent. Surface temperature increases by draws number in linear relation. Ultimate tensile strength increases linearly with reduction area (RA%) up tp (23RA).

Electrical conductivity increases in dray cold drawing up to (37%) (IACS). The hardness distribution across to wire diameter varied according to the number of draws. Water soluble oil is more suitable for lubraction in drawing process.

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Fig (1) Schema of the drawing die with thermocouple position

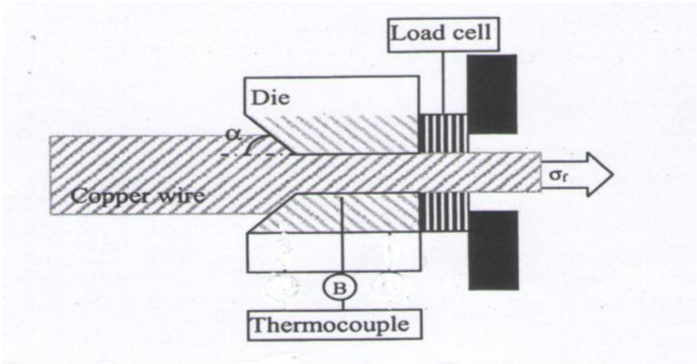

Fig. (2) Relation between wire surface temperature and draws number under dray conduction

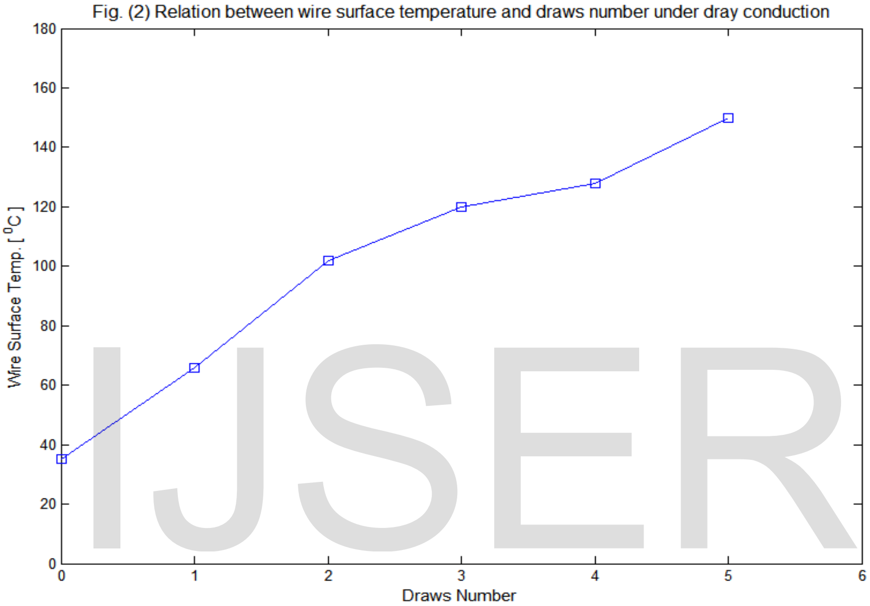

Fig. (3) Relationship between reduction area and ultimate tensile strength

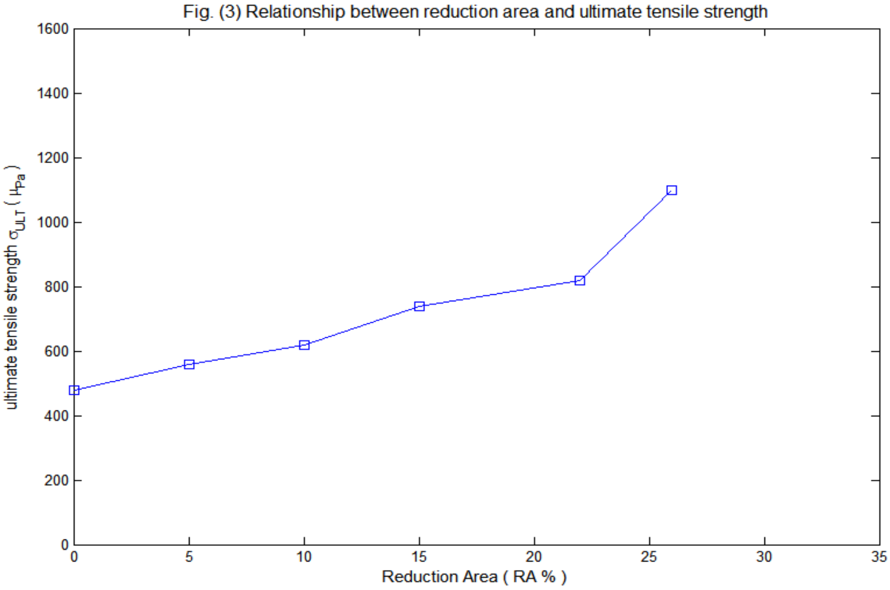

Fig. (4) Electrical conductivity of drawn wire as a function of reduction area at dray conduction

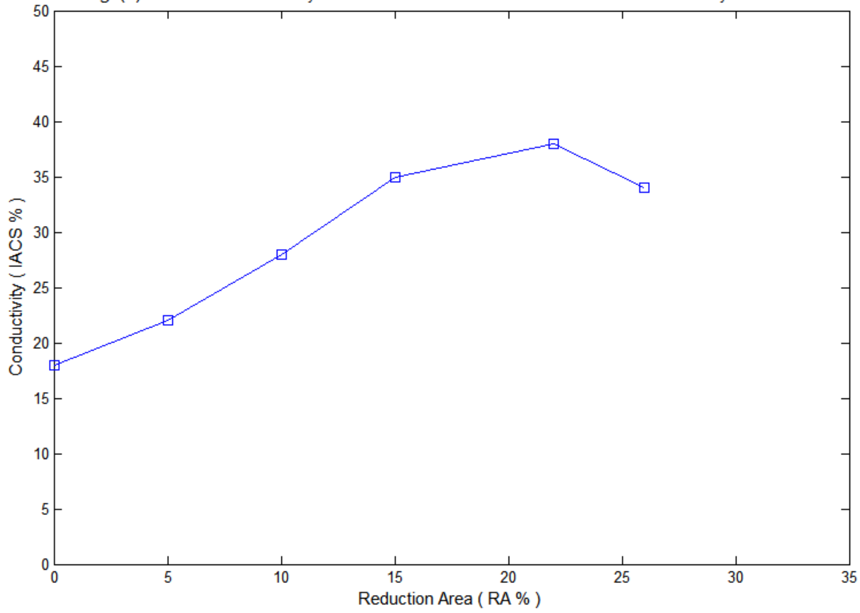

Fig. (5) Distance along diameter of drawn wire at constant reduction

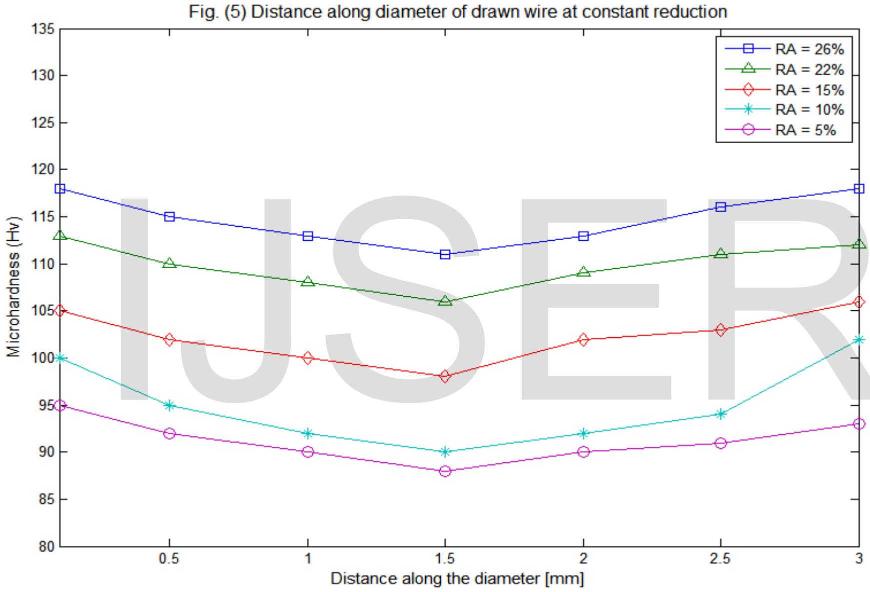

Fig. (6) Relation between surface temperature of drawn wire and (μ) with different types of oil at five draws

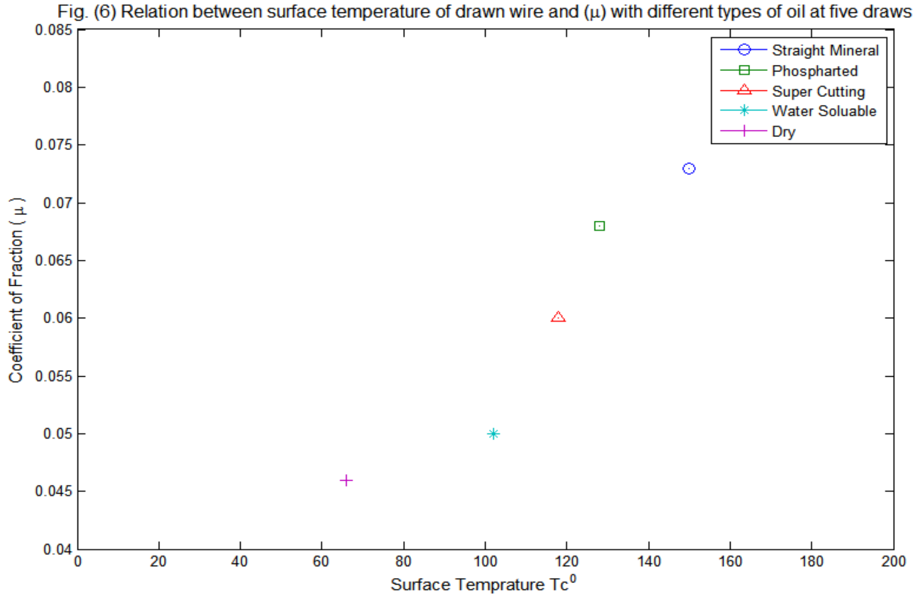

Figure (7) Normalized 3D-plot shows the ULT as a function of (IACS% and RA%),