Mechanical Properties as a Function of Zinc Content, Degree of Cold Drawing and Annealing Temperature in α-Brasses.

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Increasing zinc content up to 28 wt. % zinc was found to increase stress level and ductility. Degrees of cold drawing up to 99% reduction in cross sectional area increase stress level while decrease ductility for the different Cu-Zn alloys studied. Annealing after cold drawing increases ductility but decreases stress level. Abrupt decrease in ductility was observed after high temperature annealing of highly drawn wires and specially for alloys, with high Zn content. The results were discussed according to current solid solution hardening mechanisms, roughening of slip planes, locking of extended dislocations and difficulty of cross slipping.

Introduction:

Alloying is one of the most important methods to improve strength of metals. When brasses have the structure of α-Solid solution, an increase in the zinc content causes an increase in both strength and ductility [1].

In α - brasses the zinc atoms replace copper atoms to form a random non homogeneous substitutional solid solution. The replacement process is quite indiscriminate so that the concentration of zinc atoms can vary considerably throughout the structure. This enhances diffusion to take place to produce more stable and uniform distribution [1-3].

When a polycrystalline metal is plastically deformed the individual grains tend to rotate into a common orientation (preferred orientation). For most face centred cubic metals and alloys, the texture is a combination of both <111> and <100> texture. The degree of each depends on the degree of deformation, annealing temperature and the added solid solution alloying elements which generally lower stacking fault energy. It was accepted that <111> texture is about 20% stronger than a random structure while <100> is 20% weaker [4].

The purpose of this work is to discuss changes in mechanical properties as a function of zinc content up to 28 wt. % zinc, cold drawing up to 99% decrease in cross sectional area and annealing at temperatures 400 ^{o}C and 700 ^{o}C for four hours, after cold drawing.

Experimental Work:

The commercial pure copper and copper-zinc alloys with 6,10 and 28 wt. % zinc were used. The alloys were supplied by Helwan Company for Non-Ferrous metals in Egypt, in the form of rods 9mm. in diameter and of the chemical analysis shown in Table (1). Four rods 30 cm. long from each of Cu and its three alloys were annealed at 400 ^{o}C for 6 hours under vacuum   (10^{-6} torr.) for homogenization. The rods were then cold drawn without intermediate annealing to wires of decreasing diameters (2.5, 2, 1.5 and 1 mm. corresponding to 92, 95, 97 and 99 percent decrease in the initial cross sectional area, respectively. Some of each of the differently cold drawn wires were annealed under vacuum at 400 ^{o}C and others at 700 ^{o}C for four hours. Ultimate Tensile Stress U.T.S. and ductility percent (ξ%) were measured according to the A.S.T.M. wire specifications using Instron 1128 Machine.

Table (1)

Materials	Impurities %			
	Cu	Zn	Mg	Fe
Cu	99.966	0.00	0.0300	0.0040
Cu-6% Zn	93.810	6.11	0.0010	0.0790
Cu-10% Zn	89.996	10.00	0.0024	0.0016
Cu-28% Zn	71.989	28.00	0.0070	0.0040

Texture, dislocation density (ρ) and stacking fault probability (α) for the studied wires were quantitatively determined, under the same conditions elsewhere [5].

Results and Discussion:

Figures 1 to 3 show the obtained results for the studied wires Each of the three variable parameters studied (Zinc content, degree of cold drawing, and the annealing temperature after cold drawing) was followed at constancy of the other parameters.
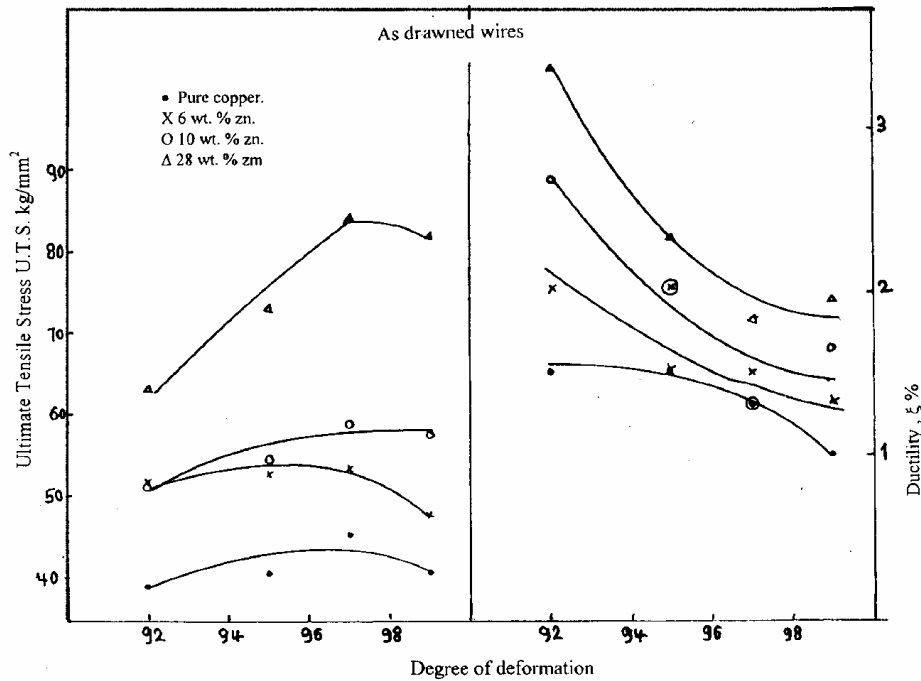

Fig.(1): Ultimate tensile stress and ductility as functions of degree of deformation for as drawn wires of brasses with different Zn content.
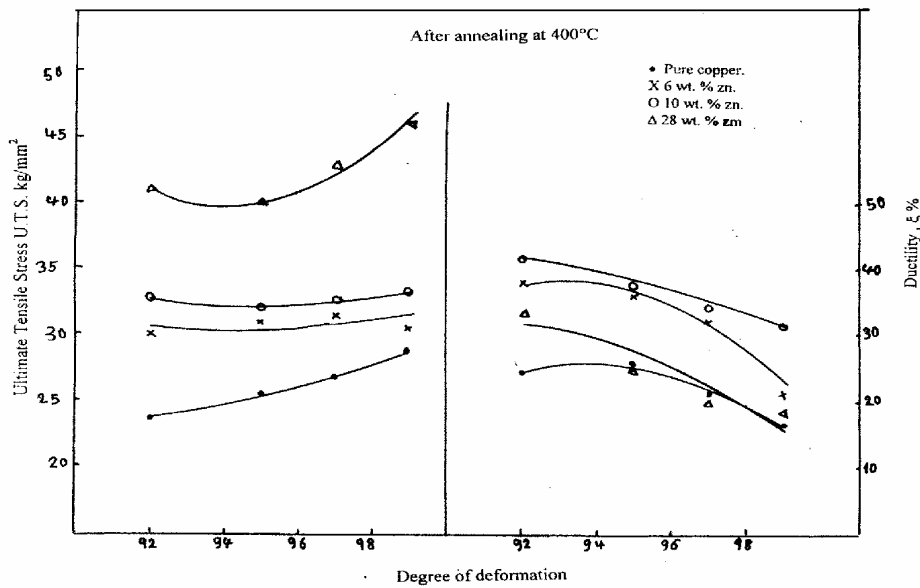
Fig.(2): Ultimate tensile stress and ductility as functions of degree of deformation for as drawn wires of brasses with different Zn content, (After annealing at 400°C).

Fig.(3): Ultimate tensile stress and ductility as functions of degree of deformation for as drawn wires of brasses with different Zn content, (After annealing at 700°C).
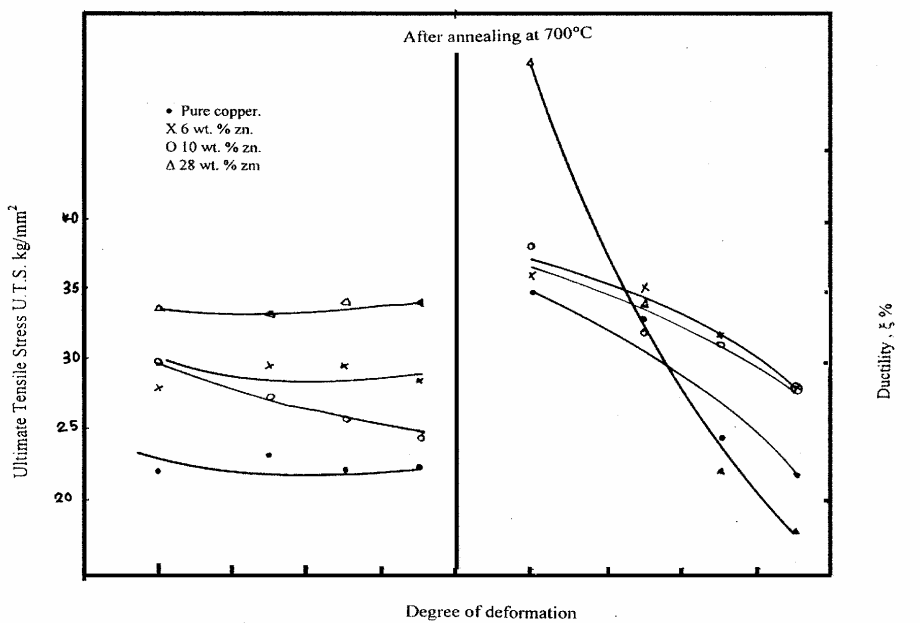
Figure (4) shows the increase of stress level with increasing zinc content at three increasing <111> texture percentages in the wires [5].
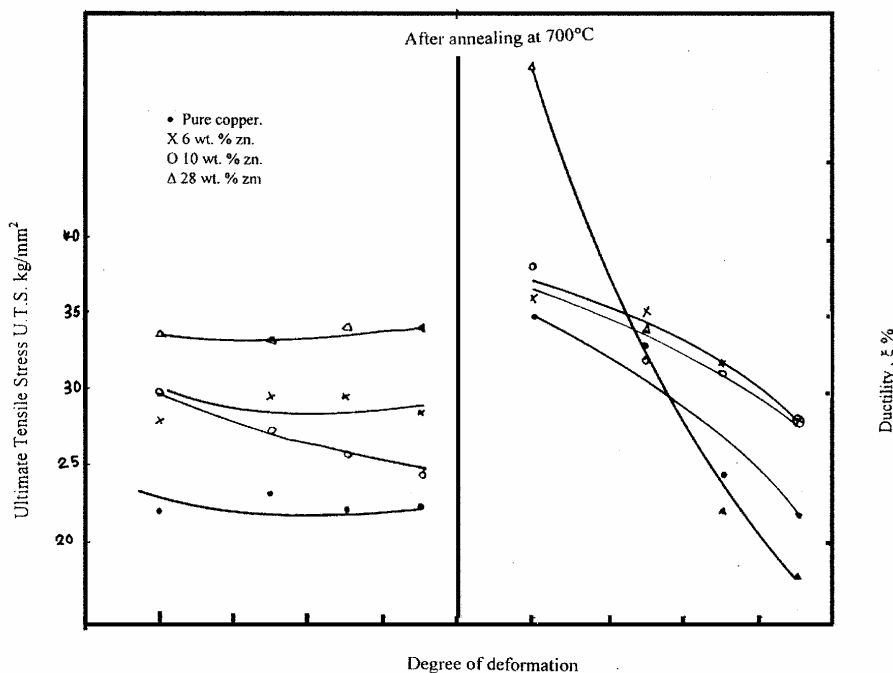

Fig.(4): The relation between U.T.S and Zn content for three different <III> texture degrees %

X <III> = 95 %

Δ <III> = 83 %

O <III> = 72 %

The hardening in solid solution alloys is expected to be due to change in the mechanism of work hardening with alloying i.e changes in dislocation density, arrangement, interactions with each other and with contaminated other imperfections [6a].

Alloying with elements which lower the stacking fault energy changes work hardening behaviour in a similar way as does a decrease in temperature [3]. Dislocation dissociation (the process which is energetically favorable in F.C.C. structure metals and alloys results in the formation of stacking faults, cross slip becomes difficult specially in case of wide stacking faults in low stacking fault energy metals and alloys [7].The observed increase in stress level by increasing both the degree of cold drawing and the percent of zinc content can be discussed considering that in cold worked metals and alloys the increased number of dislocations by cold working [5], and in the presence of

solute atoms cause distortion of the lattice [3]. Lattice can reduce its internal energy either through the dissociation of some of its dislocations forming stacking faults or by the segregation of the present solute atoms on dislocations. The movement of such dislocation configurations actually needs more energy to be applied [6b,8,9].

Obtained results show that ductility increased by increasing zinc content. This can be discussed considering the case in low stacking fault energy alloys and due to the difficulty of cross slip. Chance of dislocation interactions decrease and so work hardening decreases in turn [10, 11]. In stead of tangled and three dimensional net work structure of dislocations expected in pure Cu, a planer arrangement of dislocations predominates in these alloys. In non homogeneous alloys like α-Brasses preferential solute bonds are cut by the pass of the already present dislocations and successive ones find an easier passage on the same slip plane, so increasing slip distances [10, 11].

Changes in ductility and stress level by annealing at 400 ^{o}C and 700 ^{o}C after cold drawing seemed to be not highly affected by the formed textures. This result is supported by the increased percent of the <111> texture on annealing at 700 ^{o}C than on annealing at 400 ^{o}C [4,5].

For samples having the same Zn content and deformed to the same degree, the decreased stress level and increased ductility by annealing was accepted to be due to the enhanced recovery and recrystallisation processes by annealing [12]. Redistribution of possibly formed short-range ordered or clustered zinc atoms in the matrix by annealing may be responsible for the decreased stress level, specially for concentrated alloys [13].

The observed decrease in ductility on annealing after high cold drawing and specially for the high concentrated alloy (28 wt. % Zinc) may be due to the occurrence of grain growth and the decreased grain boundary area [12].

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